UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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

- -x

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

Tuesday, June 9, 1981

The above-entitled matter resumed at 9:00 a.m., pursuant to adjournment.

BEFORE:

HERBERT GROSSMAN, ESQ., CHAIRMAN,
Atomic Safety & Licensing Board Panel.

GEORGE A. FERGUSON, Ph.D., Member.

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

APPEARANCES:

DANIEL SWANSON, ESQ.,
RICHARD G. BACHMANN, ESQ.,
Office of the Executive Legal Director
U.S. Nuclear Regulatory Commission
Washington, D.C.,

Appearing for the NRC Staff.

EDWARD A. FIRESTONE, ESQ.,
General Electric Company
Nuclear Energy Division
175 Curtner Avenue
San Jose, California 95125

-and-

GEORGE L. EDGAR, ESQ.,

Morgan, Lewis & Bockius
1800 M Street Northwest
Washington, D.C.,

Appearing for the Applicant.

GLENN CADY, ESQ.,
Carniato & Dodge
3708 Mt. Diablo Boulevard, Suite 300
Lafayette, California 94549,

Appearing for the Intervenors
Friends of the Earth, et al.

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C O N T E N T S

P R O C E E D I N G S

JUDGE GROSSMAN: The tenth day of hearing in the show-cause proceeding is now in session.

I believe, Mr. Edgar, we're going to lead off with your panel, including Drs. Bolt and Jahns and Harding?

MR. EDGAR: That's correct. If Mr. Harding, Dr. Jahns and Dr. Bolt would take the witness stand.

JUDGE GROSSMAN: Dr. Bolt, could you stand and raise your right hand.

Whereupon,

BRUCE A. BOLT

was called as a witness on behalf of the Licensee and, having been first duly sworn, was examined and testified as follows; and

RICHARD H. JAHNS

and

RICHARD HARDING

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

DIRECT EXAMINATION

BY MR. EDGAR:

Q Would each of you gentlemen, starting with Dr. Bolt, state your name and address for the record?

A (Witness Bolt) My name is Bruce Bolt. I live at

1491 Greenwood Terrace, Berkeley, California 94708.

A (Witness Jahns) My name is Richard H. Jahns. I live at 2312 Brenner Drive in Menlo Park, California.

A (Witness Harding) My name is Richard Harding, and my address is Earth Science Associates, 701 Wilkes Road, Palo Alto, California.

MR. EDGAR: Mr. Chairman, I would like to have marked for identification four documents. The first is a document entitled "Seismicity of the Livermore Valley in Relation to the General Electric Vallecitos Plant." The authors are Bruce A. Bolt and Roger A. Hansen, and its date is March 1980. I would request that that be marked for identification as Licensee's Exhibit 47.

JUDGE GROSSMAN: So marked.

(The document referred to was marked Licensee's Exhibit No. 47 for identification.)

MR. EDGAR: The next document is a memorandum on General Electric letterhead dated June 5th, 1980, signed by A. M. Hubbard, manager, Wilmington Engineering. I would request that that be marked as Licensee's Exhibit 48.

JUDGE GROSSMAN: So marked.

(The document referred to was marked Licensee's Exhibit No. 48 for identification.)

MR. EDGAR: The next is a letter dated June 12, 1980, to Robert Darmitzel, General Electric, from K. Treher, Vice President, Parsons International, Ltd. I would ask that that be marked as Licensee's Exhibit 49.

JUDGE GROSSMAN: So marked.

(The document referred to was marked Licensee's Exhibit No. 49 for identification.)

MR. EDGAR: The final document is a letter on the letterhead of the Major Appliance Business Group, General Electric, dated June 6th, 1980, signed by Mr. V. H. Wetherby, to Mr. Darmitzel. That is misspelled. The letter in original text spells the name B-a-r-m-i-t-z-e-l. That should be D-a-r. I would ask that that be marked as Licensee's Exhibit 50.

JUDGE GROSSMAN: So marked.

(The document referred to was marked Licensee's Exhibit No. 50 for identification.)

MR. EDGAR: I would like to proceed by asking a series of questions of Dr. Bolt and have him give a few basic statements for the record.

JUDGE GROSSMAN: Proceed.

BY MR. EDGAR:

Q Dr. Bolt, do you have before you Licensee's

Exhibit 47?

A (Witness Bolt) Yes, I do.

Q And are you familiar with that document?

A Yes. This was the report that I wrote with Dr. Hansen on request.

Q Okay. Could you describe the purpose of that report and the directions you received from GE, if any, concerning that report?

A Well, the specific questions, I believe, arose not from GE, but from the Nuclear Regulatory Commission's consultants concerning the regional seismicity and the site seismicity. And these questions were passed on to me, and I was requested to endeavor to answer them based on the record that we have at the University of California Seismographic Stations on the occurrence of earthquakes in this area, and also the distribution of seismographic stations over the years in the area.

Q All right. Does your report include consideration of the 1980 Livermore earthquake sequence?

A 1979.

Q 1979.

A In October. The sequence had occurred when the report was written, and we did take that into account. I'm sorry --

Q Let me turn you to page 4 of the report. Perhaps my terms weren't clear, but the sequence of earthquakes that I am questioning you about is the January 27th, 1980 and January 24th, 1980 earthquakes.

A Oh, I usually refer to that as the Greenwood -- the Greenville fault sequence. I was thinking of some other earthquake.

Yes, the earthquakes in the Greenville fault had occurred when I wrote the report, and we did consider them.

Q Okay. In what way did you consider them, and of what significance were those earthquakes to your report?

A Well, the earthquake sequence occurred along the Greenville Fault which is some distance from the site of the General Electric plant, but because it's in the general Livermore Valley area, we looked at the way that the earthquakes were distributed along the fault, their focal depths, the mechanisms of the earthquake, in particular, and I included in the report figures which showed the fault plane solutions for the two principal earthquakes, that on January 24th, and that on January 27th, in that sequence.

Q Could you explain the phenomena of focusing and directivity in terms of its basic theory?

A Well, in seismology, focusing has two meanings. The first is the older meaning, and perhaps the most correct one, which is similar to its usage in optics.

That is to say, when light rays pass through a lens, they are focused at that particular point, and sc in seismology, when the seismic waves pass through some underground structure which we could think of roughly as a lens, the seismic wave energy can also be focused.

Now this particular phenomenon has often been appealed to, to explain pockets of rather high intensity, of particular damage in earthquakes around the world.

The problem is, of course, that one seldom knows in detail what the structural complexity is at the surface.

The second use of focusing is more recent, and this relates to the movement of the dislocation or of the rupture from the focus where the break first occurs in the rocks out along the fault, and according to work done, particularly in acoustics, when one has a source of energy which is moving, it will tend to be a concentration of wave energy in front of the moving source and a decrease behind the moving source.

For example, if one moves a loud hallo, forward, then the people in front of the loud hallo, will hear the sound at a higher level of energy than people behind. This is a well-known phenomenon in acoustics, and so it's been suggested that this also happens in seismological circumstance.

The first to so suggest it, I believe, in any serious way was Prof. Benihoff after the 1952 Curran County earthquakes, and because of the pattern of intensity that was observed there which wasn't circular around the faulting, but had some direction fix to it, he suggested that what happened was that as the fault ruptured in a particular direction, that this directivity focusing had come into play. Of course, it was a speculation. It was difficult to prove without a shadow of a doubt things of that kind, in seismology.

The theory would suggest that this is present in all earthquake dislocations and ruptures and sometimes, of course, it will work in one's favor, if you happen to be behind the rupture. Sometimes it would work to increase the energy to some extent.

Q Was this phenomena -- or let me express it another way.

In your opinion, were there observations at the Livermore earthquake or Greenville earthquake sequence, as you use the term, which are reflective of the focusing phenomena?

A Well, there we had rupture of the Greenville fault which could be observed on the surface, and the seismological evidence from the occurrence of aftershocks indicated that the rupture probably in the first principal shock moved from the north end of the fault to the south end, and the fault strikes more or less towards the developed area in the Livermore Valley, and consequently one immediately thinks that here is a case where we might see the effects of this hypothesis of directivity focusing. And I thought that we ought to certainly consider that, and in the paper I wrote with two colleagues, we said that we hazarded a guess that some of the intensity noticed in the Livermore area might have arisen because of this effect.

Q What particular site features or elements of that earthquake sequence would lead to support the hypothesis that this was observed?

A Well, the evidence is rather thin, because there were very few strong motion instruments in the area. There were no strong motion accelerometers along the fault itself as there were, for example, in the '79 Imperial Valley earthquake.

There was one strong motion instrument in the basement of the Veterans Administration Hospital which is beyond Livermore, but in the same general direction, south, that is, that showed a peak acceleration of about .17g, which is not very high acceleration, and that really doesn't indicate any particular increase in energy in that direction.

So about the only evidence there is, is that simply damage to structures in the Livermore City area seemed to be somewhat greater than damage to structures such as trailer courts and that sort of thing to the north.

Q Now you had mentioned two traditional theories of focusing. Is the first theory that you mentioned, the lens effect, a possible explanation for the events in the Greenville sequence?

A It certainly is a possibility. I think that in discussion with people about this, I pointed out the alternative explanations, and that is one.

Another is the fact that the city of Livermore is on an area of recent alluvium -- rather deep alluvial valley, and one finds many earthquakes that -- structures built on that sort of geological soil and foundation material will show enhanced intensities.

Q Dr. Jahns and Dr. Harding, do you, based on your knowledge of the two sites, do you expect similar site conditions such as those described by Dr. Bolt to obtain at the GETR site?

A (Witness Harding) It's Mr. Harding.

Q Excuse me.

A No. The Livermore Valley, as Dr. Bolt pointed out, is a deep basin with a considerable thickness, I think about 300 feet of recent alluvium near the surface.

The GETR site, on the other hand, is underlain by moderately consolidated materials in the Livermore gravels, which in turn are underlain at relatively shallow depths by cemented and indurated tertiary age rocks.

Q Dr. Bolt, if focusing were to take place in a given earthquake sequence, what is its significance, in your opinion?

A (Witness Bolt) The actual effect of focusing at the present time is very speculative. As I said, from a theoretical point of view, close to the fault and in the direction downstream, so to speak, and that is to say the direction to which the rupture is progressing, theoretically there would be some increased ground motions.

However, one has to keep in mind that intensity is the sum of many, many different factors that arise. The effect of soils and sufficial geological conditions is very well known to be most important, and that's why most analyses on strong ground motion will separate out the the records as being on the rock site, some on firm ground site, some on subsoil sites, and so on. There is hardly any question about the effect of the local sufficial conditions.

There is also the effect of the rupture mechanism itself, the type of faulting that occurs. There is the effect of the kind of geological structure that lies between the site and the source of the waves, so that in practice whether the focusing factor -- if I can call it that -- is of much significance or not, is really not known at the present time. There is some evidence that it isn't very important.

For example, in the 1906 earthquake here along the San Andreas Fault, we had very great fault rupture from som. here off the Golden Gate the rupture began and traveled south towards San Juan Batista and north towards Humboldt County for a distance of over 500 kilometers, with very clear surface expressions of the dislocation, which caused a slip along the fault of up to six meters or 18 feet, something like that, in some places.

Now if the dominant effect was this directivity focusing which would have the major effect in front of the rupture as it progressed, one might expect to see a great deal of damage just in the fault zone itself.

Now this wasn't so, and it's well known, been discussed for many years, that there are ranch houses right on the fault, as a matter of fact, which were not damaged.

As a matter of fact, I take my students up to Marin County where one c. see them there still today, and there are photographs extant which show some of these places without a window broken. These are not engineered structures, but ordinary dwelling houses, right in the fault zone where one has an 8-plus earthquake causing a very great rupture, passing by.

Unfortunately, we don't have strong motion records from this great earthquake, but there's that kind of evidence to indicate that some other mechanism comes into play, or mechanisms. to reduce the effect of this simple physical idea.

My own view is that since the effect would be most strongly pronounced in the fault zone itself, right along the rupture, there the enhancement of the wave energy is competing in practice with the attenuation of high frequency waves along the fault zones, where that's likely to be rather severe, since the geological evidence is time and time again in these fault zones, when trenching is done and one looks closely at the structure in the fault zones, we find many en echelon faults. The rock tends to be shattered, as you would expect, because of the long history of faulting in these areas, and there is developed a clay kind of material which is a result of the rock being powdered along the rupture, forming a substance called gouge, g-o-u-g-e, fault gouge, and this material will attenuate the high frequency waves quite severely and so that fortunately we have this mechanism which keeps the threshold of the high frequency waves down to levels which are comparable with what one finds off to the side somewhere in the more competent country rock.

Q As I understand it, then, one cannot separate the effects of focusing, but then how does one deal with it in practical terms in regard to the data base?

A Well, so far as the separation is concerned, I happen to believe from the physics of the thing, which I explained in the case of acoustics, that focusing is part and parcel of every earthquake. That it is always present as a factor, and therefore it is part of the data base and cannot be removed from it.

The point I was trying to make is that the significance of it as against some of these other effects that I mentioned, may be quite small, and that one has to look hard to try and find evidence of it, and one place that there is some case could be made out -- although, as I said, the evidence is rather thin -- was the Greenville Fault series.

Q Are you familiar with the acceleration readings at the Imperial Valley Station 6?

A Yes.

Q Could you explain the conditions associated with that reading?

A Well, Station 6 was one of a profile of strong motion accelerometers that had been established at right angles to the Imperial Valley fault, and one of them, one of this profile, was as a matter of fact the same place as the famous El Centro station, where the El Centro record of

1940 was obtained, which is much used in engineering practice.

Now Station 6 was to the east of the Imperial Valley fault. The El Centro station is on the west. And it was sited between the Imperial Valley fault and the Broley fault, as it's called. In the earthquake of October of '79, the Imperial fault ruptured, and the ruptur ran up by this profile, so we had an excellent oppo unity to see what the ground does very close to source, a fairly substantial source, 6.6 local magnitude.

The situation is not simple, however, at this northern end, because there was also rupture on the Broley fault, so that as the Imperial Valley fault ruptured north fr south of the border, the Mexican border, as it came up towards El Centro, it has bifurcated, and part of the rupture went further north along the Imperial fault, and part went up along the Broley fault, like the forked tongue of a snake, and here was the Station 6 sitting in between these two rupture segments.

The faulting at that place contained a fair percentage of vertical motion on the faults, so that between the Broley fault and the Imperial fault, there was a block which dropped down relative to the land on both sides, and so the Station 6 reflected this down-dropping in some way.

Q Dr. Harding and Dr. Jahns, would you explain whether the conditions at the GETR site would be similar or different from those at Station 6?

A (Witness Jahns) They would be substantially different. The Imperial Valley region is a very large elongate basin with a fill that includes very considerable thickness of geologically young and relatively poorly consolidated materials of a considerable variety.

It's also a region where on a broader scale, the crust is thin, and the thermal gradient is very high, and there's a great deal of current tectonic activity.

Q Dr. Bolt, at what frequency level were the high vertical accelerations at Imperial Valley observed?

A (Witness Bolt) Well, they would contain many frequencies, but the predominant frequency quite high, perhaps about 10 hertz, 10 cycles per second.

Q Okay. Dr. Bolt, are you familiar with the earthquake record measured at Pacoima Dam in the 1971 San Fernando event?

A It has been much discussed.

Q Could you explain the major characteristics of that reading?

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A. Well, the Pacoima record was obtained by an accelerometer on a ridge which runs up to the abutment of the dam. The peak horizontal acceleration was in excess of one g. And of course that caused a very great stir, because it was by far the greatest peak acceleration that had been instrumentally observed up to that time. The question was: Was it important when one is dealing with general ground motions? Or was it a very special case?

One of the peculiar things about the site is that, as I said, it is on a rather steep ridge. So seismologists started to look at the possibility that the ridge would act as a lens and concentrate the energy. It would be a kind of focusing of the first kind that I talked about earlier this morning, and give a very high value because the instrument was on a ridge.

Another possibility was that there would be interaction between the dam itself, which was not damaged even though this high peak acceleration occurred, and the ridge itself; that there would be some interaction between these two elements, one natural and the other manmade, and give rise to this rather high frequency peak of acceleration.

Studies I think have all supported the first view that a number of people have carried these out by different methods. Some have been done at the U.S. Geological Survey; a student of mine in his Ph.D. thesis modeled the motion using finite element technique. These have all indicated that the ridge indeed can have a very great effect on the motion at the surface. So that if one cut the ridge away, so to speak, and dropped the instrument down to the normal ground level, the peak accelerations of that amplitude would not occur.

Q Dr. Jahns or Mr. Harding, would you expect similar conditions to occur at the GETR site?

A (Witness Harding) I think I can answer that. The GETR structure itself does not sit on a steep ridge such as the accelerometer at Pacoima; but rather, a low, relatively flat rolling terrain.

Q Dr. Bolt, are you familiar with the 1.3g vertical acceleration reading at the Gosley (phonetic) earthquake?

A Yes, I am. I was immediately interested in this record and spoke, as a matter of fact, to some of the Russian seismologists about it. They were also quite interested because of implications it might have for design of their own structures, and they checked the instrument, they told me, took it back to Moscow to see if it worked all right. They didn't want to be sent to Siberia if it didn't.

(Laughter.)

And they told me that it was fine. So that I have from Dr. Shebolyn (phonetic) that in their view the instrume.. worked well, and that we can accept the measurements.

Q. What would account for the value of that measurement in terms of the conditions at Gosley?

A. The instrument was sited near to the fault and the faulting there was predominantly vertical. So that some of it might be accounted from the mechanism. It is also in an area of sedimentary material, and when one has layers of sediments there can be very steep turning of the seismic wave upwards. Strong gradients and produced in this material, so that this might be an explanation. I don't know of anybody who has yet done any bore hole work, or anything of that kind, in the area which would enable us to make definite statements about the effect of the soil and alluv' l conditions in the area on the waves.

Q. Dr. Bolt, in general what do earthquake records show about the relative magnitudes of vertical and horizontal accelerations?

A. The great majority of records from around the world indicate that measurements of peak acceleration on vertical records are less than that on the horizontal record. A few years ago I remember I had a look at this with a colleague at a seismographic station. At that time, the global data available to us that was reliable indicated the ratio of about .5, .55 times the horizontal equalled the vertical.

Now since then, there has been more records obtained near to the source of moderate earthquakes, and in some of these cases the vertical records have been as large or larger than the horizontal. But generally speaking, the vertical ground motion is of a higher frequency. The appearance of the record is different, if you look at them carefully, and sometimes strikeingly different to the horizontal strong ground motion, which is normally used in design criteria, engineering design criteria. I mean, after all, all structures are built to withstand one g static fources, and so the great concern obviously is with the horizontal shaking.

So that it is not really a simple matter of comparing peak accelerations listed in lists for vertical versus horizontal; that one doesn't want to compare apples and oranges. The frequency component is very important. Generally the vertical motions are of higher frequency than the horizontal components. So it is really engineering design considerations that have to go into the question ~s to the seismologists, what is the appropriate ratio at a particular frequency which is of importance to my structure? It is not much help to say: Well, at 20 hertz there are very high vertical motions on this particular rock condition, or something of that kind, and compare that with horizontal motions where the frequencies are more like 5 hertz.

I'm sorry to have to be a little complicated in my response, but I think it isn't a simple question that you asked.

Q Well, and as a rule of thumb for heavy structures, what sorts of frequencies, or what range of frequency is important?

A Well, if you're speaking of structures and not the electrical small mechanical devices, one is normally concerned with frequencies less than about 8 hertz. For example, for the Alaskan Pipeline studies, the GS report there concentrated on the motions of the ground which were less than 8 hertz.

Q I have a series of questions I will address to the panel, and whomever feels that they have the answer, feel free to respond.

I would like to ask whether the following theories are significant in the context of GETR proceedings, and why. First, the so-called Bolt/Jahns working hypothesis as it applies to the GETR site.

(Witness conferring.)

A. (Witness Jahns) I presume in this question you are referring to the paper that Dr. Bolt and I jointly prepared?

Q. Yes.

A. Well, this was an attempt to review several kinds of information pertinent to an evaluation of seismic hazard in the State of California. In that, we looked basically at three different kinds of evidence beginning with the notion of plate tectonics that has been developing and has been under test during the past 20 years now.

And according to this theory -- and it has been tested by geodetic means and others -- the Pacific and North American plates are drifting horizontally past each other at a reasonably well known annual rate. This provides the background, the dynamic background if you will, for an appraisal of first the plate boundary, the San Andreas Fault; and second, some splays from that boundary, branch faults; and then a large number of so-called "intra-plate faults," some of which are very important, also.

A second thing we looked at was the historic record. I mentioned that previously in these proceedings, and I won't go into further detail here.

And then the third thing we considered was a kind of sum of highly detailed investigations that have been made at carefully selected points along a few of California's active faults. These points have been investigated by means of trenches and other subsurface excavations that in effect have permitted us to go back beyond the historic record, which is pretty short, for an examination of the youngest parts of the prehistoric geologic record.

So in effect, this broadens the data base and hence the basis for understanding a little bit more about the behavior of some of these faults over a longer period of time. And it was on this sort of combined basis that we made an estimate of seismic hazards in the state.

A. (Witness Bolt) If I could just add a word to that, the paper was addressed to the general problem of preparation for a great earthquake here in California. Our "focus," if the word is not being overworked, was the whole State of California. It wasn't specifically any particular place in the State. We wanted to see just what the speed of preparation should be, and the outlay of public monies given the great concern that many of us have about the occurrence of a great earthquake somewhere in California.

So that the study and the inferences we drew were to do with great earthquakes -- that is to say, magnitude 7 or greater -- somewhere in California. We were not specific about where, but just looking at it as a whole, what is the probability that in the next ten years say there will be a great earthquake somewhere in California on the many very long and extensive faults which are known to be active, and are known to have had a history of great earthquakes.

Q. And can I assume that you weren't specifically focusing on either the Calaveras or Verona Faults in connection with that theory?

A. That's correct.

Q. Dr. Jahns, does the theory of seismic gap, in your opinion, have any applicability to the Calaveras and Verona?

A. (Witness Jahns) Well, conceivably it might, but it would be, in my mind, a very difficult thing to apply simply because of the distribution of information. Or, to put it differently, there are many other faults and areas in California where the spread of activities has been such as to make the seismic gap theory a great deal more appealing.

Q Would you -- I should have asked the first question, but would you give a brief definition of the term "seismic gap"?

A Actually, the most general definition may involve either space or time, or a combination of the two. As the word "gap" implies, it represents a situation in which let's say spatially in this instance there has been over some period of time known activity along certain reaches of say a single fault, and none along an intervening reach.

This tends to focus attention on the intervening reach as a likely candidate for the next element of seismic activity.

Q In your mind, if the theory has applicability to Calaveras and Verona, does it make any difference in regard to the seismic design bases?

A No. I don't see how it would.

Q And why?

A Well, the notion of a seismic gap in connection with either the Calaveras or Verona Fault involves, more than anything else, a matter of timing of the next event. And there are several rather superior ways of estimating that particular parameter, but as far as estimating design bases for structures and things of that sort are concerned, they would be quite unrelated to such a thing as seismic gap in estimating the timing of the event.

Q Mr. Harding, do you have before you Licensee's Exhibits 48, 49, and 50?

A (Witness Harding) Yes, I do.

Q Earlier during the proceedings there was some questioning concerning the foundation photographs. Could you give an explanation of what investigations you undertook in regard to the foundation photographs?

A Back during our first investigations out on the site, which was in the fall of '77, General Electric Company searched its files and came up with some photographs of the foundation excavation for the test reactor which was excavated I believe in '57. We looked at those photographs at that time, and I recall one instance at the site when the NRC Staff was there that we looked at these photographs together and decided that we did not see anything significant in the photographs which would suggest, for example, a fault offset.

The photos were then put away. We gave a copy to the NRC Staff, and General Electric kept the originals and filed them. It wasn't until sometime last year I believe, prior to the June ACRS meeting hearing in Sunol that the photos somehow reappeared as an issue. Apparently somebody had gone back and relooked at them again, and it was suggested that the photos did indeed show evidence of faulting.

Well, at that time we took out the original photos and investigated them again. We took them over to Stanford and tried to have them enhanced through a computer process which enhances various images on photos and had various blowups made. We made a map of the site showing the direction of each view of the photos, and studied them pretty thoroughly.

After this rather thorough investigation, we concluded that there were gravel horizons in the photo which were visible which crossed unbroken across most of these other features which had been suggested as possible faults.

Closer examination of those features showed that in most cases they were smearing of the walls of the escavation from excavation equipment. That was our conclusion.

During that time, General Electric Company also made a review of their personnel who were on the site during the construction, and came up with the names of these gentlemen who wrote the letters which are in these exhibits. I telephoned Mr. Hubbard and Mr. Dreher from the Parsons Company to ask their opinions about what they saw in the excavation. I was particularly interested in Mr. Hubbard because he had graduated from the School of Mineral Sciences at Stanford University and apparently knew something about geology.

Essentially, they told me what is contained in their letters here.

Q And what is the thrust of what you were advised?

A Well, the thrust was that they were not involved in making any detailed study of the --

MR. CADY: Excuse me, your Honor. I want to interpose an objection to any line of testimony along these lines. Any reference to these letters appears to be hearsay. These people are not present here to be cross-examined. These letters were prepared in 1980. They don't appear to be any type of a business record. And without the ability to examine these people personally, relying on Mr. Harding's testimony here would just cloud up the record on certain issues, and I want to lodge an objection at this time.

JUDGE GROSSMAN: Mr. Swanson?

MR. SWANSON: Well, I don't think I would argue that it is hearsay. I guess the question comes to reliability. I think the letters perhaps need to be judged in light of the fact that of course the authors are not here. However, I think that they perhaps at least indicate a perception on the part of these individuals as to what they saw.

I think the Board obviously can take into consideration the fact that they are thinking back 20 years as to the time I assume that they are talking about, the time of excavation twenty-some years ago, and perhaps apply weight accordingly.

I am not sure that in an NRC-type or proceeding that they need to be totally discounted because of the source. We do at least have Mr. Harding who can testify as to the communications he has had with them. This of course is not the first time in this proceeding we have had a case where an individual has had to rely on conversations with other individuals.

I think perhaps all parties have relied on that at one time or another, including Mr. Barlow. But I think as a threshold question, it is probably a matter of letting the Board apply proper weight to these matters, and taking into consideration that the authors are not here and that they are thinking back some twenty-some years as to their recollections.

JUDGE GROSSMAN: Mr. Edgar?

MR. EDGAR: Well, I think the objection is as to the question, not the documents. I have not yet made an offer for the documents. All I want to do is establish a foundation with Mr. Harding, if he can answer the last question. That is the extent of the examination.

JUDGE GROSSMAN: Well, I understand the objection to be -- Excuse me.

MR. EDGAR: Furthermore, I think the Board is well equipped to sort out the question of weight and reliability of this evidence. I think the standard is reliability here, not hearsay or the exclusionary rules won't apply here. But I can't conceive of the the Board not being able to assess and assign appropriate weight to this information.

JUDGE GROSSMAN: I believe the objection goes to the entire line of questioning, including the documents. To the extent that there is going to be any reliance upon what some people may have said who are not here in the hearing room, I think that we have to take into account the age of the recollections in determining how reliable the evidence is in order to allow it in in the first place. And those remarks are directed to Mr. Swanson.

I think that in light of that age, we would want to have the witnesses here in order to allow them to be cross-examined. I don't see that as any basis for the Board to determine how much weight to give these documents if we let them in without any kind of cross-examination.

So let me consult with my fellow Board members on that.

(Board conferring.)

JUDGE GROSSMAN: Yes. The Board is agreed completely on this, that we ought not to accept it.

MR. EDGAR: Well, then, I have no further questions and the panel is available for questioning.

JUDGE GROSSMAN: Of the panel? I'm sorry, Mr. Cady.

MR. CADY: I have no questions of this panel.

JUDGE GROSSMAN: Mr. Swanson?

MR. SWANSON: No questions.

BOARD EXAMINATION

BY JUDGE GROSSMAN:

Q Dr. Bolt, you were not asked about whether the theory of seismic gap might have any applicability to the area around the GETR site. Could you indicate what your view is on that, sir?

A (Witness Bolt) Well, I am in agreement with

Dr. Jahns that there is something in the theory of seismic gaps from the general point of view of fundamental physics. That is to say, if one is straining a region -- and there is no question that this area is being strained from the geodetic measurements -- that sooner or later some of the strain is going to be released by earthquakes, or by some other mechanism.

There is a complication in this world. It seems that some of the faults relieve strain slowly by what people call "fault creep." For example, down near Hollister there is a famous winery built across the San Andreas Fault. As a matter of fact, it is the third winery that has been built in exactly the same place. It was found there that the San Andreas is slowly slipping at the rate of a couple of inches a year. You can see that by looking along the walls of the winery. They are being distorted, and many people hold the view that this means that this slow movement is releasing the strain energy.

There is a gap there, but it is not necessarily going to be a place where there is going to be very soon a large earthquake because this other mechanism of release of energy is operable. And I think that the same sort of mechanism could well apply to some of the faults that you have been considering, your Honor, in this area.

The other side of it is that sometimes there can be earthquakes where there is no sign of any quiescence of any gap. The extraordinary case we have now of the Imperial Valley earthquake about which you have heard quite a lot, in '79 we had the magnitude 6.6 earthquake rupturing the Imperial Valley fault not where there was a gap, but where an earthquake had occurred in 1940 and ruptured the same fault.

So that you can see that this musn't be thought of as a very simple, easy way to go to a place and say "here we're going to get an earthquake." It may be helpful in some circumstances in prediction, and in other cases I would not rely on it.

JUDGE FOREMAN: Does it have a salutary effect on the wine at all?

(Laughter.)

Since there are three wineries that have been built there?

WITNESS BOLT: The Burgundy Room is particularly badly damaged at the moment.

(Laughter.)

WITNESS JAHNS: I can indicate that it is the most popular stop on our field trips at Stanford.

end JWB #2

(Laughter.)

BY JUDGE GROSSMAN:

Q Is there any evidence of strain release in the Vallecitos area? Such as you mentioned is evidenced in the Hollister area?

A (Witness Bolt) Well, I'm sure you have been dealing with the Calaveras Fault and the Heyward Fault. Those are faults that come up quite a bit, and there is evidence of slip, slow slip or creep on both those faults at certain parts of them. I'm not sure just how close the place is where the slip has been seen is to the site. I have not looked at that, but perhaps it's sufficient to say that papers have been published pointing to slip occurring on certain parts of the Heyward Fault and the Calaveras Fault.

Q Have there been any major earthquakes in this area which would detract from the application of the seismic gap theory to this particular area?

A The last great earthquake of which there is a very complete record is the earthquake on the Heyward Fault in 1868, and the southern extent of the rupture that took place at that time is not really known.

As a matter of fact, the existence of the faults weren't known very clearly at that time, but the record is clear that cracking did occur on the foothills across the Bay, and perhaps the rupture ran to the south in an area close to where you are concerned. But one must remember that the search for or correlation between earthquakes in California and faults, great faults, is relatively recent, and consequently we can only point to a period going back, I would say, to about 1868, so it's a little bit over a hundred years is all we have. And in that time, there was no great earthquake in the area that you asked about.

Q Would the fact that that great earthquake occurred in 1868, and there haven't been any since, would that make the theory of seismic gap more or less applicable to this particular area?

A Well, I think that it probably makes it less applicable because if one has relieved the strain in the general area by very great dislocation that took place in the thrust, then it will take considerable time for the strains to build up and to readjust, and this may then take place on some other fault at a considerable distance away, as far as actually walking on the ground is concerned, but perhaps not as far as looking down from an airplane, looking over the whole region of central California is concerned.

So that it seems to me that in the 100 years or so that follow a great earthquake, one could visualize all sorts of readjustments of strain taking place at various faults throughout the region, and so that it's in those circumstances rather difficult to say, "Well, look, there is a gap," because of the complexity of this readjustment that's taking place.

Q I see. So how long would you say, then, you needed a period of quiescence to be in order for the theory of seismic gap to be more applicable?

A Well, I think in the cases in which it really seems to me to be very valuable, in terms of seismic hazards around the world, where there is a clear history of great earthquakes along a long feature such as, say the Aleutian trench or say some of the great faults in China, where the record goes back thousands of years, and one finds that great earthquakes have occurred to the south and to the north, perhaps in the last 200 years, and yet nothing has happened in the intervening region.

So I think in terms of hundreds of years to make the thing really worth betting one's shirt on.

Q And is that something on which there is a consensus among experts, that it would take a few hundred years of quiescence?

A I'm not sure we could speak of a consensus. I think there would be a consensus in terms of really taking some practical action based on this theory. In terms of, say, concentrating a great deal of instrumentation in an area, spending a lot of capital to site accelerometers and arrays and do special work and so on, so one could easily say, well, there's a gap here for five years or 10 years or 20 years, but when it comes to the actual point of putting one's research career onto this theory, I think you'll find the consensus that people will wa: t to go to a place where the gap is extended for a very long time.

(Laughter.)

Q So you think they might not put instruments there unless there had been that period of quiescence for a few hundred years?

A Well, I think that's what's happening around the world now.

Q Now I notice that you did talk about strain and rate of slip. Was that one of the points that you took into account, one of the theories that you took into account in that Bolt-Jahns paper that was referred to?

A Not particularly, because we were concerned with getting an upper limit, really, to the risk and, as I said earlier, the actual implications and extent of fault creep are not very well known at the present time.

What we based it on, actually, the historical record of earthquakes going back along the San Andreas to perhaps 1800 and along some of the subsidiary faults for a lesser time, as I mentioned, and based on that record, and the geological work in trenches in Southern California on the San Andreas, then we came to some ar3-5

conclusion about the occurrence rate of the great earthquakes, so that we really didn't have to consider other parts of the fault system which may or may not have earthquakes on them, depending on the extent of fault creep and how long it will continue.

Q   If I understand what Dr. Jahns indicated, you did take three things into consideration, three major areas.

A   That's correct.

Q   Am I incorrect in assuming that if you had another reliable indicator of recurrence of earthquakes, that you wouldn't take that into account also?

A   Well, certainly we would, if we searched wherever we could for long-term reliable indicators. As he said, one was the historical record. Unfortunately, it doesn't go back far in California, compared with other places, such as China, Europe, the Middle East, and so on.

We took into account the geodetic measurements which started in the middle of the last century and indicate continual movement of the western part of this state that's on the other side of the San Andreas, relative to the eastern part, and we took into account the geological evidence in trenches of a repetition of great earthquakes, at least in that part of the San Andreas Fault, going back perhaps a thousand years.

Q Well, couldn't you have developed models based on the rate of slippage as to the occurrence of earthquakes?

A Well, we could have done that, but as you're, I'm sure, aware, the more theory -- to build a model, one has to start introducing theory into the argument, assumptions and so on, and the more one does that, the more people, particularly the general public and I think probably correctly, and politicians have some doubts about what you say.

So the purpose of this paper was to draw attention to the ever-present risk of great earthquakes in California to give the general public and the people in Sacramento who have to appropriate funds to do hazard mitigation, some idea of the time we know about which we're talking, and we thought it was sufficient -- I still think it was sufficient -- to use very simple arguments and not to present more elaborate models.

Some people have tried the more elaborate models. There are some things like that that are in the literature.

Q Well, if you had a very reliable model, even if it was complicated, you would certainly want to rely on that in making the conclusions that you present to the public, wouldn't you?

A You're correct, I would, yes.

Q And so if the rate of slip was a reliable indicator, you would certainly have relied upon it?

A I would have done that, yes.

Q If you were to base a theory of -- excuse me -- a determination of recurrence of earthquakes in this particular area, that is based upon a rate of slip, would you be able to accurately determine the rate of slip?

A I think that the best one could do in this particular area would be to put some bounds on it, and one might be able to determine a maximum rate of slip and see the consequences of that would be.

Q How would you go about doing that?

A Well, for example, at the football stadium at the University of California, we have instruments which measure the rate of slip along the Heyward Fault. The stadium was built right across the Heyward Fault. It's sometimes suggested that in the big game between Stanford and Cal, sometimes Stanford will be carried further away by a sudden movement on the fault.

(Laughter)

But for better or worse, the stadium was built right across the Heyward Fault, and there's a culvert underneath it, and this culvert is broken by the fault slip; not by earthquakes, but by the slow fault slip and we have an instrument on that which measures the amount of slip that takes place continuously.

I think it's the longest measurement, probably, of fault slip ever obtained, because I started it back in the mid-'60s, and that indicates a rate of slip on that, the average of about 2 millimeters per year of slip.

So that would be, for example, one figure that one could start with.

Q I see. That's a direct measurement of slip?

A That's a direct measurement, yes.

Q Is there any way that you could arrive at a reliable indicator of slip through merely examining the topography of an area without directly measuring slip?

A Well, the problem there is that if one sees an offset stream, for example, a stream running across the fault and finds that one side of it is -- has a zig in it and one side has been carried to the north or to the south relative to the other side, then one would suppose that that is due to movement on the fault, but that movement could be suddenly in an earthquake or from slow slip or creep or both.

So you really can't disentangle those two things, I think, from the geological record. Dr. Jahns might have a different view.

Q Well, again you are still referring not to a direct measurement of slip on a fault, but to an observance of slip on a fault in order to determine the rate of slip;

isn't that so?

A That's correct.

Q Now is there any way of determining slip without observing anything along a particular fault, but merely looking at the shape of the terrain in the area?

A I don't believe so. Not the slow slip I'm speaking of, no.

Q Would you believe that you could look at the uplift of the Vallecitos Hills, for instance, and say that you could postulate how the hills were formed and therefore determine a rate of slip that way?

A No, because some of the uplift could take place suddenly in an earthquake dislocation.

A (Witness Harding) Dr. Grossman, I think you're confusing the term slip as Dr. Bolt measures it as creep with the average long-term rate of slip, which is averaged over several events in the geologic record, and I think that point isn't quite clear in the discussion here.

Q Thank you, Mr. Harding.

We have had some discussion about -- and this is for Dr. Bolt again -- about vertical accelerations as compared to horizontal accelerations, and you did indicate that recently the figures have changed that seismologists go by so as to show an increased ratio of vertical to horizontal. Is that due to the fact that only recently were vertical accelerations really determined in any large measure?

A (Witness Bolt) No, there has always been a vertical component accelerometer with a horizontal component accelerometer, right from the beginning of measurements of strong ground motion.

One must realize that the data base of accelerations has just increased exponentially in the last few years. I am sure you have seen indications of that. Up to 1971, when the San Fernando earthquake occurred, nearly all the discussions such as we are having here were related to very few records. One was the 1940 El Centro record. There were a few others.

Suddenly in 1971, with the San Fernando earthquake, in an area -- the Los Angeles area where there had been many accelerometers placed, there came -- the record was doubled, the number of instruments available was doubled.

What was also very different there was that here we had not a strike-slip type of motion which is typical of California earthquakes, typical of the earthquakes say in this area, in the Bay area, but there was thrusting of the San Gabriel Mountains over the San Fernando Valley, so that we had a sample there of a different kind of earthquake mechanism from literally hundreds of strong motion accelerometers, so that given geological complexities, earthquake source complexities, it's really no surprise that one is starting to get a greater distribution of peak accelerations of the horizontal relative to the vertical and so on.

However, I must point out, I didn't want to give the wrong impression, that if you sit down with pencil and paper and take the average peak accelerations vertically and the average peak accelerations horizontally, one would from a whole data base available say within 20 kilometers of a major fault, one would still find a value like .6 times the vertical for the horizontal.

Q I notice some of the examples you have given in which there were large vertical accelerations related to fault movements in which there was vertical displacement, as compared to horizontal displacement.

Would you say that the ratio of vertical accelerations to horizontal would be greater and generally are greater, where there is vertical displacement?

A That's my view, but it's certainly not a consensus. I've had senior seismologic colleagues who tell me they just don't agree with that, that the evidence is not in.

Q Could the fact that there has been an increase in what you estimate to be the ratio in the last few years relate to the fact that there has been more evidence of thrust faulting episodes in the last few years?

A That would be an explanation in the case of the injection of this large amount of San Fernando earthquake data into the data base.

However, in the Imperial Valley, where some stations -- I think it's been pointed out -- showed a rather high vertical motion at high frequencies, a good deal of the explanation seems almost certainly to be the geological conditions there where the alluvial layers, the sediments have steep velocity gradients. This is known from geophysical prospecting work, and to some extent bore holes.

So that when you have steep gradients, it's just like going into a lens, a glass lens, with an optic ray. The seismic waves can be refracted very steeply upwards, and there seems to be general agreement -- I've been to a number of meetings where seismologists have studied the records down there -- and there seems to be general agreement that this happened in the Imperial Valley circumstances, that a lot of the vertical component motion there was special to that kind of geological condition, and that the steeply bending upwards of the seismic waves which normally would come in more flatter and appear on the horizontal records, was in that case steeply turned upward and appeared on the vertical records, so that's another aspect of it.

Q That's right, but I believe you also mentioned along with the steepness in that area, that there was vertical displacement at Station 6 in the Imperial Valley.

A That's quite correct, yes.

Q So that basically the instances you have referred to, the Imperial Valley Station 6, the San Fernando Fault, of -- the episode of 1971, and the Gazli event, all involved vertical displacement, and in all of them the vertical accelerations surpassed even the horizontal; isn't that so?

A You're correct, yes. In each case, however, I would point out that the vertical motions were quite high frequency, and consequently the relevance to it, to the engineering question of what should be the appropriate fraction of the horizontal motion, is not simple one.

One has to, as I said before, not compare motion in one frequency range with a motion in another frequency range, because all these things are really functions of frequency.

For example, if I got a hammer and hit a piece of concrete, I could get very high accelerations at very high frequencies, but they would be of no interest to the designers or to you, I suppose. So we have to think of it very much in terms of frequency.

Q Some other observations I understand you have made, with regard to vertical accelerations is that there may be considerable amplification from the foundation of a structure to the upper portion. Is that one of the observations you have made, sir?

A I have worked out some simple models, mechanical models, which would indicate that as the waves run up a simple mechanical spring and damping systems, there would be some amplification. But that was generally accepted, I think, in structural engineering, and often one finds that the accelerometers on the tops of buildings show much larger motions than accelerometers on the ground floor. So it is no surprise.

Q Well, haven't you even observed an example in which the amplification was at a factor of three on the vertical acceleration?

A That's correct. The upper structure. I believe that kind of amplification of building structures is often observed.

Q Well, wouldn't that also apply to the GETR structure, if there were large vertical accelerations at the foundation?

A Well, of course, I'm not competent to discuss the structural response, but I can say in general from the observational side that as one puts accelerometers further up in structures, depending on the height of the structure -- a high structure like this, for example, would have very much greater acceleration at the roof than down on the ground floors. But the buildings are designed to withstand that sort of thing. That's well known.

Q Wouldn't you expect to find a greater amount of amplification if the type of seismic event were a thrust faulting event?

A Well, I tried to indicate that I don't have definite evidence for the point of view, except the cases that we've mentioned, that I quote. And there certainly are other explanations that some of my colleagues would prefer. But I think that if there is a vertical motion on a fault, there would be enhanced vertical acceleration. The amount of this enhancement I am not clear about. It wouldn't be, I think, so far as the ground motion is concerned, more than a few percent, probably.

Q Now we have heard some discussion about the possibility of a manmade structure deflecting a shear. Were you informed of, or have you observed anything along this line, sir?

A You're speaking of faulting in the ground?

Q Yes.

A If you build some structure across the fault, and the fault may go around?

Q Yes.

A I have not observed that.

Q Well, there was one example given in which there was a large building in South America, I believe, called the Banco Centrale. Are you familiar with that particular instance?

A I didn't visit that particular earthquake in Nicuaragua.

Q Well, I believe the testimony was to the effect that there was a faulting episode and that instead of the offset occurring directly at the foundation of the building, it deflected to the side. Were you aware of any observation like that with regard to that instance, sir?

A Yes, I think I do recall seeing slides and general presentations of the damage, that that happens. It wouldn't surprise me in certain circumstances where you strike a very large competent and strong reinforced concrete or steel structure built on soft soils, because while the fault rupture is certainly not going to be deflected at great depth in the crust, that is it's running up to the surface and coming through the softer material, then the surface expression could easily locally, I think, be deflected by some manmade conditions.

Q You think that's possible, then?

A Oh, I think from the physical point of view, yes.

Q Do you know of any instances other than the one that I mentioned, that you were somewhat hazy on, in which this occurred?

A No, I don't believe offhand that I do.

Q Would you ever rely upon the possibility that this might happen in order to mitigate the effect of what an earthquake might do to a building?

A Well, I'd be open to the suggestion that if the design of a structure was such that it wasn't really anchored to the ground, but was, so to speak, on a raft foundation which was designed to have strength exceeding that of the material upon which it rests, that that would mitigate the effect of displacement on faults underneath it, and after all, ships at sea feel earthquakes, because of the seismic motion, the seismic waves coming up through the water that jolt the ship. But there can't be anything like rupture under the ship in the water. It doesn't have any strength in that sense, any shear strength.

So I think that that idea certainly can be carried over. One would want to, I suppose, test it at various scales in the laboratory and give them the material that one is dealing with. But it seems to me that it would be quite a feasible engineering thing.

Q Well, I understand the substance of what you've said to be that you would hope that would happen in an earthquake, but you wouldn't rely upon it happening?

A I wouldn't rely on it, no.

JUDGE GROSSMAN: Judge Foreman.

BY JUDGE FOREMAN:

Q I was hoping that Dr. Grossman would follow up on one of the questions that he had raised concerning rates of slip, and it was my impression -- I think Mr. Harding had pointed out that you were looking upon rates of slip as slow rates, more or less continuous rates of slip. But I'm not a geologist or seismologist, and you will recognize that by my verbiage and my conceptual grasp. So two things I ask:

Bear with me, and also make your explanations such so that I can understand them.

But, anyway, looking at it from that point of view, consider slip as occurring over a long period of time, in which the slip came about not only because of slow movements, but also because of abrupt movements in the form of offsets, and if the period of time were long enough, then one might be able to average things out and provide a number for the rate of slip.

Dr. Grossman had asked could one then draw inferences or make estimates of rates of slip based on topographical features, and he indicated the Vallecitos ar3-19

Hills, and I'm asking you that in the context that that kind of parameter was used to estimate probabilities of the likelihood of probability of occurrence of events.

In your mind, is that an appropriate way to estimate slips, using topographic data?

A (Witness Bolt) Just to clarify now your use of the word "slip," if we could do that to start with. I was using slow slip to relate to motion along the fault which does not involve earthquakes. You'll appreciate that. I think when you formulated your question then, you wanted me to consider slip as the total displacement over long periods of time which would be made of two things:

One would be the slow creep that we were speaking about earlier, and the other thing would be the offsets in earthquakes; is that correct?

end 3

A. So for the purposes of this question, we want to take "slip" to be the sum of both of these things.

Q. Is that an appropriate way in geology --

A. Yes. As I said before in answer to Judge Grossman's question, I think you really can't separate the two things. But having said that, if we now look at the total amount of offset along a fault and recognize it could be made up of episodes of creep and episodes of very large displacements or small displacements in smaller earthquakes, then I think that it could give some bound to the rate of earthquake occurrence. It could give a bound to it. You would have to make assumptions about what the percentage of the slip or the displacement that came from earthquakes was as against the percentage that came from the non-earthquake deformation.

There is also the problem, which I am sure you have recognized, that the general area can rise and fall due to general areal strain which are not related to slip along faults at all.

Q. General what kind?

A. "Area," distributed over an area.

Q. Area?

A. Area, in that sense, not up here (indicating).

So that -- but distributed over a region or an area. For example, there is evidence that the Sierra Nevada is rising slowly. The whole region, so to speak, is moving upwards. So that the reasons for levels of land, including mountains, to change are rather complicated.

Q Well, in your opinion is that parameter as we had described for estimating uplifts or rates of slip, is that an appropriate one to use in the calculations of probabilities? That is part one of the question. Is it used frequently?

A If it was tied down to a specific fault and a specific comparison of the levels on one side as against the other, I suppose it could be helpful and given considerable weight if it was to do just with the general hills where there could be many explanations. I personally wouldn't give it very much weight.

Q Let's turn to another area, the concept of seismic gap. Earlier at these sessions we heard that consideration of seismic gap wasn't terribly significant because the major earthquake that a seismic gap might predict was already a given in the considerations, for example of the design basis parameters. But I would ask of you: Is there enough credibility in the hypothesis of seismic gap that it should be considered in probability considerations? In other words, the fact that one might postulate there's a seismic gap in a given region, and one were attempting to determine the probability of a major event, should one factor that concept into the probability considerations?

A. At the present time, Judge Foreman, I would not do that. The main reason is the case I already gave you. That is to say, in the Imperial Valley if that had been done, presumably the risk would have been lower than what it turned out to be, given that the fault ruptured in 1979 along the same path that it ruptured in 1940.

Now in a gap theory, one would say on the simple view of it, it has already ruptured therefore the risk is going to be higher to the north and the south. I think that has implications on public policy in meeting earthquake risks that I would not want to build into a system. It is an interesting theory. I think it may well be true in certain circumstances, but it has exceptions. Therefore, it is not appropriate, I think, in terms of any hazard mitigation from earthquakes to put it into the equation.

Q. It could work the other way around. I think it has been suggested at these sessions that there does exist a seismic gap, a time gap in the Bay area, if not for the Bay Area for all of California, but it was suggested it applied to the Bay Area, and therefore the probability determinations or estimates that didn't consider it might well not be conservative at all in view of this sword of Damocles hanging over our head in a sense, if the seismic gap considerations were not considered.

A Well, you see, I don't think one has to call on it at all. What one calls on in terms of the hazard from great earthquakes in California are the geodetic measurements which indicate from triangulation across the whole state that the Fairlon Islands, for example, are moving north relative to Mt. Diablo at a rate of some inches per year. So that one is not relying on a gap theory, but is relying on very hard measurements of strain building up in the rocks of the crust of California.

Now that is very different from saying: Well, nothing has happened for awhile at place X somewhere in the world. It mightn't be happening because there is no strain building up. And I want to approach these things in a much more deterministic and firmer way.

Q I guess, then, it is not entirely clear to me what the meaningfulness of this concept of seismic gap is, either for political considerations, for alerting people that make policy to do something; or for considerations of design parameters as such.

A. No.

Q. The seismic gap hypothesis and its meaningfulness alludes me. I don't know whether you can enlighten me any more on that?

A. Well, I think it alludes me, too, Judge Foreman. As I said in an earlier answer to Judge Grossman, I think that where we are struggling say in the science is to say where should we put our instruments to catch a big earthquake.

As I am sure you have seen already, one of the great problems in this whole business, we could be much less conservative if we really knew what happened in an 8+ earthquake. A lot of the conservatism is built into the whole business because one wants to be quite sure that one is going to cover the whole possibility.

So that in our attempts in seismology to catch a big earthquake, we have to use anything that is available, and one of these things is the gap theory. So we say: Well, if we're going to go to the People's Republic of China, for example, which is happening now, and quite a number of seismological groups are working with the Chinese -- you say: Where in their 2500 year history have there been big earthquakes? But there have been none for the last 300 years, say. And that would be a place where you would maybe want to put your instruments and spend five years of your life working, rather than a place where there had just been a big earthquake.

It seems to me that in that sense it makes sense.

Q From the viewpoint of investigations?

A Investigations; exactly.

Q I am changing the subject a little now. Frankly from my layman's point of view, I was absolutely fascinated by the hypothesis in the analyses that led to the inference that heavy buildings could divert faulting from their foundations.

A (Nodding in the affirmative.)

Q To me, it has many, many considerations aside from determining the hazard to the GETR structure.

A Yes.

Q And one of the things that occurs to me is that in an area of high seismologic activity such as in San Francisco, there are many, many heavy buildings that are built all through San Francisco.

A Yes.

Q And if one were to place a measure of credence on that particular hypothesis -- and now I am asking you the question -- could one predict then that any of the faulting would occur along the streets, then, in between these buildings, since these buildings would all divert?

(Laughter.)

Is that even in a minor sense, is that a credible hypothesis? And following further, if indeed heavy buildings on the proper soil conditions do divert faults, why haven't people observed these say in settings where there are heavy buildings?

A Well, the reason that they haven't observed them and wouldn't observe them in San Francisco is because no faults have ruptured, generally speaking, through cities, except in the case you mentioned with the Bank of America. It is not thought that there would be earthquakes hereabouts that involve faulting through San Francisco itself. The San Andreas Fault fortunately is out at sea here. So it is not the case that there will be faulting through the streets of San Francisco.

Some of the photos that you see that look like faults are the failure of the soils in the filled areas, so that the streets look slumped as though faults have run through them, but it is just the failure of the foundation conditions. So I think that your interesting speculation is not likely to be put to the test.

Q But you tell me that the stadium of my alma mater is built on the Hayward Fault.

A That's true. There is an example.

Q Fortunately I did not know that when I went to watch football games, or I wouldn't have enjoyed them at all.

(Laughter.)

That is a pretty heavy structure, in many ways.

A Well, yes, but the mass is distributed around the seating, and so on. There are expansion joints in it. As a matter of fact, when you go to the next game there, if you go up to the top of the stadium at the southern end you will find there was an expansion joint. It was built in sections. It wasn't one coherent structure, connected structure. You will find that that particular expansion joint, which I suppose was a few tenths of an inch gap when it was built, is now over an inch wide and it is opening. So that as the fault slowly slips, one part of the stadium is sailing past the other part, fortunately at a very slow rate so it doesn't affect anything. But there aren't very many examples.

A lot is said about hazard from fault rupture under structures, but fortunately there are not all that many buildings that are built across known faults. The winery is one example I gave you. The stadium is another at Berkeley. But for various reasons, people are usually aware of geological conditions in the fault zone and keep the buildings away from them.

Q I know you've been asked this, or I think you have been asked this, but I would like to hear it again. Is it a common belief among geologists that faults will be diverted from beneath heavy buildings? Or just haven't they given much thought to it?

A I think there hasn't been very much thought given to it. It is certainly a belief that has been talked about, and I have been aware of it for many years, this idea; and in one form it has already been put into practice. There is a nuclear reactor in South Africa which the French constructed where, first of all, a concrete platform was poured on the rock, and then supports were put up with Teflon on them, and then another platform which the structures were built on was put on top of these Teflon slabs. The idea being not to avoid the effect of fault rupture underneath the structure because there are no faults there, but in the shaking, the ground will shake underneath this platform and slip on the Teflon. So that that is a rather clever idea. I don't know whether we would be bold enough to do it, but the French certainly have done it to decouple this heavy structure from the ground itself by having it on, so to say, slides or skids. Their engineers and so on believe, the French, that that will work.

Q Does it make sense to you?

A Yes, it does.

Q Well, let me wander a little more. During the course of these proceedings, I have learned a fair amount. I have learned a little bit about the way geologists and seismologists draw inferences, and a good deal of that comes from drawing regression analysis curves and then picking points off curves in order to make predictions. And very often the magnitudes are in some cases correlated with fault lengths and other things.

The question I would ask of you relates to focusing. As I understand it, the concept of focusing, or the idea of focusing has been a relatively recently recognized phenomenon, whether it be a lens effect or the acoustic effect.

In your mind, knowing that that phenomenon does occur, would that alter any of the correlations that can be drawn, or any of the inferences that can be drawn from your regression analysis curves? By that I mean, knowing something about a possible event, and say focusing occurred here, and therefore it is not appropriate to draw inferences from this curve which contains information from events that had no focusing? What is the importance of focusing is what I am asking.

A. Yes. I understand the question. I think that for the procedures that are used in estimating the maximum credible events that are involved in the kinds of hearings you are concerned with, it really doesn't have any implication at the present time, because in my view focusing is involved in every earthquake, whenever an earthquake occurs. That is to say, rupture occurs, there will be focusing.

So that every point around this rupture will be influenced in some way with this effect. In a very small zone at the front, the motions would have a factor in them which would tend to increase. In other parts all around there would be a factor which would tend to decrease them. But it is so difficult to separate this factor. We might be talking about 10 years, or way in the future, if it could ever be done.

But the only practical procedure is to pursue a conservative line; recognize that focusing is one of many variabilities that is in the data; take the data as a whole; and then work with some bounds to the data depending on how critical the structure is. One of course doesn't take the smallest, or the mean, perhaps, but something higher than that. I think there is no other way at the present time to treat it.

Q This is by virtue of the fact that seismology and geology are relatively new areas of investigation and one draws inferences empirically? One is collecting data and then doing things with it?

A I would much prefer to, because of the great complexity of the geological world as against the world you can work with in chemistry and physics and the laboratory, to stay as close as possible to the observations.

Q I have another question or so, if you don't mind. I should say that this is entirely for my education about geology, and I don't think it has meaningfulness in terms of our plant. But as long as I have you here, and you are so kindly answering my questions, I will take a couple of minutes.

Am I right in reading that the Las Positas Fault is a left lateral slip fault which is very unusual? Is that the fault that is a left lateral slip? Or all other lateral slip faults in the region are right lateral siip faults?

A. Well, to tell you the truth, since I have not studied the general detail of this plant from the geological point of view, I'm not sure offhand whether it's left or gith?

Q. Mr. Harding, you would know that.

A. (Witness Harding) Dr. Herd mapped it as a left lateral fault; yes.

Q. Now my question. In terms of its relating activity from the Las Positas Fault to the Verona Fault, Dr. Herd as I recall had indicated that there these joined, and the fact that the Verona Fault is a thrust fault and the Las Positas Fault is an "anomalous," and I am putting quotation marks around it, is a strange fault that somehow got shifted backwards compared to other faults in the area. In other words, the strains that are existing on his area somehow screwed that one up.

Can you draw any information about the meaningfulness of the proximity of those two faults with respect to what's happening -- what might happen on the Verona Fault, and I guess in terms of what might happen to the GETR?

A. Well --

Q. Is the fact that this is so anomalous and this is a strange combination of geologic circumstances make any difference?

A. (Witness Bolt) Judge Foreman, you are the one who is educating me, because I really am not aware of these relationships that you are talking about this morning, and I think that any comment I would make on this would be virtually worthless because I've really not thought about it at all.

Q. Well --

A. I am just not involved with the geology out there. I've just been involved with the seismological aspects, the occurrence of earthquakes and that sort of thing.

Q. Well, maybe Mr. Harding? Are you in a position to speak to that? Or Dr. Jahns?

A. (Witness Harding) Let me start, and maybe Dr. Jahns will want to add something.

The Las Positas Fault is only unusual in the sense that it is a northeast striking left lateral slip fault in an area that is characterized by northwest striking right lateral slip faults. That is not an impossible situation, however. It can be argued that it is a part of a conjugate fault system which we see in other areas of the world.

I think what is more inconsistent in my view is the pattern of movement that has been observed on the Verona Fault itself. In this case, we have a fault which is nearly parallel to the Calaveras Fault, a northwest striking right lateral strike/slip fault. With that orientation in a similar stress regime, I would expect that the Verona Fault would show a considerable component of right lateral movement also; it is a parallel fault. We don't see that. What we see is almost purely dip/slip movement. Where there is oblique slip movement on one trench, it might be to the left, and on another trench it might be to the right, but a very small component of oblique slip.

So to me, that is where the inconsistency lies.

Another inconsistency is that at least in our opinion the evidence from the trenches does not indicate a direct connection between the Verona Fault and the Las Positas Fault. Where the Las Positas Fault has been trenched, and it is known as some eight miles east of the GETR in the southeast corner of the Livermore Valley, I am not convinced that it crosses for example the Livermore Fault and several other geologic features out there in order to make this connection with the Verona.

Does that answer your question?

Q Yes. I guess in view of the "anomalous" characteristics of the Verona Fault, can one draw many inferences about its future behavior, then, since the conditions there don't seem to explain why that fault has behaved so differently from the Calaveras Fault and from other faults in the region?

A I think the only way you can draw the inferences are to look at the geologic record that is on those shears themselves to see what has happened on those particular shears in the past, in order to try to make some estimation of what is going to happen in the future.

Q I see. Just from the data.

JUDGE FOREMAN: Thank you very much.

JUDGE GROSSMAN: Judge Ferguson?

JUDGE FERGUSON: Let's take a break.

JUDGE GROSSMAN: We will take a 10-minute break.

end JWB #4

JUDGE GROSSMAN: Judge Ferguson?

BY JUDGE FERGUSON:

Q I have a few very brief questions.

Dr. Bolt, just to make certain that I understood at least some of the general statements you made, you had indicated that -- I'm speaking now about components of acceleration, vertical vs. horizontal. You said many measurements have been taken and you, I think, indicated that it's your belief that the vertical is on the order of .5 to .55 of the horizontal; is that correct?

A (Witness Bolt) That's correct.

Q Then you went back later to say that that's a general statement, but there somewhere the vertical can exceed the horizontal?

A That's correct.

Q And you pointed out if you included everything, it comes out to be an average of about .6, that is the vertical being about .6 of the horizontal; is that correct?

A That's correct.

Q And that would be a good number to use, I suppose.

Do you know whether or not -- are you familiar at all with the use that structural engineers make of these two components of acceleration?

A Well, I am in a general way, Judge Ferguson.

I do want to make one point which may have got by when I was answering a question along these lines from Judge Grossman, if you'll permit me.

He mentioned the number of cases where vertical accelerations have been observed recently and San Fernando was mentioned. I want to make it clear that the .12g or the 1.15g at Pacoima was, of course, not vertical component. I think that might have given the impression that that was an example of very high vertical component. That was a horizontal component acceleration, and that for the record, the big horizontal -- the vertical was less in that case.

So far as specifically your question, I have been interested over the years that, for example, in the design of dams, it has been shown that the vertical acceleration should be taken into account, but that it's not a major concern for most dam builders, and that's really only a recent result that some of my colleagues at Berkeley have done by rather elaborate finite element analyses.

I give the example because that's something I have been most familiar with. But it depends a good deal on the structure. It's really an engineering question as to whether you need to take it into account at all, and so that I can point to certain observations of ground motions, had the observations of one component relative to another, should be taken into account, whether they should put great weight on it and give it the full observational mean value, or whether it should be discounted or not, is really an engineering question beyond my competence.

Q I'm not really asking you to testify as a structural engineer.

A No.

Q We have had testimony in this hearing that generally structural engineers use about the figure you gave, about .6 or 2/3rds of the vertical acceleration as compared to the horizontal acceleration when considering structures, and I just wanted, if possible, to get your view as a man in your area of expertise as to the meaningfulness of that particular ratio.

Would you simply say that it's been your -- it's your belief that on an average about .6 of the horizontal is equal to the vertical insofar as accelerations are concerned?

A That's correct.

Q You did go on to say that you wanted to make it very clear that frequency had a very important consideration when you're talking about accelerations, and you went further to point out that it is always true that the vertical frequency is higher than the horizontal; is that a correct statement?

A I wouldn't be of the opinion to say always, but in most cases, that's true.

Q Could you tell us physically why that's the case?

A The vertical component usually is made up of the seismic P-wave. I have to be a little technical. And as you know, in an elastic media, there are certain kinds of elastic waves that can propagate.

One is the P-wave, or the primary wave.

The second is the shear wave, or the S-wave.

And then there are the surface waves.

Well, the P-wave has a particle motion like sound wave in air. That's to say it's compressions and rarefactions. My voice is doing compressions and rarefactions. So in the rocks the P-waves travel compressions and rarefactions along the direction of propagation, so as the wave comes up to the site coming up rather steeply, the motion will be along the direction of the ray, and hence vertical or essentially vertical.

So most of the energy that one sees on vertical component records is made up of the P-waves, at least in the early part of the record. But horizontal components, there you are dealing with transverse components of the ground, which is the shear motion of the ground. Apples and oranges again. Different kinds of waves.

Q All right. I think that's clear.

Speaking now about the effect of these motions on buildings, did I understand you correctly to say that it's your understanding that buildings always amplify motions?

A I believe that unless the building is an extraordinary construction with lots of damping in it, that would be the case, because the building is a frame structure -- well, I'm starting to qualify the thing. I'm generally speaking of observations on frame structures such as this building.

When you have a frame structure, the rigidity is less than the rocks, so the energy is coming in from the rocks and the soils underneath the structure. Here you have a rather elastic structure which is going to sway very much more than the foundation does, and an instrument on the roof will express these large motions. It is well known, both observationally and theoretically, and engineers routinely calculate these things which agree with the observations very personally.

On the other hand, if one had a very rigid structure which was designed so that the general elastic properties were like the rocks underneath, then there would be very little amplification of the motion. If one designed a structure that had dampers inside it -- and that's been suggested, I don't know whether it's ever been done -- but in any event, these partition walls absorb a great deal of energy and a lot of shaking.

If one designed a building where there was lots of opportunity for the energy to be absorbed by destroying nonstructural elements, and so on and so forth, one could conceive a case where at the top of the building there would be less energy than there would be at the bottom, but that's not the usual kind of structure.

Q What I was trying to get at is the basis for your statement that buildings always amplify ground motion. Is that really based on a logical argument such as you have just given, or is that based on measurements that you might be familiar with?

A Well, I'll just qualify the "always" there. I said it in haste.

Generally speaking, the ordinary structural kind of building will amplify ground motion. That is based on both calculations structural engineers do, and that is based on the theory of mechanics, and it's also based on observations. Quite a lot of strong motion records have been obtained in the ground floors, intermediate floors and on the roof of high structures, frame structures, and they indicate a progression of amplitude of the structures.

Q Dr. Bolt, that's very helpful.

Mr. Harding, let me make a statement, in all sincerity. I was ecstatic to see you here this morning. I did not know you were coming back.

(Laughter.)

A (Witness Harding) Neither did I.

(Laughter.)

Q I hope this is not a fault, but I want to slip into this discussion of some material that Dr. Jackson brought to us. In Dr. Jackson's testimony -- I'm not asking you to testify as regards his testimony -- I was just very interested in a statement he made, and I was wondering if you could shed any light on the statement. I'm going to read Dr. Jackson's statement from his prepared testimony on page 8. Dr. Jackson said:

"In the last few months, about 20 net slip determinations have come to our attention that we are presently reviewing and will be able to discuss at the hearing if appropriate. We understand that GE is reviewing the same data and plans to present the results of their reviews at the hearing."

And, incidentally, this has to do with the San Fernando Valley event.

Have we covered that?

A Yes. That refers to the measurements in the paper by Robert Sharp which we discussed at Livermore a week or so ago.

Q Those were the 20 new net slip determinations that were made?

A They were new to Mr. Jackson; they were not new to us, because we had included those in an analysis we did some time ago, included them along with the other data from Barrows and others. Actually, there were about 10 different papers to get information from.

Q Is GE doing anything further with those results?

A No. What we did was what Dr. Reed reported on at Livermore, was to go back and look at those again and see if it really made any difference to our original analysis, which it did not, because they were already included in the original analysis.

Q Very good. Well, that certainly helps clear that up in my mind.

One final thing, Mr. Harding. I heard you use the word "Verona Fault" this morning, and somehow I had gotten the impression that you were a nonbeliever in the fault. Am I mischaracterizing you?

A I think I am still a nonbeliever in the fault.

Q I see. You did, however, just recently this morning make some attempt to show a lack of similarity in response to Judge Grossman -- Judge Foreman's questions, showed some inconsistencies between the Las Positas Fault and the other fault, if in fact it is a fault.

Was that consistent?

A Well, the problem you get into when you have what is maybe an ambiguous situation, and you start to investigate either possibility of what can occur, is that as you go down either path, you sort of get trapped into various assumptions. That's kind of the case that happened with us assuming that the structures out here we were seeing were in fact tectonic.

If we did, in fact, have the Verona Fault, then you have to treat it as a fault, talk about it as a fault, and try to examine it and try to characterize it as though it is a fault.

I'm not sure, does that answer your question?

Q It does if you believe that all of these observations that you have referred to or you were referring to when you were answering Judge Foreman's question could be explained on your landslide hypothesis.

A Yes.

JUDGE FERGUSON: All right. I have no further.

BY JUDGE GROSSMAN:

Q I have just a few follow-ups for Dr. Bolt with regard to Judge Foreman's questions and your answers to him.

You indicated that one of the problems of basing a recurrence of earthquakes on the rate of slip would also relate to having to make an assumption with regard to creep as opposed to displacement because of a tectonic event.

Does this relate both to any model you would use, and also to applying that model, if you were to apply it to a particular event?

A (Witness Bolt) That's quite correct. You'd have to assume it in two places.

Q Well, is there any general figure you could assume that would apply worldwide?

A I don't believe so. Of course, as I mentioned also, one could seek a bound and assume at both places that everything you saw was related to, we'll say, earthquake offsets, and that might be helpful in those extreme conditions, depending on the criticality of the structure, that it might be a worthwhile thing if one wanted to be so conservative.

Q But could creeping, let's say 80 percent in one place and 20 percent --

A Oh, yes, it could vary all over the place.

Q And could you make any generalization with regard to the Verona area?

A No.

Q That South African example that you mentioned, that was an attempt or is an attempt, is it not, to make that reactor into a free-floating type of structure?

A Exactly.

Q That wouldn't have any applicability to GETR here, would it?

A Well, I told the example not just because it's an interesting case, but because it does give an indication that people take seriously the notion that one can decouple heavy structures from the basic rock motions, and that's an extreme example where it's engineered in, but it's in the same line of thinking that if you have soft soil conditions and the foundations are right, that they will, so to speak, act as the Teflon. I mean the alluvium will act as the Teflon and allow slip to take place, rather than moving that enormous mass by these ground accelerations. The fractures are easily taken out by the soft soils underneath, and that's where the slip will occur.

Q Would you consider the Livermore gravels to be that kind of soft soil?

A It depends if they were waterlogged and just what the proportion of sand in them was. I'm not sure of the details.

Q In answer to Judge Foreman's questions, you indicated that there was focusing in every earthquake, and that that should be taken into account.

Would that be taken into account in making an assumption that whatever may be the expected the mean accelerations, they may well be exceeded in certain areas of the offset?

A Yes, one would work from the mean of this data base that contains the effects of focusing among other things, and then again depending on the case in question when one is dealing with a particular site, build in the conservatism after one has done that.

Q Now one final question:

One of the conclusions that has been presented to the Board with regard to a probabilistic study of this site was that based on a classical probabilistic study, the chance of there being an earthquake of greater than a 6 magnitude on the Verona Fault would be no greater than 10^{-4}.

From your experience in seismology, is there any area that you can tell us in which the chance of there being a greater than 10^{-4} -- in which there is a possibility greater than 10^{-4} that there would be a 6 or greater magnitude earthquake?

A That's a difficult question to ask me, Judge Grossman.

Q Excuse me. Let me limit the area to basically the size area that we are talking about now, which is a near field area of the GETR site.

A Oh, the near field area of the GETR site?

Q No, I'm saying the size. Is there any place in the country in which there is an area of that size that you would consider basically the near field around the GETR site, in which the probability is greater than 10^{-4} that you would have a 6 or greater magnitude event in any particular year?

A I have never conducted calculations so finely in any part of California. I just couldn't answer. I couldn't answer affirmatively in this case.

Q Well, I know that you're not a probabilistic man, and I really just wanted to get your general observation as to whether there is any sort of area that you could say, well, the chances are greater than --

A No, I don't believe so. No.

Q You don't believe there is any such area?

A No, I don't think so.

JUDGE GROSSMAN: Mr. Edgar?

REDIRECT EXAMINATION

BY MR. EDGAR:

Q Dr. Bolt, one basic point:

There was discussion of the physics involved in deflection of a fault around a structure. Is it your opinion that an engineering analysis of that phenomenon would be feasible?

A (Witness Bolt) Yes, I think it would be feasible involving soils engineers together with structural engineers and geologists.

Q And would you be willing in the hypothetical case to rely on that competent engineering analysis of that phenomenon?

A Yes, I would.

MR. EDGAR: No further questions.

end 5

JUDGE FOREMAN: Mr. Edgar, before you let Dr. Bolt go, I think I am speaking for the Board, but in any event I am speaking for myself. I don't think it was our intention in dealing with the two letters that you have, that you not have Dr. Bolt speak to your other exhibit, the Exhibit No. 47, "Seismicity of the Livermore Valley in Relationship to the General Electric Vallecitos Plant." Indeed, I am not sure what you had in mind in presenting that?

MR. EDGAR: All I wanted to do was establish a foundation for several questions which had arisen in the record some days ago. In particular, the statement was made on three or four occasions that when Dr. Bolt did his study of microseismicity that there had been directions given to him to ignore the Livermore earthquakes.

Well, based on his testimony this morning, that is not in fact true.

The other purpose of having the document before everyone was to establish a basis in the record for the scope of Dr. Bolt's review, or role in connection with GETR. The report is in fact his role in the GETR review.

While we are at it, I marked it for identification, and I will now offer it into evidence.

JUDGE GROSSMAN: Mr. Cady?

MR. CADY: No objection.

JUDGE GROSSMAN: Mr. Swanson?

MR. SWANSON: No objection.

JUDGE GROSSMAN: Admitted.

(The document referred to, previously marked as Licensee's Exhibit No. 47 for identification, was received in evidence.)

JUDGE FOREMAN: As long as we have a few more minutes of Dr. Bolt's time, I wonder if you could summarize that for us? Oh, I'm sorry. I don't mean to -- you see, I'm not a lawyer. I'm not sensitive to these things.

You go ahead.

JUDGE GROSSMAN: First I think we ought to allow Mr. Cady and Mr. Swanson to have some more recross, and then we can do that.

Mr. Cady?

MR. CADY: I have no questions, but Judge Foreman's question is a good one as far as asking Dr. Bolt to summarize the paper.

JUDGE GROSSMAN: Mr. Swanson?

MR. SWANSON: I have no questions.

JUDGE GROSSMAN: No questions? Okay.

JUDGE FOREMAN: I think I indicated, but it would be helpful to us if you could speak to this paper perhaps in the form of a summary of what you did, and what your conclusions were?

WITNESS BOLT: Yes. What I did was, together with Dr. Hansen, consult the data files that we have at Berkeley on the historical earthquakes, and on the earthquakes that have occurred since instruments were first established in this part of the world. You may be interested that that was in 1887 when there were seismographs installed at Berkeley, and at Leek Observatory, and they were the first seismographs as a matter of fact in the Western Hemisphere to operate, and those stations have continued to operate since that time.

So that you can think of essentially from the turn of the century we have some instrumental recordings of earthquakes in this area of interest. Before that, we have historical documents which summarize "felt" reports of earthquakes. So that we listed the historical earthquakes up to the turn of the century, and then coming into this century more and more instrumental results. That is factual information and that was presented in the form of a figure.

What we found was that -- that is Figure 1 of this report -- that the epicenters of these earthquakes were generally speaking scattered throughout the region with some exceptions. The Calaveras Fault Zone has a few earthquakes along it, no great concentration but there is a concentration to the west along a fault which is I believe the Hayward Fault further away from the site.

The Greenville Fault Zone is shown there, but we didn't plot on that the various aftershocks of the Greenville Fault sequence that we mentioned earlier today. It was -- they were just being worked up at the time in detail and didn't really affect any of the conclusions. So that that Figure 1 represents what is the factual situation with regard to the location of earthquakes over the time period available to us.

We did discuss to some extent the problem of precision of these points. As one comes up to more recent times, the precision increases. And I think you have heard already testimony from Dr. Kovatch on this question of precision, and I agree with his testimony that if you go back to some of the earthquakes in the early part of the centry these points would only be able to be fixed because there were a limited number of stations within 10 kilometers or so; whereas, some of the more recent ones where we have quite a few seismographs, the number keeps changing. But we could say back in 1979, anyway, perhaps 10 seismographs just in the area of the map, one could locate these events within a kilometer or so. So there was an order of magnitude improvement. That is part of the summary.

As to the focal depths, we pointed out that the focal depths of earthquakes in the area is rather shallow and normal for central California. They are in the upper part of the crust, generally speaking, less than 15 kilometers and mostly less than 10 kilometers deep, the focii. Of course most of these earthquakes plotted here don't have ruptures that come to the surface; that practically all, as a matter of fact, of the symbols that are marked here would be associated with earthquakes in which the fault rupture is many miles beneath the surface, and it never comes to the surface at all.

Then as to the focal mechanisms, we can't go back unfortunately and work out focal mechanisms in the early days because there aren't any stations, obviously. What we did was to give a number of cases which are shown on Figure 2 where the fault plane solutions can be made with some confidence.

In the cases that we showed where you get the circles divided into four zones, when one has that kind of zonal pattern with white-black, white-black, quadrantal pattern, that indicates that the actual displacement on the fault was in a strike/slip mode; that the motion was essentially horizontal with slippage one side relative to the other.

So that the best evidence that we had on that was that these earthquakes anyway, some near the Tesla Fault, one near the Fault marked as the "Verona" Fault on here -- I must say, there was some difficulty from a seismological point of view in getting base maps for the epicenters because the geological mapping has changed rapidly in recent years. So a map even five years ago would be different from a map just a few years ago. I'm sure you've met that problem.

But in any event, it is marked on there as the Verona Fault. Th-t doesn't mean that I know, one way or the other, whether it is there or not. It means that it comes off a geological map that was available to us. And the earthquake A near to that trend was a right lateral strike/slip type of motion.

We were also asked to say something about the microearthquakes, whether there were any micro-earthquakes which were occurring around the facility. In recent years, there have been enough seismographs I think to detect earthquakes going down to magnitudes about 2, or even a little less, which are classified as microearthquakes, very small earthquakes, and there was no indication of that. I did give it as -- or we gave it as our opinion that the placement of instruments just in the vicinity to detect even tinier earthquakes wouldn't be very useful, because one was presumably already dealing with quite large earthquakes for design purposes, and they are therefore the occurrence of magnitude 1 or magnitude 0 earthquakes, I couldn't see would be very helpful.

That is my summary.

JUDGE GROSSMAN: Thank you.

BY JUDGE FERGUSON:

Q Just one quick question for my information. I wanted to ask about the measurement of vertical and horizontal accelerations. Did I understand you to testify earlier that in all or most cases that have been measured, both the vertical and the horizontal readings were taken? Is that correct?

A (Witness Bolt) Yes. That's correct.

Q Is it always the case?

A It's always the case. Of course sometimes one of the components doesn't work, and so you will see sometimes gaps in the lists.

Q But setting aside that experimental error --

A It's always there. The three components are always present.

Q Even in very early measurements?

A Well, the earliest measurements go back I think to about the Long Beach earthquake in the '30s, and from the first the instruments were designed to measure the three components of the ground.

JUDGE FERGUSON: Thank you.

JUDGE GROSSMAN: Before we dismiss the panel, there was again a motion of that Sharp Open File Report by Mr. Harding.

Mr. Cady, you have had a good night's sleep on that. Are you offering that?

MR. CADY: No, we're not, your Honor. I reviewed the document and the testimony by Dr. Kovatch did cover it adequately in my opinion.

JUDGE GROSSMAN: Fine. I would like to thank the panel of persons who came here again, and I especially would like to thank Dr. Bolt. The Board certainly appreciates the fact that you are a very busy man and have taken your valuable time to come here for this. Thank you.

WITNESS BOLT: Thank you, Judge Grossman.

(Witnesses Bolt, Jahns and Harding excused.)

JUDGE FOREMAN: Mr. Swanson, I would like to raise a point with you, and I may have some misinformation, but it was my impression at the very beginning of our hearings here in San Francisco that you had some discussion about the photographs of the excavation; and that your people had looked at them, and had seen some features that they had not seen before. Am I getting that confused with the photographs in Trench T-1? I thought that these were photographs of the excavation.

MR. SULLIVAN: There were in fact photographs that were reviewed by, among others, the panel members of our geology-seismology panel, and in fact I believe it was Dr. Brabb who made a statement as to the current interpretation of what they saw in the photographs. So there has been testimony as to that, as well as photographs of Trench T-1.

Now the photograph that was more recently brought to the attention of the panel members, very recently, was in fact the photograph of Trench T-1.

JUDGE FOREMAN: It wasn't that there were some concerns about seeing some new information on the photographs of the excavation? It seemed to me -- my memory is hazy here -- that you had spoken about a conversation with your experts that somebody indeed had seen some features on the excavation photographs, and that you were going to have those reproduced in a form that could better view those differences; and that you were going to deal with them at the hearing. I have heard nothing more. Am I wrong in this whole series of events?

MR. SULLIVAN: Yes. I think there might be some misinterpretation. To my recollection, there was at least one statement by Dr. Brabb that there were some features observed in some, I guess reproductions of the photograph which led them to question the -- and again I am recapping what I understand -- I understood earlier that they had thought there were two probable faults, but that when they had had an opportunity to look at the photograph itself and more carefully examine it, what they saw on the photograph they realized that some of the features show --

(Mr. Sullivan and Dr. Brabb confer.)

MR. SULLIVAN: Just a moment.

MR. EDGAR: I can address it in terms of my understanding. If one looks at the SER of May 1980 there is a statement in the SER to the effect that the NRC Staff had USGS review the foundation excavation photographs. At that time, it was felt that there was a probable fault under the foundation.

Subsequent to that time, Dr. Brabb reviewed better quality photographs. The stuff he had to work with wasn't of high quality, and at the June ACRS meeting he indicated that he had downgraded his assessment from "probable" to "possible."

During my cross-examination of Dr. Brabb, he testified to that effect, that he felt it was possible. There was one other set of photographs that came into the record which were Staff Exhibits Nos. 5-A and 5-B, which was not the foundation excavation, but rather photographs of one location within Trench T-1.

So that is where I see the record.

JUDGE FOREMAN: I see. Well, that may well straighten me out.

MR. SULLIVAN: We agree with that statement. I am told that I -- I guess I didn't accurately state the -- I didn't get through it, but as far as I got I had not accurately stated the evolution of those photographs of the excavation. Indeed, the testimony you heard of Dr. Brabb was based on his viewing of a print that was made up from the negative that was taken of the excavation; that earlier they had seen a poorer quality photograph.

JUDGE GROSSMAN: Did Mr. Edgar's statement clarify the entire situation?

MR. SULLIVAN: It was accurate; yes.

JUDGE FOREMAN: Thank you.

JUDGE GROSSMAN: Would the structural panel please --

MR. EDGAR: Yes, sir. I believe they are ready.

Whereupon,

GARRISON KOST,

DWIGHT GILLILAND,

and

HAROLD DURLOFSKY

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

BOARD EXAMINATION (resumed)

JUDGE GROSSMAN: We left off yesterday with Judge Ferguson in the midst of his examination.

Would the panel please identify itself again, the individuals on the panel?

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

WITNESS GILLILAND: I am Dwight Gilliland. I am with General Electric Company, Pleasanton, California.

WITNESS DURLOFSKY: I am Harold Durlofsky, with Structural Mechanics Analysis.

BY JUDGE FERGUSON:

Q Let's resume not quite where we left off yesterday, but as a continuation of the testimony that we have just had.

This question is directed to you, Dr. Kost. You I think have heard the testimony that has been given at least by Dr. Bolt, and I am not asking you to comment necessarily on his testimony. I am asking you to give me your opinion again just so that I am clear and the record is clear.

This has to do with amplification of accelerations, both vertical and horizontal. Yesterday I believe in response to Judge Grossman's question you testified that it was your belief that vertical accelerations would not be amplified.

I followed that question when I began speaking with you by asking you again whether or not you felt vertical accelerations would be amplified by building structures. You qualified your answer and said that in some cases it could, but for short buildings it probably would not be -- there would be no amplification.

Have I correctly characterized your testimony?

A. (Witness Kost) I think that is generally true. When we talk about amplification of horizontal and vertical accelerations, I think we have to keep in mind in that question exactly what type of a building or a part of a building that we are talking about. If we first consider the vertical accelerations, what I had in mind in a fairly stiff building such as we have here, it is that the vertical accelerations would not be amplified greatly.

Now to me I will qualify and explain what I mean by that. It would not be amplified more than say 1-1/2 or 2 times the input accelerations. My concern in first responding to your question was that perhaps we were thinking about isolated long-span beams which are very flexible in a vertical direction, and which can be amplified. We don't have that situation in the concrete core structure of the reactor building.

The question of vertical accelerations in the amplification of the vertical accelerations is one that has been discussed for many years in the engineering profession. In general, the building codes, conventional building codes, have excluded any consideration of vertical amplification. This is still the case today.

However, in the nuclear industry, there began to be a concern about the possibility of vertical amplification and vertical motions, and because of this concern the consideration of this amplification was incorporated in the design, as we have done in the GETR plant.

Q What is the basis for the concern by nuclear contractors?

A I think the concern is the desire to more accurately represent the response of buildings in earthquakes.

Q Okay. You did, I think -- and I am referring to your testimony of yesterday -- you did point out that the structure that we are concerned with, namely the GE Test Reactor, was one where you did not think vertical accelerations would have very much significance. Is that a correct statement?

A Yes, that is correct.

Q And this is based on your analysis of the structure? Your computer analysis of the structure? Is that also correct?

A It is based on several things here. First of all, I would like to point out that we did indeed use vertical motions as the input to the structure. Those were indeed amplified somewhat as you go up the structure. That is, the motions at the operating floor, which is the highest floor on the concrete structure, are amplified above those which are input. However, the stresses induced in the structure due to the vertical accelerations themselves are very low, on the order of a few psi.

Similarly with the piping systems, the primary system, which is part of the reactor pressure vessel, those analyses and evaluations include the effects of the vertical accelerations, as well as the horizontal. And as I recall, when we did the original analyses of the primary system, the reactor pressure vessel, we did the first analyses with the system as is, without any additional restraints in order to determine whether there was a need to add the restraints.

And as I recall, the displacements were primarily in the horizontal directions -- that is, the displacements of the piping systems were primarily in the horizontal directions since, as is the case with most piping systems, they are well supported in the vertical direction and they tend to be unsupported in the lateral direction.

So my conclusion was that the forces induced in the piping system were primarily due to the horizontal motions. So this led me to the statement that the vertical accelerations were not significant also for the piping system.

Q What I am trying -- Did you have something you would like to say?

A (Witness Durlofsky) I just wanted to make a general comment, that the response of a building depends on the input of course, but it also depends on the stiffness of the building. And the building has different stiffnesses, and different modes.

Generally, it is most flexible in the lateral direction, and it is most stiff in the axial vertical direction. And that is why you see little response in the vertical direction, and significantly more response in the lateral direction, which is what Dr. Kost has found in his analysis. Th-t is the usual case.

Q But surely we con conceive of buildings where that of course would not be the case?

A Oh, certainly; yes.

Q Surely. Yes, we will get to stiffnesses and those matters in just a moment. But for the time being, I just wanted to make sure that I was clear on what we were seeing yesterday.

While we are on the subject, and since we did talk about it with Dr. Bolt it was his testimony that based on information that he has, vertical accelerations were about .6 times the horizontal acceleration. We have had testimony earlier in the hearing that structural engineers use a factor of about two-thirds. Is that correct?

A. (Witness Kost) Yes.

Q. Could you tell me, Dr. Kost, where that comes from, the two-thirds' figure?

A. The two-thirds I believe is probably equivalent to the .6 figure that Dr. Bolt quoted.

Q. The magnitudes are about the same, but I am asking about the origin of the two-thirds.

A. Okay. It is my understanding that the two-thirds factor is based on an analysis of peak values for a number of historic earthquakes. That is, the horizontal and vertical accelerations were compared and the ratios calculated from those records.

Q. In other words, the data base is the same that Dr. Bolt was referring to? Is that correct?

A. I suspect it's the same; and it's also the same as Dr. Hall was referring to several days ago.

Q. As a structural engi eer, do you use the two-thirds' rule?

A. Yes.

Q. Did you use it in the analysis you did for this structure?

A. Yes; that's correct.

Q. Okay. I had a question for clarification, and it is on page 3 of the testimony, your testimony. I am just a little confused about a number. Perhaps you can clarify that number quickly for me.

(Pause.)

That seems to be an incorrect reference, but let me ask the question. This has to do with vibratory ground motion and fault displacement.

My understanding is that General Electric proposed certain maximum values for the vibratory ground motion and fault displacement. The NRC proposed certain values for the maximum vibratory ground motion and fault displacement. And based on my reading, the NRC had proposed a maximum vibratory ground motion of .6g with a fault displacement of one meter; and General Electric proposed a .3g.

Did you later analyze it based on the NRC recommendation of .6g?

A. The structures and systems have been analyzed for the NRC criteria for both the Calaveras and the Verona Faults.

Q. So that is for the .6g? Is that correct?

A. That's correct.

Q. All right. That's fine.

Now I hesitate to start this line of questioning since it is so close to 12:00, but let me ask a short question that may have a short answer.

You have just said that the systems were analyzed based on a .6g maximum vibratory ground motion. Your seismic triggers are qualified to a .5g. Is that correct?

end JWB #6

A (Witness Gilliland) Yes, that's correct.

Q How was that figure determined or selected?

A The .5g is a value that was given us by the manufacturer. As you may recall, the seismic triggers actuate at about .01g. They are set to actuate at that point. They then no longer are required to remain functional.

Once that action occurs, no subsequent action is demanded of the seismic switch, so that while the qualification of that particular unit would not necessarily say that it would survive a .6 shaking, it doesn't have to.

Q We have used the word "qualified" or instruments being qualified, materials being qualified, and I have a few questions regarding that, and as I ask those questions, would you be good enough to remember to tell me who in fact did the qualification?

Let's begin by talking about the qualification of the seismic triggers.

A That was performed by the vendor. That information that we have noted is from the vendor.

Q I see. I would say that as I was reading through this testimony, you make reference to several references, and they are the Licensee's exhibit references. I must apologize for not having read all of those references, so perhaps some of my questions are answered in the references, but nevertheless I will ask the questions so that it will get in the record this way.

(Board conferring.)

JUDGE GROSSMAN: Why don't we adjourn until 1:15.

(Whereupon, at 12:03 p.m., the hearing was recessed, to reconvene at 1:15 p.m., this same day.)

- - - - -

AFTERNOON SESSION

(1:15 p.m.)

Whereupon,

GARRISON KOST,

DWIGHT GILLILAND, and

HAROLD DURLOFSKY

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

JUDGE GROSSMAN: Judge Ferguson.

EXAMINATION BY THE BOARD (Continued)

BY JUDGE FERGUSON:

Q Gentlemen, let's continue where we left off before the recess.

I would like to ask a few questions, if I may, concerning some of the material contained in your testimony on page 22. Let's take a look at page 22 of your prefiled testimony. Do you have that in front of you?

A (Witness Gilliland) Yes, sir.

Q Good.

Yesterday I believe we were talking about vibratory motion and its effect upon the plant. We identified the fact that one of our concerns was that the control rods remain seated under any motion, any unexpected motion. We did discuss the fact that it's very unlikely that the motion of these rods would be significant in the case of an earthquake.

I'd like for you to tell me, if you can, as briefly as you can, what the analysis you refer to in the middle of page 22 was that you performed to assure that the control rod assemblies will in fact not be forced out of the core by seismic motions.

(Panel conferring.)

A (Witness Gilliland) I just wanted to make sure I had all the right information.

The analysis was done by General Electric personnel, personnel who are no ally involved in vibratory motions in core components, and they were given a response spectrum by Engineering Decision Analysis Company, who had previously determined what the response spectra were for the third floor of the building.

Now this is an elevation considerably higher than the control rod assemblies are, but we chose to apply that because we felt it would be very conservative.

That was then given to these persons in GE and they did a calculation, a vibratory analysis, and I do not know the details of the methods employed, but it was a calculational evaluation, and they determined that the amount of movement, given the excitation via the response spectra we gave them for the third floor would cause the control rod assemblies to move a very small amount.

I can't recall the amount of movement as a function of damping value, but it was quite small, an inch or two.

Q The control rods moved an inch or two?

A Yes, an inch or two, that's my recollection. And the damping value -- I don't recall it, either. I'd have to look.

Q Okay. Could you -- if you're looking at page 22, there is a reference 13 given there. Would it be your feeling that the details of what you have just said is contained in that reference?

A No. The reference, reference 13, has to do with an evaluation that was done regarding the issue of can you get some collection of circumstances that would allow you to withdraw because of electrical short-circuits and so on.

Q I see.

A So their evaluation in reference 13 is that one.

A (Witness Durlofsky) I can comment on the type of analysis that GE did. I'm somewhat familiar with their procedures.

Usually what they do -- I'm sure what they did in this case -- is to do a time history analysis of the fuel rod response. That's opposed to a spectra analysis that we normally do on the building, the hull.

The time history will give them the displacement for any time during the seismic event that they are considering, during the earthquake that they are considering.

I'd also like to say something in response to a question that you raised yesterday, a little belatedly, on the question of whether we do any testing. The analytical methods that we use are well-founded on tests.

For example, these fuel rod response analyses, GE does an extensive amount of fuel rod testing on their shake machines, where they will actually put fuel rod assemblies on the machine and simulate an earthquake motion, and correlate that with analyses that they have done.

I think this morning it was indicated that there is very strong correlation between the methods we use, using response spectra, and test results from shake machines. It's very difficult to instrument something and wait for an earthquake to happen for a couple of reasons:

Normally the earthquake won't have sufficient response associated with it that we can get good measurable quantities out of it; whereas if we take it and put it on a shake machine, take a prototype structure and mount it on a shake machine, we know we are putting enough energy input to get the response. So that's normally the way these things are tested.

Q I think I can understand that.

Do you feel that's how Mr. Gilliland came up with an answer of about an inch as a result of this test on the prototype machine?

A Well, I think that was done by analysis, but the analysis was correlated to tests that were run.

Q I see.

A GE at San Jose regularly performs both those analyses and those tests. The normal procedure would be if you have a computer code that does one of these things, you try to correlate against some specific test results.

Q That's very comforting to know that that in fact has been done.

Mr. Gilliland, did you want to say anything further on that point?

A (Witness Gilliland) I was looking to see if we had brought that document. We have not. But if you need that information, that is if you want more information, I can have it here tomorrow.

Q Well, I'm not requesting it at this point in time.

A All right.

Q I'd like to turn briefly now to the reactor vessel itself.

In your prefiled testimony, you indicate that this vessel is centered by three struts; is that correct?

A That's correct, near the top of the vessel.

Q Right. And you indicated that one of the struts was found to be inadequate and you replaced it. Could you give us a little background as to why that action was necessary?

A (Witness Kost) I think I can respond to that.

As we explained in one of the sections of the testimony here, we analyzed the reactor pressure vessel and the associated piping and equipment.

Part of the output of that evaluation was the forces in the various braces, and we found that the stress on that particular bolt was excessive, and we replaced it with a larger bolt or a higher strength bolt.

Q I assume these struts are placed uniformly around the vessel; is that correct? That is 120 degrees apart, something of that type?

A I think not. Just one second.

As I recall, on a clock they would be at 12:00, 3:00 and 6:00 o'clock.

Q I see. So they are not uniformly placed?

A That's correct.

Q I see. Which one was replaced? Maybe you can tell me, if you're more familiar with the analysis, what was it about the analysis that showed more stress on one of the struts than the other two? Was it the way -- well, why don't you tell me why there was more stress on one of the struts rather than the other two, recognizing, of course that they are not symmetrically placed.

A Without looking at the actual geometry, if it were the strut that was at 3:00 o'clock -- which I think it was -- then in that case resisting seismic loads along the axis of the strut, you only have a single strut.

However, for the other two, you have two struts which resist the load.

Q Was there an obstruction that would prevent strut at 9:00 o'clock?

A I'm not sure. Just one second.

(Panel conferring.)

A (Witness Kost) These struts were part of the original design.

Q I understand that.

A And I don't know why there wasn't the additional one.

Q Okay. But just by increasing the strength of one of the struts, you were able to solve at least the stresses that you would predict theoretically; is that correct?

A For that strut.

Q All right. Let's continue with the concept of strengthening the structure to resist the increased accelerations and increased forces.

You say that a number of restraints were installed, and the question I have now is that one of the constraints or restraints that you had intended to install was a restraint to be placed on the underside of the canal floor. I'm on page 25, if that would be helpful. You said:

"It is now planned to mount it on the floor of the equipment room."

The statement is that one time you had planned to place a restraint in one position, and now you have changed your mind, and I am not sure I understand why that change was made. Could you help me?

(Panel conferring.)

A (Witness Kost) During the process of evaluations here, one of the tasks was to evaluate the integrity of the canal floor, the fuel canal floor for the possibility of a cask-drop accident, where the cask would impact the base of the canal.

Now Dr. Durlofsky knows more about the details of that analysis, but one thing that we wanted to do is to preclude any possibility or to avoid any influence of the possibility of any spalling of the concrete on the piping systems. Thus, we did not hang the pipes from the concrete floor, but supported them on the floor below.

Q Dr. Durlofsky, did you have something you wanted to add?

A (Witness Durlofsky) Not to that in particular, but I do have a general comment I'd like to add. The process of stiffening pipes, the way that works is to essentially stiffen the overall pipe configuration so that the frequency -- the frequency in your piping system is raised.

Once you do that, you effectively get less of a seismic input from your earthquake, since your maximum earthquake input tends to occur at well under 10 hertz, and that's why most of these supports were added, both to the vessel and to the piping, simply to raise the frequency.

This speaks somewhat to the question of vertical acceleration. In vertical accelerations, we have a stiffer member vertically than we have laterally, and that's why we don't see the high acceleration values vertically that we see in the horizontal directions.

I don't know if that confuses the situation, or clarifies it.

Q No, I think that's helpful.

Sticking with the canal for a moment, on page 26, you say in your testimony that:

"There are two leaktight containers to assure water will remain over the stored fuel elements, in the unlikely event that water is drained from the canal."

I guess that's the purpose of the container configuration that you have now installed or plan to install; is that correct?

A (Witness Gilliland) That's correct.

Q The bottom of the canal, as I understand your diagram, is below the top of the reactor vessel; is that correct?

A It's below the top -- let's see. Yes, it's below the top of the reactor vessel.

Q I see.

A But above the core.

Q All right. Let me now move on to a postulated event which you discuss in your testimony. You indicate that it is possible in an event to lose some water, and in one of your diagrams you show what you estimate to be the level of the water, the lowest level that the water will achieve in the event.

Is that level above -- that is, the level of the water in the reactor vessel -- is that level above or below the bottom of the canal tank?

Is my question clear?

A Yes, your question is clear. I have to do -- I think I have to do some arithmetic to answer your question. What we are talking about, I believe, is the hypothesized, and at this juncture what the restraints on the primary piping system, the nonmechanistic failure, double-ended pipe break of the piping in the primary system, which would drain or we have assumed, at least, a rapid draining of water from the pool to 5-1/2 feet above the core.

Q Yes.

A And so the question is, at that point, what is its relationship to the top of the canal storage tanks. Is that --

Q Well, that's a sort of intermediate question. But let me tell you what the final question is, and perhaps that will help you answer that.

In the event that you just described, such that the water level is 5, 5-1/2 feet above the fuel, would the canal normally be drained if the water were at that level?

A No, normally it would not be. The canal would normally be full. In fact, the canal is always normally full, and the only way one can get rapid loss of water from either of those two containers is to have the double-ended pipe break, which has the effect of reducing the pool water level. Because there is leakage around the gates between the canal and the pool, there will be a reduction in canal height, because of that loss of water into the pool. But there are no occasions operational in nature in terms of normal operation in which the canal water is lowered.

Q I'm speaking more in terms of an abnormal situation like an event where the water above the core is 5-1/2 feet.

A Okay. Now in that circumstance, the water will drain from the canal to the pool at some rate, and there is some leakage --

Q My question is, what then would be the level of the water in the canal?

A You mean at the point where it's 5-1/2 feet?

Q 5-1/2 feet above the core.

A At that particular point, at the starting point of this event, and you instantaneously drop the water 5-1/2 feet above the core, the water level in the canal would be at its normal operating height at the start of that, which is about --

Q Yes, but let's speak about the end of that.

A Later?

Q Yes.

A I'll have to look.

(Pause.)

Q Mr. Gilliland, will it take you some time to do that? I don't want to rush you, but I don't want to really spend a lot of time on it, either.

A I'm sorry, I don't have it on the top of my head. It would take a couple of minutes for me to find that.

Q I wonder if you could keep it in the back of your mind, and perhaps during a break you could give us that answer.

A Yes, I'll do that.

Q The thrust behind this is that I understand from the design and the description of the design the important thing is if you are storing fuel in the canal, you want to be sure that it's properly cooled; is that correct?

A That's correct.

Q I'm turning now to the fuel flood system, and you go through a fairly detailed discussion of how that is to operate. I'd like for you to enlighten me as regards your analysis which showed that in an event, an earthquake event, a long time period is required before makeup water is necessary, and then you go on to indicate that that makeup water is necessary at a relatively slow rate, 2 gallons a minute or something like that, as I recall.

Could you give us just a little background information on first of all why you feel the long time period is available for you to add water, and briefly tell us how you determine 2 gallons per minute rate?

A The long time period, some days -- I think our design value is five to seven days -- it was our assumption that in that period of time, one could effect a resupply of of these tanks, should it become necessary.

Q Let me interrupt for just a moment at that point. I think your testimony said seven days.

A Why would it take that long?

Q No, why do you feel it would take that long? What was the scenario? What had you assumed would happen that would give you that amount of time?

A Oh, I'm sorry. We designed the reservoir size, given the flow rate which we'll discuss in a moment, such that it would give us that length of time. The flow rate, the demand flow rate, is such as to allow us to have those days to resupply, and that was one of the inputs we put into the size of the reservoir. So we arbitrarily picked a length of time that we thought would be one in which we could resupply.

Q The assumption that you're making is that you're losing water only by evaporation; is that correct?

A That's correct, boil-off and evaporation.

Q I see.

A And at that juncture, the only water that we are supplying is to the two containers that have the fuel elements in them.

Q So this isn't really a catastrophic event that you are thinking of, it's just sort of a shutdown of the reactor and water being boiled off; is that right, as a result of decay heat?

A That's right. That's right.

Q I assume other scenarios were investigated as regards the way water could be lost; is that correct?

A You mean from the two fuel containers, or at other --

Q No, I'm thinking primarily of the reactor vessel.

A Well, by the installation of the stand pipes, which raises the water level should there be a leak in the pool so that water remains above the core, and by the installation of the restraints which will ensure that loads will not cause loss of integrity of the reactor vessel, it is our belief that it is reasonable to assume that the reactor vessel will remain intact, and that is the assumption that we have gone forth with.

Insofar as other mechanisms for the loss of water, we -- I suppose there are any number, depending on how one looks at it, we thought that by the use of this so-called double-ended pipe break for the one line in the primary system, an immediate loss of water based on that flow rate, we thought that was a very conservative and encompassing, enveloping assumption to make. So that other kinds of water losses that one might postulate would be at a slower rate than that one.

And so while there are other scenarios, we felt that was the most conservative one, and that's the reason we employed it.

Q Thank you.

Dr. Durlofsky, going back to something you said a moment ago, namely that all of the calculations or many of the calculations are supported by laboratory experiments or mock-up experiments, and thinking in terms of the restraints that have been installed, could you tell me at this time how many of the restraints that we see in the testimony have in fact been installed, a rough percentage? I'm not really asking for a number. Have all been installed, or about half, or what number would you say?

(Panel conferring.)

A (Witness Durlofsky) Mr. Gilliland just whispered to me about 80 percent. I'll go along with that number.

(Laughter.)

Let me say this: I didn't mean to infer that we specifically run a test for each analysis. What I meant to say is that there are generic tests that are performed. For example, the frame structure will be put on a shake table and subjected to simulated earthquake motion, and the frequencies will be measured.

Now those frequencies will be compared to analytical calculations to see whether the finite element procedures that we use are appropriate.

Q But coming out of the analysis, if I understand it correctly, you have come up with recommendations as to where certain restraints should be placed on certain pipes; is that correct?

A EDAC did, yes.

Q And the purpose of the restraints, as you have indicated before, testified before, is to increase the frequency vibration in the event of a motion of a pipe; is that right?

A In order to understand that, if I could refer you to page 43 in the lower right-hand corner of the page, there is a response spectra shown.

end 7

Q Yes.
A What one sees is, with increasing periods, the period is one over the frequency. So there is a point at which the response is the greatest as you stiffen your structure and change your period when you get that maximum response point. And a large part of the analysis then is to design your structure so that you are not close to the maximum response in the earthquake.
Q I think I can understand that, but that isn't my question. My question is: Coming out of your analysis you have identified certain places in the reactor building itself where pipes should be restrained.
A That's true.
Q And that's the basis of one of the figures I see in your testimony. Is that correct?
A I'm not --
A (Witness Kost) I think I can answer that, and the answer is "yes."
Q Okay. Fine.
My next question is: If 80 percent within the limits of uncertainty of the restraints have already been installed, was there a measurement, any measurement of the amount of -- No, I think I will not pursue that, because you cannot really measure the shaking of the

pipes until the ground moves, and the ground hasn't moved yet, I presume, to allow you to check your calculations on that. So let me not pursue that any further.

I would like to go a little deeper in the plant and talk about the mat on which the plant rests. Your testimony says that that mat is 4'8" thick. Is that correct?

A. That's correct.

Q. Is that mat exposed anywhere? Can you actually see it? The building I know rests on it, but is that the top of the ground floor?

A. No. The top of the mat is about 20 feet below grade, and there is no trench or pit whereby you could view the mat.

Q. Let me direct your attention to page 12 in your testimony, Figure 7. Do you have that in front of you?

A. (Witness Gilliland) Yes.

Q. I see a marking there that says, "elevation 546 feet 3 inches," is it?

A. Yes, that's correct.

Q. Is that the bottom of the mat? Or some other point?

A. That's the bottom of the mat.

Q I also see on Figure 7 a box that says, in which there are the words "experimental area" near that mat. Is that clear?

A (Witness Kost) Yes.

Q Or the "process piping area," either area there. I am just trying to get you to focus on those rooms at the bottom there.

Now from your figure they do not rest on the mat, but they look like they might not be 20 feet from the mat. Is that incorrect? I am really asking, what is the cloest observation point you have to the mat? And from this figure, it appears to me to be either the bottom of either of those rooms that I just described.

A (Witness Gilliland) In terms of interior access, I believe that is true. The thickness of the concrete that you see below those spaces is marked as you have indicated, "process piping area," and "experiment" area is about a foot-and-a-half thick, the concrete there. And then the mat lies below that.

Q Okay. So the mat is a foot below the bottom of the floor of those rooms? Is that correct?

A Yes. Yes, in excess of a foot.

Q That's fine.

A (Witness Kost) We have used the term "basement floor slab" to denote that floor that is immediately below each of those rooms you are pointing out.

Q One foot above the mat? Is that correct, Mr. Gilliland?

A (Witness Gilliland) Yes. It is about a foot-and-a-half.

Q The reactor floor slab, did you say?

A (Witness Kost) The basement floor slab.

Q The basement floor slab. Very good.

Has any member on the panel ever seen the basement floor slab, visually actually seen that first-hand?

A Yes.

A (Witness Gilliland) The basement?

Q Yes.

A Yes. The top surface of it.

Q The top surface of it. Good. When was the last time you saw that basement floor slab, Mr. Gilliland?

A It is recently, within a few weeks.

Q Good. You also, Dr. Kost?

A (Witness Kost) Not so recent. I think it has probably been a year since I have been in --

Q But you have seen it, visually seen it?

A Yes.

Q My question is: As you walked over that basement floor slab, have you ever seen any cracks in the floor slab? Large cracks, small cracks?

A (Witness Gilliland) I was trying to think of any small cracks. There are no large cracks. I don't recall seeing any. I didn't get down and look closely, but I don't recall having seen any. Those floors are mostly not painted, so the concrete is accessible for that kind of a view --

Q I see.

A -- but I recall seeing none.

Q What about the exterior wall ring? I think that is what it is labeled as?

A "Ring wall."

Q Have you ever noticed any cracks in the ring wall?

A No, I have not. But again, I haven't looked at it carefully. There are no large cracks, and I don't recall having seen any small -- any cracks.

A (Witness Kost) I don't recall, either, but I would imagine there would be the normal surface shrinkage cracks that you are always seeing in a concrete wall or a concrete slab.

Q Yes, I think I can understand that. I was really trying to find out if there was a crack or cracks large or small that, based on your expert opinion, would in fact be major cracks, cracks that would go through the structure. And both of you testified that you have never seen any such cracks. Is that correct?

A. (Witness Gilliland) That's correct.

A. (Witness Kost) That's correct.

Q. Now, Dr. Kost, you are a structural engineer, and I assume you have seen many structures. Incidentally, this ring wall was poured in place? Is that my understanding?

A. That's correct.

Q. You've seen many structures. Is it not common to find cracks in poured-in-place walls or structures as large, just from normal settling, normal construction defects, normal events that you might just expect to be there?

A. It's often the case that you do observe cracks in walls due to settlement. That happens, certainly, more frequently in the cases where you have a structure that is supported on individual isolated footings and the walls basically span between those footings.

Q. Let's focus on things that have a large base such as this building.

A. In these cases, the cracks are very rare, or rare.

Q. Is that from good construction technique, good design technique? Or just by the nature of the geometry of the building?

A. I think it is more by nature of the geometry. The reason I say that is that, for the mat type of foundations, the loads on the soils are spread over a very large area, and the average pressure on the foundation soils are fairly low. And as a result, you would tend not to have as much relative displacement as you would when you didn't have the mat foundation system.

Q. Yes. That's correct. I think I understand that when you have a large area, or a large mat, the load is spread over that mat. But we have an unusual situation here. As I have been able to understand it, we have the mat which is fairly thick, four feet eight inches you say, but sitting on one side of that mat or on one-half of that mat is this massive concrete shield around the reactor. Would you think that the mat is so constructed to make the forces uniform on the mat with large mass of concrete sitting on one-half of it?

A. No. It would not be uniform. Certainly there would be some deformations in the mat, just as the structure exists today, which would tend to produce higher soil pressures underneath the walls which are supported by the mat.

Q I see. And yet we see no cracking at all? At least you have not observed any?

A That's correct.

Q Before leaving that point -- and I don't want to dwell on it -- why do you think that is the case, Doctor -- assuming there are no cracks, assuming that if there were any there you would have seen them?

A Is the question why I don't think --

Q No. Why do you think the case is as you have observed? Namely, no cracks in a building where loads are certainly not uniform, and they are fairly large. Was this -- Well, why don't you answer that question, if you can.

A I think we have said that we have not observed cracks in the basement floor slab.

Q That's correct.

A That is as far as I think I can carry my statements.

Q I'm giving you that. I am assuming you have seen none in the basement floor slab. By that, you are not suggesting there may be some in the mat, are you?

A No, I'm not suggesting that. I'm saying I don't know.

Q Very good.

A But the mat is very thick. I mean, it is very thick. I mean, it is four feet eight inches thick. This will indeed tend to distribute the loads from the walls to a broader area, although not enough to make it ideally perfectly uniform loading. The mat is reinforced. There are reinforcing bars running in both directions which would tend to preclude cracking.

I'm not sure that that answers your question.

Q Do you think that that answers the question in your mind? Or maybe I shouldn't say it that way. Does that give you comfort knowing that we have such a massive mass of concrete sitting on one-half of a disk, and the disk has not cracked? Is that just due to the fact that it is well reinforced? And does that give you -- Is that comforting to you to know that?

A Well, yes. It is a well reinforced, very thick mat. The loads on the foundation are light. There has been no observed cracks in the walls that would indicate any type of relative deformation that would indicate that the mat is somehow cracking. I would think that if one were to envision, or to hypothesize cracks in the mat, there should be some other sorts of distress within the structure in the parts that we can observe. But to my knowledge, there isn't that, any distress.

Q Well, let's leave that for the moment and move on.

Dr. Kost, I am not asking you to testify to things you're not aware of. I'm only trying to understand how much of the analysis is related to actual observation. Your testimony indicates that a great deal of analysis has been done, and I am only probing to try to understand the relationship between the analysis and life as it exists at GETR.

We turn now to a matter that I think you, Dr. Durlofsky, brought up earlier. That is, the whole matter of stiffness and damping coefficients. Now it is clear from your testimony that you have attempted to model this total structure. In the model you have used stiffness and damping coefficients as at least depicted in some of the drawing figures contained in your testimony.

Again I ask you to relate the numbers that you got, and I assume -- let me ask: Are these experimental stiffness constants and damping coefficients that you use? Or are they not measured values?

A. (Witness Durlofsky) They're a little bit of both. Let me explain -- Is this question addressed to me?

Q. To anyone on the panel.

A. Okay, I will start, and perhaps Dr. Kost will speak to it, too.

There is a standard procedure from moving from a structure to a mathematical model. In this procedure, one taks into account the geometry of the structure, of course, and the material properties. The material properties are arrived at by tests.

Q Maybe we can cut that short and get sort of to your final answer, if you possibly can. I don't want to cut you off, if you feel that the background is necessary, but try to shorten the background if you will.

A Well, I am almost there.

Q All right.

A And so in building into the mathematical model, one does have a constituitive relationship which is arrived at by tests.

Q So how did you get the damping coefficients and the stiffness constants that you used --

A Damping coefficients are --

Q Excuse me. -- the damping coefficients and stiffness constants that you used in your model? Where did the numbers actually come from?

A The stiffness coefficients come out of the analysis. One inputs the geometry and the material properties, and the program calculates the stiffness coefficients that it uses.

Q I see.

A The damping coefficients are assumed. These are -- there is criteria that we use for an SSE condition, or an OBE condition -- that is, a safe shutdown earthquake, or an operating basis earthquake. These are standard values, conservative values that the NRC recommends, and that is generally what we will use.

A (Witness Kost) I could comment on the source of some of these numbers, if you wish. Studies have been done at various times in the past to measure damping values in highrise buildings, for example, and piping systems, duct work, cable trays, and so on. And that type of information has been collected, assimilated, and put forth in one of the Regulatory Guides which gives a set of damping values for different components.

Q I think I understand that. The thing that I did not understand was how these numbers were actually arrived at for the building that is peculiar for this particular site. It is my -- Well, let me ask the question this way:

Numbers from handbooks and Regulatory Guides, as you have just suggested, are surely not site specific. Is that correct?

A They are more general. That is correct.

Q And if I had a stiffness coefficient for an

I-beam, say, that stiffness coefficient would not be the same if that I-beam were loaded one way versus a beam loaded another way. Is that correct?

A (Witness Durlofsky) No, that's not. It would be the same, the stiffness coefficient would be. The load does not affect that calculation.

Q I see.

A (Witness Kost) Do you want -- We could define "stiffness," what we mean by "stiffness coefficient." Perhaps we are all visualizing something--

Q No, I think I understand what you are referring to when you speak of a "stiffness coefficient."

A Okay.

Q But what I had in mind, Dr. Durlofsky, was perhaps how that beam would respond with a given stiffness coefficient to a vibratory motion. For a given vibratory motion, it seems to me the beam responds differently even with a constant stiffness coefficient, depending on how it is supported. Is that not correct?

A Yes. The supports are an important part of the response, and the stiffness.

Q And that was the basis of your whole analysis of the motion of the pipes?

A Yes, it was.

Q Which enabled you to replace the restraints?

Is that correct?

A. Yes.

Q. So tell me again how the damping coefficients were obtained for this particular structure?

A. Damping is a very difficult quantity to quantify. The usual procedure is to use reasonably conservative numbers that have been determined either experimentally or analytically. These values are just taken as a value when one assumes two percent, five percent damping, and introduces that into either the calculation of the response spectra that one uses, or if he's doing a direct integration procedure then his integration procedures will assume some damping quantity.

Q. If you chose either five or ten percent, how could you be certain it was conservative or not conservative?

A. By comparison with experiments, and the fact-- well, I should say that one can't be any more certain than the values that one uses for the yield strength of steel. These are experimentally determined quantities, and basically empirical quantities.

Q. But the five percent damping isn't experimentally determined. Isn't that correct?

A. Yes. Well, it would be. They would have done tests to determine -- these quantities are usually specified by the NRC or topical documents. If you're analyzing a building, the codes will tell you what damping values you should use and they, I am sure, give you conservative numbers.

Q You're certain of that?

A Yes.

Q What is the basis of your certainty there, Dr. Durlofsky?

A Well, I am as certain of that as am if one, for example, does a stress analysis and uses the yield value for the material, that that is a conservative number. This is the basis of our engineering calculations.

Q All right. Continuing with the concept of conservative values, let me ask you to turn your attention to page 53 of your testimony. As I understand it, in this part of your testimony you have indicated that you have done both a linear analysis and a nonlinear analysis, and you have found that in each case the nonlinear analysis gives you more conservative values than the linear analysis. Is that correct? I am trying to remember now your testimony.

A (Witness Kost) Right. The nonlinear analyses produced less response than the linear analyses did, which indicated that the linear analyses were conservative.

Q The linear analyses were conservative?
A. Yes.
Q Okay. You have obtained forces from your analysis -- and I am on page 53 of your testimony -- and these forces you obtained from your dymatic analyses were applied in a conservative fashion to determine internal stresses within the concrete core structure.

Briefly tell me what that "conservative fashion" is that you used in your analyses in applying forces?
A. The forces that we are discussing on this page were obtained from the mathematical model that is shown on Figure A-12 where the -- oh, I'm sorry, that is page 51. In this case, we have obtained the forces at individual floor levels, basically the inertial forces.

Now the model that was used to determine the internal distribution of these forces within the reactor concrete core structure was a three-dimensional finite-element model which divides the structure into a number of smaller substructures, and these inertial forces from the lump mass model on Figure A-12 were applied to the finite-element model at the discrete floor levels. That is, they're applied as concentrated loads at each floor level, rather than as they occur in

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fact, which is a more distributed nature up and down the height of the structure.

Q So is that the basis of your conservation, when you say you apply them in a conservative fashion?

A That's the basis of this statement here. There are other conservatisms in the finite element model that we use to determine the stress, specifically in the region between the basement and the floor level. We have only utilized the walls that are part of the reactor, of the concrete core structure, and have excluded the remainder of the ring wall in the stress analyses.

Q The forces that you got from your nonlinear analysis were smaller than those you got from the linear analysis; is that correct?

A That's correct. It ranged from reductions of 20 to, as I recall, 30 or 40 percent, in that range.

Q I would like to discuss very briefly the analysis of fault intersecting the base of the reactor structure. Specifically I call your attention to Figure A-13 on page 57. That discussion preceding and following that figure is an analysis, as I understand it, of what the effect is of a fault intersecting the base of the building as shown, and you drew several conclusions based on where that fault might intersect the base of the building. If you can imagine an angle formed by the base of the structure and the line that represents, I believe, the fault in Figure A-13, calling that angle phi, for example, is it not, or would it not be true that that angle is important in your analysis of the effects of the fault intersecting the base?

That is, would not the effects vary depending upon that angle?

A (Witness Kost) To make sure I understand, you have defined that angle as the angle between the horizontal plane and the plane of the fault?

Q The strike of the fault, or the angle of the fault.

A Okay. The angle could influence the analyses in two ways:

First of all, for the case that is shown here in Case 1-B -- let me review this for a second.

(Pause.)

The reason I wanted to do that is to distinguish between the assumptions that we have made, and in both of these cases here, Cases 1-A and 1-B, we have assumed that the pressure on that wall is equal to what I mentioned the other day as the passive pressure. That's the pressure when you push a wall into a soil medium, and that's the maximum force that you can develop on that wall, and it's a function of the properties of the soil.

It's basically the failure, the force that would produce failure in the soil, and we have applied that force to both Wall A and B in the two separate cases that are shown here, and therefore, since we have used this maximum force which is a function of the soil properties, there would be no explicit effect of the angle phi on the outcome of these analyses.

Now we have envisioned this force as a force perpendicular to the face of the wall. That is, we have these vertical Walls A and B, and if one had that force inclined at an angle, it would produce both a normal force and a frictional force on that wall. And the normal force is that component that produces the most severe bending stresses on the wall.

Therefore, using the maximum passive pressure on the wall encompasses the angles that one might envision.

Q I think somehow we got off track.

A Okay. Sorry.

Q Let's go back. You are clear as to what I'm calling angle phi, right? It's the angle between that slanted line in Figure A-13. Is that fault?

A Show schematically, yes.

Q Between the fault and the base or the pad on which the reactor rests, the horizontal. Okay, I'm calling that angle phi.

Now I guess my question is: You have assumed that that angle phi is a certain value, and you have analyzed the effect of that fault intersecting the pad in different positions. In one case, it's on the far left-hand corner. In the other case, it's on the far right-hand corner, and then there are two intermediate cases that you discuss.

A That's correct.

Q Okay. Now my only question is -- two questions: What value of phi did you use in your analysis? I'm not really looking for the magnitude of it, I'm looking for the description. Where did it come from?

A Oh, the range of values that were described by the NRC criteria are from 10 to 45 degrees.

Q And that's the only range they investigated; is that right?

A That's correct.

Q Now you indicate under certain circumstances, namely Case A-1, that there will be a pressure on Wall A, the ring wall, because of the fault intersecting the base, as indicated. Now presumably that pressure will vary, depending upon the value of phi; is that right? I would imagine if phi were 10 degrees, that pressure would be higher because you would be pushing more earth, so to speak. And when I say pushing more earth, I would mean the wedge of earth to the left of Wall A. If phi were, say, 45 degrees, the amount of earth in that wedge would be smaller; is that a correct interpretation?

A That's a correct interpretation and, in fact -- and this is based on my discussions with Mr. Meehan about the properties of the soil in the failure plane -- the soil in this region would locally fail at a phi angle of about 28 to 30 degrees. This is based on the properties.

So, in fact, the most likely situation that you would have on the left-hand side of the figure in Case 1-A is the fault beginning at the lower left-hand corner of the structure, and the failure plane then would be a function of the soil properties, and that would be at about 28 degrees, and that is what gives you the maximum passive pressure that I mentioned a minute ago.

Q I see. One of the cases that you describe as that fault intersects the base of the reactor would lead to a rotation of the building, of the structure, rotation of the structure. And I'll try to be specific and tell you what case that was. It was either Case B or C, I don't recall immediately. Do you recall?

A I think you are referring to page 60, Figure A-16, which is Case 2.

Q Yes.

A And Case 2-B, to be specific.

Q Case 2-B would be the one that would cause the building to rotate?

A Counterclockwise on the page.

Q What did you find the maximum value of that rotation to be for the cases you studied?

A The maximum rotation would be for the case with the fault angle phi, as we defined before, is at 45 degrees, and that angle and the maximum tilt or rotation would be, as I recall, 4 degrees.

Q 4 degrees?

A Right.

Q Let me describe a hypothetical case, and you tell me, if you can, what you think might happen. Let us assume that the fault did intersect the base of the structure, causing the rotation of 4 degrees, as you have suggested, and at the time of that rotation and because of the rotation, you had a rupture of primary water such that the core is no longer covered by the normal depth of water; but that you have no feedwater now other than perhaps your reserve, your reservoirs at the top of the hill.

I'd like to know what you think the effect of the tilt of the building would be as regards the level of water that would remain above the core in the case I have just described.

I hope my scenario is clear. Is there any amplification I need to make, or do you have the picture in mind?

A (Witness Gilliland) I think I understand.

If you hypothesized -- if that's the limit of the hypothesis, and nothing happens to the primary system, this double-ended pipe break, one would expect the water level to remain pretty much as it is before the event.

If you used the assumptions that we did in evaluating this, the double-ended pipe break, then the pool level would drop. Our assumption is instantaneously. It wouldn't be quite that rapidly. And eventually --

Q To 5-1/2 feet?

A Yes, to 5-1/2 feet. Above the core. And then eventually if you -- well, there is some conflicting and complex issues here with respect to water loss from the canal and the pool, but insofar as water supply to the two containers, the reactor pressure vessel and the canal storage tanks, the supply would continue and all of the fuel that's in either of these containers would remain covered. The stand pipes are tall enough, of course, the vessel is quite tall with respect to the location of the fuel and the height of the canal storage tank with respect to the length of the fuel is such that tilting of this nature would still be provided, that the water would fully cover these elements.

Q Well, that, of course, could happen that way. I was thinking of a more severe case, and I think it's something you could calculate very quickly, but I thought perhaps you might have an estimate on top of your head which would be helpful. I didn't want to depend upon water filling the vessel from the canal or from the reservoir. I simply wanted to assume that there was 5-1/2 feet of water over the core and you just tilted it 4 degrees.

Well, it's a calculation that's very simple. I won't ask you to do that now. But it is your feeling that that tilt of 4 degrees would not uncover the fuel?

A No, it would not.

Q Do you know how much water would remain?

A The fuel is 5-1/2 feet below that point.

Q Yes.

A And we haven't calculated that value, but the 4 degree tilt is a very small amount of change.

Q I understand.

A So if I were to guess, it's still over 5 feet. It would be between 5 and 5-1/2, but I don't know the number.

Q Well, as I said, I think it's a simple calculation that can be done.

I saw little discussion of any damage that might result to the reactor vessel as a result of a seismic event. I assume you think none will occur; is that correct?

A That's correct.

Q Because of the restraints that you have put in, and you assume that nothing will drop on it?

A That is correct.

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

JUDGE GROSSMAN: Judge Foreman?

BY JUDGE FOREMAN:

Q I have a few questions. I'd like to start off with a simple one.

Dr. Ferguson had asked about your analyses that dealt with the removal of control rods after they had scrammed, and how seismic events might influence that.

Can you postulate a scenario as to how those control rods could pop out enough to withdraw and restart up the reactor? How is that a possibility?

A (Witness Gilliland) Our analysis indicates that it is unlikely to the point of incredible.

Q There is no likelihood of a vertical acceleration just pushing them back right out again?

A No, no. I think the answer to your question is no.

Q Okay. So that in a sense you are being overly conservative by doing analyses to make sure they wouldn't pop out, because it's really hard to see how they might.

A Well, that's right. It is hard to see how they would. However, the analysis was done to make sure that our belief in this case was founded on something more than our opinion.

Q I believe -- just let me check a page number here.

On page 3 of your testimony, Exhibit No. 22, in the first paragraph, there are listed all of the structures that are contained within the reinforced concrete structure.

A Yes, that's correct.

Q I am asking questions like a lawyer; one thing at a time. I'll get to what I really want to know in a moment.

(Laughter.)

What structures are outside of the concrete protective barrier that are contained within this steel containment building? Is there a listing of those? Or is there a --

A I believe there is not. At least not in this document.

Q Is there a figure that we could look at?

A Well, I was thinking about that vertical section, if we can find it. Here is one. Let's look at page 12 for just a moment. That would be Figure 7. The equipment in which we are principally interested is inside the heavy concrete core structure.

However, there is equipment that's exterior to that in which we have an interest. One of these is the polar crane which is above the third floor level, and you'll see it in the upper part. It looks like -- let's see. I see no label on it, but -- well, yes, there is, a 15-ton crane, equipment handling, right in the center, the figure near the top. That's a piece of equipment that's outside that zone, and for which we have provided structural members to catch it, should it derail in the event of a seismic occurrence.

Q What is the honeycomb made of? I never did hear what material it was made of.

A It's aluminum.

Also on the third floor level is an article of equipment we call the missile shield, which is normally over the pool during operation, and for some operations it is moved away to the right, as it is shown in the figure.

There is also the fuel handling platform which is shown to the left, also on the upper floor. It is used to speed the refueling and defueling operations.

There is also some experimental equipment at the third floor level. And, let's see -- and there's some equipment, some experimental equipment that's in other spaces, both on the second and on the first floor, associated with the experimental work that's performed at the facility, but not with reactor operation proper.

So I think the major items of equipment are those that I have enumerated that are either on or above the third floor.

Q And those experimental areas, is it likely that there ever would be any radioactive material?

A No, normally there is not. Once in a while there is an experiment performed in which small quantities of radioactive material are involved, that are cycled into the core and out, and sometimes these spaces are used for that; but normally there is not.

Of course, the experiments that are put into the reactor, or adjacent to it, occasionally are radioactive, in that fuel testing of a different type that's in this reactor has been done at this facility, and sometimes that material comes after it's been operated, and so it would be radioactive. But in that case, that material is handled inside shielded casks.

Q And none of your product -- by product, I mean your neutron exposed materials that you use for radiography or medical purposes -- is ever brought into that area, into the area outside of the reactor shield and kept there for any length of time?

A No, the normal location for them is either in the core, adjacent to the core, or in the canal, and when they are moved, they are also moved in shielded containers. That is when they are moved outside the facility.

Q So that your designation of your steel structure as a containment does not mean containment against radioactivity?

A Well, it is, of course, an enclosure for all of the things that go inside. In the normal operation, no. There are some evaluations that have been performed that are in our Safety Analysis Reports that have been forwarded previously, both when the reactor first started, and when the power level was changed in 1966, and also in a more recent analysis set that we did in which there are some accident assumptions made that take account of the containment as a means for controlling release.

For the seismic event that we have under consideration, no, there is -- we have evaluated what modest amount of material would be involved, and if you assume that the containment does not maintain its integrity as we did for that analysis, it does not produce exposure rates of consequence outside the building.

Q I guess I was attracted to your statement and your qualification each time you said "not normally" would one find radioactive materials. In what sense are you saying that?

A Well, the principal focus of operation is to produce radioisotopes, both for pharmaceutical purposes and for industrial purposes. One material in particular -- two materials for radiography purposes, and then, of course, as I indicated, the irradiation and testing of fuel.

And the reason I can't say absolutely that there is never an experiment that involves radioactive material in these other experiment areas is that occasionally there is one.

We did a very low-level experiment, I believe, for Berkeley, I can't remember, for the University of California a number of years ago. And so rarely, but occasionally, something like that will come along.

Any consequential level of radioactive material, though, is not outside the zone, the canal pool.

Q You had indicated that indeed that might be the case, and I may have misunderstood you, so correct me. If indeed that might be the case that that would be contained in a shielded cask?

A That's correct. These areas that are outside the shielded zone are occupied at various times by our personnel and, of course, it's not possible to have -- it's not reasonable to have materials with high radioactive levels in those zones. They must be shielded, and they are.

Q The shielded casks aren't designed, positioned, supported, et cetera, to allow for a seismic event, are they?

A Well, it depends, I suppose, on where they are. I can't answer your question well in regard to that. We didn't evaluate the casks in that relationship. They are moved, counting all of the time that they are there, they move relatively infrequently, and so they are in motion relatively infrequently. They would be in one place or the other, the bottom of the canal, on the third floor, or outside the building. Most of the time they would be in one of those static locations, and we haven't done an evaluation for that.

We are in the process of doing cask evaluations, but that has to do with transportation.

Q Dr. Kost, were you thinking of saying something?

A (Witness Kost) No, I wasn't.

Q Is the requirement of bringing your plant down to safe shutdown condition during a seismic event -- does that include allowing for or comparing or preventing release of radioactivity offsite; or for that matter, even within the confinement area that falls within that definition, does it?

A (Witness Gilliland) Well, what we did is to take -- is to examine the situation as best we could see it with respect to the reactor and by far the largest issue of concern has to do with the fuel elements themselves, and we wanted to assure that their integrity would be maintained, and that's the focus of the effort and, in fact, I believe that we have done that.

There are some fuel capsules that are normally irradiated in the pool, and we did an evaluation for those capsules, should there be a loss of water and in particular an interruption of their integrity with this event.

We also assumed that these capsules which are fueled within -- that is, these are fuel rods within capsules -- we assumed the failure parts of that system in the analysis and the release of the material that had accumulated, and this is a pretty modest amount of material, and represented no consequential release.

Now one of the things that will occur, and that we have hypothesized will occur, is the lowering of the level in the pool in the canal, and when you have the fuel elements that are stored in both those locations, or at least in our assumed scenario, we said they would be in both locations, the direct radiation is a point of concern for personnel inside the building, if in fact those levels of water did get out. And the length of time one would be there or could be there, would be restricted because of those exposure levels.

Q Repeat for me, or maybe I didn't hear it properly -- but bear with me, if you will -- your product as it's taken out of the reactor after having been exposed to neutrons, how is that taken out and where is it stored until it's ready for transportation?

A These materials are encapsulated for radiation, of course, and placed in various locations in the reactor, and adjacent to the reactor.

We have some facilities which allow for the removal of these isotopes during reactor operation through a canal gate -- through a gate that's between the canal and the pool. Those can be removed during operation. They are handled under water for the obvious advantages of the shielding of the water, placed in a cask, and the cask transported outside the facility. Because many of these products have short half-lifes, that's one of their large advantages in the use of certainly medical diagnostics. There is a great urgency in getting them out, getting them separated, and getting them shipped. So their time in that facility is very short once they are removed from the reactor.

These are the positions in the pool during the operation. There are other capsules that are placed in the core, and their access is only possible during reactor shutdown periods, which occur every two to three weeks in normal operation, and these, too, are of a similar kind, in most cases, where it is important remove materials quicly, put them in the casks and ship them, to move them to our reprocessing facility and ship them to the processing facility. And so materials are both in the pool adjacent to the reactor, in the reactor. They are moved to the storage canal mostly for transfer to casks. Occasionally they are held there for a longer period of time, and then they are transported in the casks out of the facility.

Q You indicated that many of your materials -- I guess it's molybdenum-99?

A That's correct.

Q -- have short half-lifes.

A That's correct.

Q And therefore they are there for short periods of time. But I don't think that's necessarily meaningful, because that particular batch may be there for a short period of time, but there are subsequent batches, even though they are short-lived, that means there are still high levels of radioactivity. Albeit each batch has a short half-life, there are high levels of radioactivity for a fair amount of time there.

A That's correct. They are in a form and they are of a nature which does not provide you with other than direct radiation issuance, so far as their radioactive levels. Concerns with the fuel have to do if you interrupt the integrity of the fuel plate, for example. Here, in the case of these materials, you are not faced with that same issue. They do provide you with a radiation source which if the water is lost or is partially lost, the level of radiation is up and it adds to that because of their presence. But that's the way it adds. It does not constitute -- it isn't as if the material -- the material is not loose, it is not free. It is encapsulated and sometimes the material form in which it is makes it difficult for it to be released, even if it were open, out of the capsule.

Q Well, I think I understand, and I certainly agree that the primary concern is indeed, or are indeed the fuel rods. There is no doubt about it. But I think that at least I would like to ask you, because it seems to me that it's a problem that if a seismic event should occur while you were making transfers of relatively high levels of radioactivity, that indeed there could be some problems of dispersal of that material, perhaps if not in the plant, exposing your personnel, certainly offsite, and in safe shutdown or -- I don't know whether this would be considered as part of safe shutdown.

It seems to me that provision should be made to deal with the situation wherein those materials are in transport, or if they are stored or the like.

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What thinking have you done about that?

A. The materials that are exterior to the reactor facility are -- and the transportation of them specifically has been given attention by someone else besides me in the organization, so I am not awfully familiar with the details of that. I am aware that the casks themselves are undergoing careful scrutiny and evaluation, and in some cases testing to affirm that they will meet the transportation requirements.

I don't know. I haven't looked at the details of that. My guess would be that, given what appear to be very rigorous transportation requirements, that the casks having met those, they would meet any earthquake demands wherever they happened to be.

Q. And the "transportation requirement" being transportation from out of the reactor onto a truck, freight car, however? I am thinking -- I could envision vulnerable transition times wherein fortuitously a seismic event might occur.

A. Well, I think again --

Q. Is that possible? Or am I presenting a scenario that is not at all likely?

A. It is possible. If you can't pick your time for the earthquake, so you of necessity assume that some of these events can be going on, some of these handling operations. However -- and I am talking in genera terms here, and probably if I did some digging I could give you some better specifics.

My recollect is that the quantity of material that is involved in these transfers is small, and the form in which it is doesn't provide a ready way for it to be dispersed, even if you were to crush a capsule, which is hard to envision if it was inside a cask.

But the major point I should make is that my recollect is that the quantities of materials are quite small in terms of the kind of hazard one might consider for a site boundary for a reactor facility, or for other kinds of facilities that handle radioactive material.

Q It would be helpful if we could be reassured that that really isn't a problem.

A Let me see if I can find -- I have another piece of homework to do at the break.

Q Well, if not at the break, at ome other time. But I would like to see that dealt with.

A Okay.

Q And in the same vein of thinking about radioactivity, aside from that which might be released from the core -- again, these are lower levels and may not be catastrophic, but they could be of significance to the surrounding countryside, if not only for low-level health considerations if they got out at all, the psychological effects as were manifested after Three Mile Island. Those in themselves become very, very significant matters that one must think about.

So in the same vein, among other things that occur to me were those subsurface tanks in which you store your drain waters that leak out -- although they may not be leaking out now -- that you have. Now that you have those in sealed tanks, but certainly you will be having drain waters that leak out that are radioactive, that in turn you will be running through ion exchange columns to clear up those waters, and then the ion exchange materials which will be concentrating radioactivity. Are those dealt with in a fashion that one can be quite comfortable that they won't be dispersed during the time of a seismic event?

Are you comfortable that that problem is dealt with?

A. I am comfortable that the resins that are in the tanks will almost assuredly stay in the tanks. I want to confer in a moment with Dr. Kost and Dr. Durlofsky to see if they confirm that they haven't done an analysis on the demineralizer tanks.

As Dr. Durlofsky pointed out in a conversation we had earlier with respect to the underground tanks, if one wanted to pick a best location to try to be sure that tank integrity were maintained under these kinds of circumstances, you would probably put them underground. I know that doesn't guarantee that won't have a difficulty, but the changes are much improved by their location.

My reassurance comes in the fact that the quantity of material is quite low. We did do an evaluation of if one were to release contaminated water to the ground, and the exposure to a person who is at the boundary. I think the 50-year exposure from that I believe is in the neighborhood of 10 millirems total.

Q. For which isotopes?

A. That is for the collection.

Q. For the total?

A. For the collection that would be in the water. And that takes into account distance, and the fact that this is underground, and so on. But that is relative to exposure that a human receives in a year. It is quite low.

Q. That happens to be my particular area of interest, exposure to human beings, so I am aware and I am sensitive to those numbers.

A All right. Good.

Q However -- and again my information may be wrong, but I've heard it several times -- indeed there was a release offsite of tritium, and perhaps other isotopes, during the normal operation of GETR in times gone by. Is that true?

A My understanding is that the tritium levels in offsite water are above background. Also my understanding is that it is way, way below the federal standards which are at least in part regulating here.

I believe that -- and I may misspeak this, but I can get the orders of magnitude I think in perspective. It seems to me the tritium level limit is in the neighborhood of three -- three million picocuries per liter.

My recollection is that our -- that we've seen 2000 in some of the water samples. And I don't know whether that -- I can't recall where that was taken.

Q You see, that was as a result of normal operations, and one might wonder, and you could reassure us on that, whether if the pathway for that release is still there, whether a seismic event might result in a much higher level of release of radioactive isotopes into the water. Is that a likely possibility? Or have you looked at it? And how have you assured yourself?

A. Well, in fact that has been looked at, and that was the evaluation I referred to earlier that produced this 10 millirem 50-year dose rate.

Q. You didn't choose to provide that in your testimony at all, the radiological consequences offsite-- the offsite radiological consequences of any event. Was that because you didn't think it was significant enough to make a difference?

A. Well --

Q. As a likely -- well, first of all, as likely enough? And secondly, if it did happen, it wasn't significant enough a hazard? Is that why you didn't do it?

A. Well, it is a low hazard. But the -- it is my understanding, and this is the reason some of this that we did not do the work in this area, that the show-cause issues were restricted to what should be the proper design bases, and could the facility be made to meet those design bases? And that the subject of consequences was not one that was involved in the show-cause order.

Q. I guess that's why I asked you earlier. It seems to me that the design and structure of the plant should consider the prevention of the release of radioactivity into the environment. And that is not necessarily a "consequence." It is providing for a safe operation of the plant.

Now I may be once again in my niavete, I may be adding a dimension that isn't considered "safe shutdown," but to me it seems that way. I haven't discussed this with my fellow Board members, so we might have some other thoughts on the matter.

JUDGE GROSSMAN: Well, we have discussed it. I'm sorry --

JUDGE FOREMAN: Go ahead.

JUDGE GROSSMAN: We discussed it briefly, and it was my understanding -- and perhaps the Staff will have something to say about this -- that you did have to be concerned with consequences beyond what the standards are for a release of effluents under the appropriate sections.

MR. EDGAR: Well, I can point out one thing that the Staff's SER reflects an analysis and a review of this very subject. It is in the SER.

JUDGE FOREMAN: But you didn't choose to deal with it.

MR. EDGAR: We had independent analyses that were not different in result, and these results reflected the Staff's review.

JUDGE FOREMAN: I guess what I am saying is, it wasn't apparent to me until just this moment that you had done something like that.

MR. EDGAR: I see.

JUDGE FOREMAN: And that indeed they had -- that they did coincide or supported the Staff's analysis. And with the many things that you were so careful about in providing, it sort of surprised me that you hadn't.

I guess also the potential release of radioactivity offsite heightened my attention and my concern because of information that had been brought out. This isn't evidence, but it is information that I have that indicated that there have been some new measurements that suggest that the flow of groundwater beneath the GETR is different from what had been expected, or what it had been considered to be in years gone by.

I don't know for certain whether this creates a more dangerous or a more serious hazard to the surrounding community because of this new evidence or not, but if it does then the questions I am asking about your analyses and what you have done to prevent the release of radioactivity as part of a seismic event become more meaningful, at least to me.

WITNESS GILLILAND: I am not aware of altered data with respect to the hydrology.

BY JUDGE FOREMAN:

Q I see. I may be wrong, although I believe I could track it down.

A (Witness Gilliland) I'm not aware of that to which you refer.

Q Let me take a look at my notes here. I am just about done with that particular line of questioning, but I would like to review with you some of the information that you said that you were going to provide us. I have been so busy thinking about what I have to say, I may not recall all of it. But if you could help me out, too, or even my colleagues here, one of them that I know is information relating to the potential hazard associated with the concomitance of an earthquake during transport -- during removal of your product from the reactor and transport, and its handling when it is outside of your reactor protective shield.

And if it is convenient -- and I say this advisedly, meaning that I have confidence that your analyses are okay; I am not questioning them -- but if it is convenient for me to see those analyses involving the potential releases offsite, it would be useful for me to review them.

Okay, I would like then to go on to some other areas.

Dr. Kost, I am pretty sure I know the answer to this, but I would like to sort of have it on the record. Have you considered the effect on the stress capacity of the concrete in the reactor shield of many, many years of exposure to high levels of neutrons? Has that exposure changed the stress capacity?

(Witnesses conferring.)

(Board conferring.)

JUDGE GROSSMAN: Let me ask, Mr. Cady: Do you have a witness here who has got to go on and leave? That was my understanding.

MR. CADY: Yes, your Honor. I told him he would go at about 2:00 o'clock. I didn't realize that the examination would be this extensive.

JUDGE FOREMAN: Can he come back tomorrow?

JUDGE GROSSMAN: Well, as long as you gentlemen have to look something up, would you want to --

JUDGE FOREMAN: I don't mind. I just don't want to truncate the testimony and the cross-examination of your witness, because we are sort of wedging him in. I have a feeling he might feel pressured.

(Board conferring.)

JUDGE GROSSMAN: I'm sorry I asked. We will just have to bear with this.

JUDGE FOREMAN: I don't really have too much longer.

WITNESS GILLILAND: We're going to give you a two-part answer.

BY JUDGE FOREMAN:

Q To the two-part question.

(Laughter.)

A (Witness Gilliland) At least a two-part answer. I don't have the specific data, but we did evaluate the neutron levels at various locations around the core, and found, because of the thickness of the water from the reactor to those locations, that the exposure rates were quite low. So from that point of view, one wouldn't expect to see neutron effects of consequence in either the concrete or in other members. So that is my part of it.

A (Witness Kost) We have taken several concrete cores, actually bored out of the walls, and measured the strengths of these cores to confirm the strength of the concrete and the fact that the strength has increased with age, as is documented in the literature, too. This is a well-observed fact.

So we have three things in determining the concrete strength. One was the original tests when the plant was built. The second was the published data with regard to increase in concrete strength with time. And the third were several core tests that we took at the plant to confirm the current capacity or strength of the concrete.

Q And taking out those cores didn't weaken the concrete?

A No.

(Laughter.)

Q As far as you know, are there any structural materials on which you rely that have been in the plant since the beginning that have been exposed to neutrons that are likely to show radiation effects? Are you satisfied that there are no radiation effects on any of your structural material?

A (Witness Gilliland) That's correct.

Q And the basis for that is your knowledge about the effect of neutrons on various structural materials?

A Well, that and the level of neutrons that impinge upon those materials.

Q But some of those materials aren't necessarily heavily shielded by water.

A Well, that's correct. Of course the structural members that are a part of the core assembly and the reactor vessel. In the case of the reactor vessel, which is aluminum, there have been -- there were placed in the core region as close to the vessel as we could get them at the beginning of operation of the reactor a number of samples of the material like that in the reactor vessel. And those have been periodically, one at a time, withdrawn and tests performed on them to observe changes in their characteristics.

There is nothing in that data to indicate that we are coming to any point of difficulty with respect to the vessel.

I believe that the principal other components that are in the reactor -- the grid plate, which is at the bottom, and if I recall correctly it is of stainless steel, our evaluations are that it too is satisfactory.

We do have occasions when we do have beryllium in the core region, for example, and it will suffer some radiation effects. And it has been replaced on occasion, as those begin to manifest themselves in distortion of those articles of hardware.

Q But those aren't structural members.

A That's correct. I'm sorry. I wasn't trying to --

Q No, I'm not correcting you. I'm asking.

A You're correct.

Q They aren't structural members?

A That isn't structural; nor -- the reactor veseel I guess is the closest in that assembly you would come to a structural member. The -- I think that --

(Witnesses conferring.)

I think that is probably a good place to stop, unless there are questions. I think the exposure rates are low for the principal number of, or quantities of structural materials, except for those that are in the vessel itself.

Q I was pretty sure that you had given thought to it, but I wanted to hear it and have it said.

A Yes. Okay.

Q Dr. Kost, this question is more for my edification than for anything involving my judgments and the like, and it is a brief question. Dr. Hall spent a good deal of time it seems to me -- and please correct me if my impression is wrong -- indicating that the use of free-field measurements of acceleration in calculations were quite conservative because of interactions with soil and with buildings that attenuated the accelerations quite considerably. Is that a proper perception?

A (Witness Kost) Yes. I think that is correct. There are a number of factors that go into the selection of these free-field numbers. And as Dr. Hall indicated, the engineering approaches to develop these effective accelerations and the earthquake engineers such as Dr. Hall take the information that is developed by the geologists and the seismologists, who basically characterize the earthquake in terms of the free-field motions. And then, considering the fact that the high frequency single pulse type of accelerations that we see in many of these records are inconsequential in terms of response, considering the fact that these high frequency waves -- high frequency motions tend not to excite to a great degree these very large structures, and also considering the fact that the damage of structures is not well indicated by these high free field motions, in fact if one were to use these motions that are developed by the seismologists and go through analytical models and compute the response of the structure using these free field instrumental values, one would determine that the response is much higher. That is, you would always -- and I think I can generalize that -- you are always overpredicting the damage on the structure.

As a result, we use these reduced effective values that are generated by people such as Dr. Hall based on the geologist's and seismologist's information. This then becomes the engineering criteria, but there is a second point in here.

Dr. Hall mentioned that the motions within the base of the building is less than the free-field motions, and that is generally true, too. I think we can visualize that in our situation as follows: Visualize the waves coming up to the surface from the source of the earthquake. The amplitude of those seismic waves tend to be higher near the surface than at the surface. And if you are down about 20 feet, or 21 feet below the surface, the motions would be somewhat less.

We have not taken that into account in these analyses. We have actually used the free-field -- the effective accelerations of the free field, and not the motions that one could expect to occur at the base of the structure, which we would expect to be less.

Q Could you explain to me, then, how that squares with what you have been saying about the increase in accelerations as one goes up in buildings, that the accelerations in the lower floors are much lower, or are lower than the accelerations on the higher floors? Because it seems to me there, then, that the buildings are amplifying the waves, rather than damping them, as you have described earlier, unless I am completely misunderstanding what you have said.

A Well, there are two parts to it. First, I was talking about the difference between the ground motions outside of the structure and at the base of the structure.

Now those motions that we would agree upon, or arrive at at the base of the structure, can indeed be and are amplified by the structure as they propagate up the structure. And when the frequency of the vibration -- that is, the natural frequency of vibration of the structure -- is in the range of the frequencies of the input motion -- that is, the earthquake motion -- then you will have the amplification either in the horizontal or in the vertical direction. That amplification is demonstrated both in the historical records when you measure it, and the amplification is also shown in the results of the evaluations that we've done for the GETR building.

We have put motions at the operating floor level, the top of the concrete interior concrete structure, and they are higher by about 50 percent than the motions that we have input at the base of the structure.

end
JWB
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Q Did you want to say something?

A (Witness Durlofsky) I was just going to point out that what Dr. Kost meant by free field motion is the motion in the soil itself.

Q I thought that was an instrument measure with the free field motion. Isn't that a measurement you take off an instrument?

A Yeah, it can be, but that's the motion that we input at the base of the building. The motion that you're speaking of is amplified by the building itself.

Now at the base of the building it's not amplified at all. The base of the building just sees the free field motion. The higher levels will see an amplified motion.

So what Dr. Kost said was that actually the free field motions at the surface or the base of the building is usually subsurface, but conservatively we use the surface motion, which is somewhat higher. Do you see the distinction between motion at the base of the building and at the higher levels?

A (Witness Kost) Perhaps I could help a little bit. There are several terms that we have been using here, starting with the information developed by the geologists and the seismologists. We call that the instrumental values the P instrumental values, and that's the common terminology that is used for those numbers.

Then a person such as Dr. Hall takes those data and develops what is called the free field design criteria, which is meant to apply at the surface away from the structure, and those incorporate the idea of effective acceleration, and I meant that to be the free field motions or the effective design motions that are used as criteria for the facility.

Then we go from that to the base of the structure, up to the top of the structure.

Q And each time in your analyses you factor in the amplification factors that result -- that result from building your building higher and higher? You start with your effective accelerations as your base, and then work from there?

A That's correct.

Q Thanks.

Now I have a difficult question. It's difficult for me, but in my mind I think it bears upon -- it bears on my understanding of what is happening, but it might bear on the safety of structures, and I am looking to the information that you provided starting on page 57, and going on to 58 and 59 and further.

The questions I would ask of you, looking at A-13, where we have a wall impinging on Wall B, and as I recall, you had indicated that there might be failure in a very localized region in the site of the GETR. It was a few feet, I think, below six feet and down to 13 feet, and I assume that's because that was the height of the basement wall. Am I right in that, as to why the damage which involved crumbling of the concrete or rupturing of the concrete -- are my perceptions correct?

A Partially, and perhaps I could take a minute and go over what I said about that wall. I didn't say failure or crumbling or words like that.

Q Okay.

A This Case 1-B is one of four that we've looked at for the Verona event. Now if the fault were to intersect Wall B, you can see by the slanted line with the arrow on top of it, which is meant to represent the fault plane, and again I represent the fault plane as a single plane or a single line and not a zone of failure or space which would really be more likely the case, as I understand it, from the soils engineers.

But if we were to imagine that the wall, or rather the basemat were intersected, as shown here, most of the force from the pushing of the soil against the right-hand side of the building there, would be resisted by the basemat itself. You can see it's a very rigid, stiff structure there.

Now if the fault were to intersect higher up on the structure, for example, anywhere at an elevation, anywhere betwee: :he grade, that is the ground surface and six feet below the ground surface, there would just be a small loaded area of that wall. That is, the soil would just be pushing on a very small six foot deep slice of that wall or area of the wall.

Now we have performed calculations for that case, and have shown that the stresses in the wall for that case would be within the capacity, so there would be no cracking or yielding of the steel.

Q And 6 is the magic number?

A 6 is not a magic number. It so happens as you go below that, the load on the wall increases because you are applying the force to a --

Q It's a transition?

A Right. There is certainly a transition, and if you are between six feet and the top of the basement slab, then there is a possibility for the damage to form that I mentioned the other day, specifically the concrete will crack and the steel will yield.

Now we haven't tried to quantify what the deformations would be off that wall. That is how far the wall would be pushed in. Certainly something less than the maximum surface rupture offset. You would have a combination of both phenomena, that is the soil failing and the wall moving in, and you would have some net displacement of the wall towards the center of the reactor building. Something, as I said, for our criteria, less than the three feet or one meter criterion.

Now the other thing to keep in mind, though, thinking of this particular case, this is a region that's exterior to our concrete core structure, and even though we have this pushing effect on this wall here, at the same time, of course, we have a shaking motion that's going on in the interior concrete core structure, and within that core structure, then, at the same time the stresses are actually quite low.

Now what do I mean by quite low? I think it's worthwhile to talk about capacities here for a minute, too, because I think it will help put a lot of this into perspective here.

As we have gone through these evaluations of the concrete core structure, we have selected as a capacity value a very restricted definition, and we have said that that is initiation of cracking, and initiation of cracking means that we have the beginning of a small -- small, in terms of width -- crack that would develop along a particular wall. So we set that as our goal to demonstrate that the stresses within the structure are such that we are below this initiation of cracking.

Now for the Verona case, for Case 1-B -- and I don't have the exact number in front of me -- we would find that the stresses are well below, probably on the order of probably a third to a quarter, somewhere in that range, of the stress that would produce initiation of cracking.

So you can see the wall -- we have some damage over here in Wall B. The core structure is still very sound.

Q Excuse me. Well, finish what you're saying.

A And I wanted to say something, too, about these capacity numbers that we use in general here, and it's an important point to keep in mind here, because we talk about different parameters, different input numbers, and we spend a lot of time arguing over different g levels and changing those by plus or minus 5 or 10 percent here, or other numbers, and there s been a lot of discussion on this issue.

But really what we've done is achieve a level of protection against a very, very severe seismic event, and in these structures inherent -- and we have shown the structures are adequate for the events we have been talking about.

Now inherent in these structures, however, is a significant amount of reserve strength. I can use a number that would define this initiation of cracking. We are always below that number. But then the ultimate strength is still quite a bit high, perhaps 60 percent above that number, before you would -- now ultimate strength just means larger cracks. Okay?

Q I don't understand.

A It's defined -- okay, it's defined -- I won't use the word "ultimate," that's engineering jargon. Okay, the first criterion is the threshold for initiation of shear cracking that I mentioned here. We are well below that.

Now there is still reserve strength beyond that. You could still continue to load the structure beyond that, and at the stage where you would begin to get larger deformations for small increases in load, that is you would begin -- if you were pushing on the structure, you would begin to deform the structure faster than at the lower level. That would be what we would call an ultimate strength.

It still has not collapsed. All it means is that you have seen larger cracks in a wall. So I don't want anybody to think here in this proceeding that we are near anything that people would visualize as collapse, which you see in earthquake -- historic or earthquake photographs, newspaper photographs, where you have office buildings or more flimsy structures that indeed have suffered very badly in earthquakes. We don't see all the structures that have survived, and for this particular structure, and each of the components we have gone through, there is a tremendous margin, a factor of safety beyond that which we are showing in our calculations.

Q I guess I wasn't anticipating that there would be a collapse. I think I understood that there would be effects upon the concrete. But my question comes -- and this is the real question -- what happens when that's pushing and cracking and you're shaking the building at the same time? Then what happens to that section? That's a much more severe set of circumstances.

A Yes, and in the numbers that I was giving you, I was taking into account that both phenomena are occurring simultaneously.

Q I see. You had anticipated my question and were answering it already.

A I don't know that I anticipated your question, but I was trying to demonstrate that we are meeting the criteria of simultaneous vibratory motions and the surface rupture offset for the Verona event.

Q Now I happened to pick this particular instant to illustrate what I was trying to ask, because I'm not a structural engineer and so forth. I wasn't able to look to the worst case scenario in which that might happen, and I'm sure you've thought about this.

Where on the structure would the worst set of circumstances happen? Where on the structure, say involving the impact of the offset and the shaking -- where in that structure would be the worst possible situation? What sort of scenario there? And how did you deal with it?

Is my question clear?

A Yes, it is. The reason for showing these four cases, or two cases and subcases in Figure A-13 and Figure A-16, the reason is to demonstrate the systematic way that we went through our analyses to answer your question, because we had to answer it for ourselves first.

We wanted to make sure that there wasn't something here that we missed, so once we decided to assume that the surface rupture offset could intersect the structure in spite of the arguments we have heard contrary to that, once we made that assumption, then we systematically looked at the cases that are shown in Figures A-13, page 57, and A-16, page 60.

The case that we -- in our judgment, and based on our calculations and evaluation -- the case that is the worst -- and I think this responds to your question -- is Case 2-B on Figure A-16, which is on page 60.

Now the reason that I say that is you can see here that the fault is hypothesized to come up underneath the reactor building and slightly to the left-hand side of the center of gravity of the structure.

That is, the main weight of the structure is only slightly offset from the center of gravity -- the geometric center. So if the fault were to intercept the base of the foundation as shown here, it is possible, although I really believe highly unlikely, that you will have some small unsupported length that is shown to the left of the intersection part of the fault in the basemat.

It shows as an absence of cross-hatched or stippled foundation material.

Is it clear where that length is?

Q Yes.

A Now having that unsupported length means just what it says, a certain percentage of the structure then is not supported. It wants to cantilever. Okay.

Now this, you can visualize, will induce stresses in the superstructure, that is the structure on up from the base of the basemat, because it's cantilevering, and you do not have support of the entire -- of all the walls.

For this reason, this turned out to be the worst case, and we not only looked at this from the point of view of the diagram as shown in Figure A-16, but we also looked at what orientation and plan, that is looking down -- what orientation the fault would have to have to produce the worst case.

And let me just see here if I have a good figure to illustrate that.

If you could please refer back to Figure A-2, which is page 33, and look in the upper left-hand corner, you will see the orientation of the walls in the basement.

Now with the fault oriented more or less as the north arrow is shown here, but at a slight angle to that, and if it were to intersect -- this will be a little difficult to describe without being able to point to it -- but basically if it were to intersect such that the support of the lower left-hand wall, that's at about 8:00 o'clock -- if the support of that wall were to be eliminated by the surface rupture offset, that has the effect of producing the highest shear, that is the highest stress in the wall that you see that's running basically left to right on the diagram, slightly to the -- above the center of the core. It's the thinner wall that has a slight kink in it. You can see the wall that's roughly at about 11:00 o'clock; slightly below that, there's a thinner wall. By removing the support of the thicker wall down at the bottom of the page that I was mentioning, that produces the highest shear in that wall.

Q Within the core?

A Within the concrete core structure. So by means of looking at the potential locations where the surface arl1-12

rupture offset could intersect underneath the structure and then taking an orientation of that fault with respect to the structure, we were able to identify the critical case that you have asked about.

Q And all things considered, you come out all right, you think?

A That's correct.

Q Thank you very much.

JUDGE GROSSMAN: Mr. Edgar?

MR. EDGAR: I wonder if we might have a five-minute break, or the afternoon break?

JUDGE GROSSMAN: Yes.

(Recess.)

end 11

JUDGE GROSSMAN: Before we proceed, I think Judge Foreman would like to recall a witness, Mr. Meehan. Could he be available today?

MR. EDGAR: We will check that out right now.

JUDGE FOREMAN: I would just as soon him be here tomorrow.

JUDGE GROSSMAN: I'm not sure that we are going to go on tomorrow. I think from what the parties have indicated, we might complete the case today.

JUDGE FOREMAN: That's the first I've heard of it. I would be willing to --

MR. EDGAR: We can inquire about Mr. Meehan's availability.

JUDGE GROSSMAN: Could you, for today or tomorrow. That is, see if he is available today, and also if he would be available tomorrow, if we can't complete it today.

MR. EDGAR: We will get the call made right now.

JUDGE GROSSMAN: Thank you.

JUDGE FOREMAN: I would just as soon have time to think over some of the questions I would like to ask him, anyway, so tomorrow really would be better.

JUDGE GROSSMAN: Mr. Edgar?

MR. EDGAR: I just have one note for the record.

Dr. Foreman asked about the analysis of the radiological analyses, and I wanted to provide a citation. In our February 2tth, 1981, Interrogatory Updates, we included an Attachment A to that which listed all GE submittals to the NRC. The submittal in question is reference three, attachment number five. That reference in turn is cited in the NRC's SAR Section, which discusses this. So the document in question, or the submittal in question is dated November 11th, 1977. It is Reference Three in Attachment A to GE's interrogatory updates.

JUDGE FOREMAN: I am going to ask you to repeat that in a minute.

(Pause.)

MR. EDGAR: GE's February 25th, 1981, Interrogatory Updates include a list of all submittals to NRC in Attachment A. On Attachment A, the document in question is identified as Reference Three, Attachment Number Five. And it was submitted to the NRC under date of November 11, 1977.

WITNESS GILLILAND: Judge Grossman, I had two items. Is this a good time?

JUDGE GROSSMAN: It sounds fine to me.

WITNESS GILLILAND: All right. First of all, I was asked a question by Mr. Cady yesterday with respect to the depth of the sump that was in the reactor building.

My response was, I find in looking last night, somewhat incorrect. I stated that it was not thicker than the basement floor. Actually, it extends about 2-1/2 feet into the basemat. So the record needs to be corrected in that regard.

JUDGE GROSSMAN: Thank you.

MR. CADY: Excuse me. Is that the foundation mat? The basement, or the foundation mat?

WITNESS GILLILAND: It extends into the foundation mat about 2-1/2 feet.

MR. CADY: Thank you.

WITNESS GILLILAND: The next has to do with the questions that were raised by Judge Foreman just a few minutes ago. Two things:

One, with respect to the hydrology of the area, I asked if we had any new data. I was not aware of any new data. There are no new data that we are aware of. We are aware that there was a newspaper account with respect to hydrology of the area, but we have no other information. And we have had confirmation by the USGS of the hydrological assumptions that we have employed. So we believe that what we have employed is sound.

The second thing has to do with the handling of material exterior to the -- well, the "shield structure, as you referred to it. A couple of things: One is, as I indicated, that transfer is to shielded casks, and they of course have bolted lids, and they are moved only in that condition. There have been analyses performed, and Dr. Durlofsky has done these. So if you are interested in that, he could comment briefly with respect to those evaluations.

BY JUDGE FOREMAN:

Q Well, I am curious as to their behavior in the maximum seismic event that has been postulated.

A (Witness Durlofsky) The problem of transporting casks is much more difficult than the seismic event problem, believe it or not. We look at a great number of conditions that are much more severe than the seismic condition.

For example, it has to pass not only analysis but testing of a 30-foot drop onto a relatively unyielding surface. We have to look at conditions such as fire inside of the cask, and fire outside of the cask. We have to look at such conditions as dropping the cask onto a sharp object from a height of several feet. We have to look at vibrational loads that are incurred during transport of the casks.

There is an entire matrix of requirements that is set up by the NRC in qualifying these casks before they can be used for transporting materials. Most of these requirements are structurally much more severe than withstanding some vibrational loads due to an earthquake.

Q It is my impression that those are the characteristics that are necessary for flasks to transport fuel rods.

A That's right. Those are the same requirements.

Q Are those the same casks that are used to transport the products that come out of --

A They may not be the same casks, necessarily, but they're the same requirements that we have to look at, yes.

Q So your product is transported in those same type of casks that have those characteristics?

A Yes.

A (Witness Gilliland) I had one other item in response to Dr. Ferguson's question with respect to the height of the water. I am trying to find a figure that would be useful. You might look at Figure 11 -- I'm sorry, page 11, Figure 6.

(Pause.)

My recollect of the question was: If you hypothesized the double-ended pipe break and the water lost to 5-1/2 feet above the core, what is the height of what water with respect to the water that's in the canal after some time?

The top of the fuel in the core is about 4-1/2 feet from the bottom of the canal. The height of the water above the core is 5-1/2 feet after that event. So that eventually the canal level will drain down to within about a foot-and-a-half of the bottom of the canal. The height of the fuel storage baskets is about 4-1/2 feet. So the water level in the canal at that juncture would be below the height of the fuel storage baskets.

JUDGE FERGUSON: Thank you, Mr. Gilliland.

JUDGE GROSSMAN: Mr. Edgar, anything further?

JUDGE FOREMAN: Excuse me.

BY JUDGE FOREMAN:

Q. Did you speak to the times of transferring your product from out of the shield into the casks? Those products are put into the casks while they're within the reactor shield?

A. (Witness Gilliland) That's correct.

JUDGE GROSSMAN: Mr. Edgar?

MR. EDGAR: I just wanted to give the Board a brief report. We were not able to reach Mr. Meehan by phone. We will try again. Mr. Harding has been contacted and he is trying to locate him.

JUDGE GROSSMAN: Thank you.

JUDGE FOREMAN: I think tomorrow will be all right.

JUDGE GROSSMAN: Mr. Cady?

MR. CADY: I was just going to ask Judge Foreman if the nature of his question had to do with the hydrology or the underlying water at the site, the ground water.

JUDGE FOREMAN: I don't understand your question.

MR. CADY: Well, is that the purpose that you wished to talk to Mr. Meehan about?

JUDGE FOREMAN: No.

MR. CADY: Excuse me. I have no other questions of this panel.

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: I have no other questions.

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

(Panel dismissed.)

JUDGE GROSSMAN: Mr. Rutherford, I believe?

Whereupon,

JOHN B. RUTHERFORD

was called as a witness on behalf of Intervenors and, having been first duly sworn, was examined and testified as follows:

JUDGE GROSSMAN: Please be seated, sir. Would you state your full name and address for the reporter, please.

THE WITNESS: My name is John Bruceman Rutherford, and my present home address is 1141 Chestnut Street, Apartment #3, San Francisco.

JUDGE GROSSMAN: Mr. Cady?

DIRECT EXAMINATION

BY MR. CADY:

Q Mr. Rutherford, would you care to give a brief summary of your testimony, and the conclusions that you derived from your investigations into the relative issues here?

A Yes. I made a brief written statement in anticipation of the fact that I might not be able to be here, but I will attempt to summarize that.

I have reviewed the material -- chiefly the geological and the seismological material -- with the intent to answer a single question: Given the available data about the possibility of offset either close to or perhaps under the reactor, would I recommend if it had not been built that it be built there? Or it having been built, should it be permitted to operate?

My conclusion from the evidence I have seen is that I would recommend that it not be built if it weren't built; and that it not be allowed to operate.

JUDGE GROSSMAN: Does that conclude the statement, Mr. Cady?

MR. CADY: Yes, your Honor.

JUDGE GROSSMAN: Mr. Edgar?

MR. EDGAR: No questions.

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: No questions.

JUDGE GROSSMAN: Dr. Foreman?

BOARD EXAMINATION

BY JUDGE FOREMAN:

Q Mr. Rutherford, first of all could you tell us a little bit about your background and who you are?

A Yes. I am president of a small -- we have about 35 employees -- a small consulting structural engineering firm here in San Francisco. In the last ten years or so -- I am a licensed structural engineer in the State of California, but by chief experience in the last ten years has been in site evaluation, analyzing the physical properties and the geological hazards which must be considered in developing a particular piece of property.

Q Could you tell us your educational background?

A Yes. I have a Batchelor of Science Degree from Lehigh University. I have studied at Stanford University. And I have a Master of Science Degree from Cal Tech.

Q What sort of -- You indicate that you are involved in a small firm. What companies employ you? What sort of things do you do?

A Wel work for the Department of Defense, for indirectly at least for the Department of Energy. We have -- most of our work I would say at the present time is for public agencies.

Q For what?

A For public agencies.

I am personally working for the State of California at the present time on several projects.

Q Could you tell us the nature of those projects so we can understand what you do?

A Yes. My current assignment for the State is working for the State Attorney General's Office to evaluate three coastal sites from the standpoint of development, to look at the physical constraints, the topography, hydrology, the geology, and particularly the geological hazards in order to eventually arrive at an appraisal value for that property. First of all, whether it is suitable for development at all. And if it is suitable for development, what would be the market price of that property.

Q I see. So that this isn't necessarily -- this doesn't involve very extensive engineering analysis or geologic analyses? This is primarily to give an estimate of the value of the property?

A Primarily it is to evaluate the work of various consultants who are experts in perhaps as many as ten different fields, and to put all that together, to synthesize it, and from that synthesis to arrive at some conclusion as to the merits of the issue.

Q But you don't use that for information to design structures, to build structures?

A Yes. Yes, I do. I am telling you my current assignments. I am currently involved in designing a large structure in the City of Pacific Grove in Monterey, the Monterey Bay Aquarium, which is David Packard's gift essentially to the City of Monterey and Pacific Grove. I am personally designing the marine work in the structure, and I am actively engaged in designing the foundation and part of the structural elements of this building.

And my past experience, I have been in business for perhaps 25 years. My past experience is largely structural engineering design.

Q Could you tell us a couple of more things that you've done in the past, particularly as they relate to geologic and seismic analysis, the particular areas that we are involved in?

A Yes. I have examined, for example, the entire campus of the University of California at Santa Cruz from the standpoint of geological and physiographical features to assist in the preparation of their long-range development plan.

And perhaps some more exotic assignment was to examine the Valley of the Kings in Egypt, and to prepare a report to identify the physical hazards of the valley, and to prepare schematic estimates for conservation and protection of the Tombs of the Pharoahs.

Q Tell us how that bears upon insights that are required for seismic and geologic understanding?

A That particular study bears on this only from the standpoint of this geological work that we did in trying to evaluate the extensive rock movements which have occurred, and to estimate the probability of seismic or earthquake movement in the valley.

Q Is it a highly active tectonic area?

A. No, it is not. And I think it is highly unlikely that within the foreseeable future there will be a major earthquake in that region. But that is part of the analysis we had to go through. The primary analysis that we performed there, which perhaps relates to this, is the effect of rock movement not due to earthquake but due to expansive rock, and the effect of infrequent flooding upon that rock, and the measurement of movement which is caused in the rock-cut tombs of the Pharoahs.

Q. Mr. Rutherford, I am sure you anticipate what I am driving at. What I would like to know are just the sort of things you would like to know were you asking these questions.

A. Sure.

Q. Name.y, what is your basis for an unsupported statement saying that you wouldn't build a plant, and that you wouldn't let it operate? That really isn't enough to provide us with any information to make a judgment on. So in this first round of questioning, you understand, I am trying to find the basis for where your expertise is so that we can understand, at least in one sense, how you are qualified to say that.

A. Sure, I understand your --

Q. So would you, rather than my asking you it question by question like this -- this is not an adversary kind of relationship. I want information, so help me.

A. Is it all right if I take a few minutes to take a running start at this?

Q. You take as long as you want.

A. My experience now, as I said, is to try to arrive at a decision. In other words, no longer do I do the detail work I used to in analysis and design. So I think I am forced to take a philosophical and sort of historical approach to engineering decisions.

Basically I think you can subdivide the basis for engineering decisions into three main categories. One is analysis. In other words, constructing a mathematical model of what is proposed, and try and make that model as close to reality as possible.

The second is: Materials and small-scale testing. In other words, take the materials of which that particular project or building is supposed to be built, and subject the material itself to certain tests. And then subject perhaps elements, larger elements of it, and then perhaps go even further than that and construct physical models, small models of it, and subject them to tests.

And then the third element is essentially experience, or what you might call full-scale real testing. And to me, that is the single most important element of these three elements: engineering experience.

In other words, let me give you an example to try to explain that. Earthquake design is relatively new. I think that only since the 1906 earthquake have there been serious and consistent attempts on the part of engineers to deal with this particular problem. My experience has been since about 1950 when I first entered the field that we learned most as engineers, not from analysis and not from materials or small-scale testing, the thing we learned the most from is going down after there is an earthquake, say the San Fernando earthquake, and spending a few weeks looking around to see what has happened.

Therefore, I feel that in this particular instance there have been I think very competent professionals who have performed the first two elements of this trio of essential elements. But we don't have that third, and I hope we never do in the case of a reactor. I hope we never have to go through that kind of a test. But given what seems to be the evidence as far as the fault prediction is concerned, and taking Dick Meehan's view that perhaps this is caused by a landslide; that the vertical offset he sees are not necessarily evidence of a fault; and that from that he reasons that there might be as much as 20 centimeters of offset in the future. Going from that minimum estimate up to Earl Brabb's maximum estimate of 2.5 meters of offset, which are of fault origin, and possibly beneath the building, I would say that we shouldn't take that risk with this kind of structure.

Q Well, are you basing that on studies that you have done concerning the capability of building structures, and putting them together so that they can withstand stresses, as such?

A Yes. And with the knowledge that engineering is not a science. Engineering is an art. And if I were called upon as a structural engineer to design this particular structure, and if I were told that: Well, look, you can't anticipate anywhere between 10 and 20 centimeters up to 2.5 meters of differential movement beneath this structure, I could never guarantee that that structure would survive intact.

In fact, my prediction would be that probably there would be some damage, and possibly some significant damage, due to that motion.

Q In what time period?

A Well, caused by the earthquake itself. Caused by the vertical offset.

Q Well, just for example, if somebody through well-reasoned considerations, a number of people through well-reasoned considerations said that it is not likely that the severe earthquake with which one is dealing will occur, or the probability that it is likely to occur is sometime in the next 10,000 years, that makes an awful lot of difference, doesn't it?

A No, not --

Q It doesn't seem to bother you?

A Not to engineering practice, because in this state we take Holocene times, or your 10- or 11,000 year period as being recently active. And we, for exqmple, as structural engineers, given these facts, or given the range of expert opinions, would not put a schoolhouse on that particular site. We would not put an important structure such as a hposital on that site. And I consider that a reactor is also an important structure, not necessarily because it has to function like a hospital, but certain systems within it must function in order to prevent danger to the public health and safety.

And for that reason, I would put it in that same category of "public building," and I would say we could not put a school there, and we should not put a reactor there.

Q Of course there are many buildings that have been designed for and built on faults, as we have heard.

A There have been schools built on faults in this state. In fact, there are some less than 20 miles from here. But these schools gradually are being shut down for that very reason. I participated, for example, in a study of a school which was probably pretty close to a fault, if not on a fault, down in Portola Valley. That school is now shut down.

Q Because of?

A Because of the fault.

Q At your urging?

A Not directly at my urging, because eventually another engineer got the commission. It was at his urging.

Q Well --

A We recently --

Q Excuse me. Go ahead.

A To give you another example, we recently participated in the construction of a hospital which replaces the Olive View Hospital, which was severely damaged by the San Fernando earthquake. There again, we took great precautions in examining the site. We trenched the site through twice. And even though there was absolutely no evidence of offset, the fact that there was offset offsite of the fault through there, we participated in rejecting at least two or three other sites for this particular hospital, and I would do the same thing again.

end #12

To take a very small scale example, a year ago, a client came to me and asked me whether I would design, or my office would design a structure for a home on a lot which is relatively close to the San Andreas Fault, and we went down, and together with the consulting geologist, did the geological hazard study and found some pretty marginal evidence of a fault through that lot, a 3/4 acre lot, and my recommendation to that client was don't build there.

Q So you're of the conservatism that you should never build near a fault, then?

A I would say if there is any reason to believe that there is an active fault within recent times, that you should not build within an area which you feel could be subject to fault rupture.

I'm also aware of the fact that geologists and soils engineers are working in a state of the art with regard to fault identification and earthquake prediction which is still relatively in its infancy, and so I tend to be on the conservative side, knowing enough about the subject to know how much I don't know and how much they don't know.

You take the example that was presented to you during this hearing of two excellent professionals, absolutely excellent people, like Dick Meehan and Earl Brabb.

And they are coming up with as far as cause is concerned two totally different explanations for what they see, although they both agree that there is evidence of offset, and with relatively large predictions, differences in predictions on the magnitude of movement, that can be anticipated from this.

So given this diversity of opinion, I think it would be prudent not to resume operation of that nuclear reactor.

Q Are you saying then that there really is no specific reason or specific information, either engineering, geologic or seismic information, that you could present to us in the form of analysis?

A That's quite correct. There is no --

Q -- that you could present to us, but it's just that your opinion is in view of the fact there are some differences of opinion, that you come to your conclusion, that's the basis for your conclusion?

A Not only the differences of opinion, but the areas of agreement. There seems to be general agreement, perhaps not universal, but pretty general consensus among the people who have examined this particular site, first that there has been vertical offset in the past; second, that it's quite likely that some of that vertical offset has occurred in the recent past; and third, that some vertical or horizontal differential movement could occur, whether induced by landslide or by earthquake in the foreseeable future; and fourth, that it's possible that that may occur directly beneath the building. And those are the four general areas of agreement that I see, in the evidence that I have reviewed, and that's what leads me to the conclusion that I just presented.

JUDGE FOREMAN: Well, thank you.

JUDGE GROSSMAN: Judge Ferguson?

BY JUDGE FERGUSON:

Q Brief question, Mr. Rutherford:

What damage to the General Electric Test Reactor do you believe will result from a magnitude 6.0 earthquake on the Verona Fault?

A It depends whether the fault rupture occurred beneath the structure, or whether the fault rupture occurs somewhere not beneath the structure.

Q Let's assume the very worst case that you can imagine.

A A magnitude 6 earthquake could impose significant damage if the fault rupture occurred beneath the structure. If fault rupture occurred at a reasonable distance away from the structure, I think that the reactor could very well survive that particular event intact.

Q Well, let's focus on the worst case that you have described; namely the fault directly beneath the reactor. You said significant damage. Could you be more specific?

A When I say significant damage, I refer not necessarily to total collapse of the structure. I really don't think that would happen. It would take a tremendous amount of energy, and I just don't see that happening.

What I do see is that there may be damage to the various systems that operate within this reactor which could cause an accidental release of radioactive material.

Q What do you have in mind? What type of damage to what system?

A To the piping systems, to all the various things which must operate in order to safely shut down the reactor in case of an earthquake. I followed the incident at Three Mile Island with some interest, because I was born seven miles from where that reactor is, and I still have a farm there, and it seems to me that one person with maybe eight hours of hard concentration could have fairly easily thought of the scenario which actually happened there. But the problem is that there are almost an infinite number of scenarios with sequences of events which can occur, in a fairly sophisticated and complex system like a nuclear reactor, and so my contention is, first of all, that the operation of a reactor as compared to what happens when you have an event like an earthquake, fairly predictable -- in other words, you're really running a full scale test on reactors in this country on a continuing basis, and you have a number of incidents which have occurred, and these are being corrected and that is why it amounts to a full scale operational test.

But we have had no full scale earthquake test on a nuclear reactor, and I just don't believe in putting reactors where they could be subjected to that kind of test.

Q I appreciate your answer. I still have difficulty in understanding just specifically what damage you would expect to what piping as a result of the earthquake.

A I don't either, because I haven't run through enough scenarios, and I doubt that anybody can possibly cover all the scenarios that happened. I just know from experience that these scenarios exist, that they have happened historically, and they will happen again in the future, so I am not putting my finger specifically on one single weak point of this reactor as it responds to fault rupture beneath the structure.

All I am saying is we just don't know enough about what happens during a fault rupture occurrence to be able to predict accurately what will happen.

Q Do you believe that the damage that would result from the 6.0 earthquake on the Verona Fault would in fact cause damage at the reactor, whatever damage you can envision when you make the statement some structural damage, that

that damage would in fact cause a hazard to the safety of the public?

A Yes, I think it could.

Q Could you tell us what that is?

A Release of radioactive material.

Q You feel that radioactive material will be released?

A I think it could be released.

Q You cannot be specific as to how you think it will be released?

A No, no, I think that --

Q You indicate there might be some damage to piping in the event of an earthquake. Do you feel the piping at the reactor can be modified in such a way to resist an earthquake of a magnitude 6.0 on the fault that I discussed?

A I think things can be done to strengthen the systems, but I don't think we know enough about the event, the maximum credible event which is being discussed here. I don't think we know enough about that event to adequately design such a system.

Q Have you reviewed all of the material and all of the studies that have been done by the Licensee and the NRC Staff?

A I doubt that I have. I have reviewed chiefly the geological material.

Q I see.

JUDGE FERGUSON: I have no further questions.

JUDGE GROSSMAN: Mr. Cady?

MR. CADY: No questions.

JUDGE GROSSMAN: Mr. Swanson? I'm sorry, it's Mr. Edgar's turn.

MR. EDGAR: No questions.

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: No questions.

JUDGE GROSSMAN: Thank you, Mr. Rutherford.

THE WITNESS: Thank you.

(Witness excused.)

JUDGE GROSSMAN: The Staff's structural panel now.

MR. BACHMANN: Could we take a very short break?

JUDGE GROSSMAN: Certainly. Five minutes?

MR. BACHMANN: Five minutes.

JUDGE GROSSMAN: Fine.

(Recess.)

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: Yes, sir. Judge Grossman, the Staff now calls as witnesses Mr. John Burdoin, Mr. Christian Nelson and Mr. Joseph Martore.

JUDGE GROSSMAN: Excuse me for a second while I gather my notes.

Whereupon,

JOHN F. BURDOIN

was called as a witness on behalf of the Staff and, having been first duly sworn, was examined and testified as follows; and

CHRISTIAN C. NELSON

and

JOSEPH A. MARTORE

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

JUDGE GROSSMAN: Let's start with Mr. Martore, and everyone on the panel please state your names and addresses.

WITNESS MARTORE: Mr. Chairman, I did that previously.

JUDGE GROSSMAN: I know, but the reporter would like you identified at this point so she knows who is speaking.

WITNESS MARTORE: My name is Joseph Martore, Division of Licensing, U.S. Nuclear Regulatory Commission, Washington, D.C.

WITNESS NELSON: Christian C. Nelson, Division of Licensing, U.S. Nuclear Regulatory Commission, Washington, D.C.

WITNESS BURDOIN: John F. Burdoin, Reactor Inspector, Region V, Walnut Creek, California.

JUDGE GROSSMAN: Mr. Bachmann:

MR. BACHMANN: At this time I'd ask that the prefiled written testimony of Mr. Nelson, Mr. Martore and Mr. Burdoin be received into evidence and bound into the transcript as though read.

MR. EDGAR: No objection.

MR. CADY: No objection.

JUDGE GROSSMAN: Admitted.

(The documents follow:)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

TESTIMONY OF JOHN F. BURDOIN

Q.1. Please state your name and position with the NRC.

A.1. My name is John F. Burdoin. I am employed as a Reactor Inspector, Reactor Construction Projects Branch, Region V, U.S. Nuclear Regulatory Commission, Walnut Creek, California 94595.

Q.2. Please describe your educational background and previous positions held.

A.2. I have a Bachelor of Electrical Engineering Degree from the University of Minnesota. I am registered as a Professional Engineer in California in electrical, mechanical and nuclear engineering.

I have been employed by the NRC since August 1976. As an Engineering Systems Analyst, I analyze and evaluate specific features associated with the design and operating characteristics of licensed power and testing reactors in regard to the engineering features of electrical instrumentation and control systems and auxiliary and power conversion systems.

Prior to my present employment, I was employed by the Lawrence Livermore National Laboratory at Livermore, California for a period of 18 years.

During this period, I served in various positions in the field of electrical engineering.

Q.3. Please describe the extent of your participation in the NRC Staff's review of the GETR for this proceeding.

A.3. I prepared Section B of the October 27, 1980 portion of the Staff's Safety Evaluation Report entitled "GETR Electrical, Instrumentation and Control Systems" in the areas of the seismic scram system and control and instrumentation equipment important to safety.

Q.4. Briefly summarize the results of the Staff's review and your conclusions.

A.4. The licensee has described in detail the electrical, instrumentation and control equipment, as well as proposed modifications, necessary for automatic operations at the initiation of a seismic event. We have reviewed this equipment as well as the reliability of the scram and valve actuation circuitry in the context of redundancy, power loss, operating experience, and functional testing and in-service surveillance of scram systems and components. Furthermore, we have reviewed the response times for the scram action events for safe shutdown of the reactor. Based on our evaluation, it is concluded that:

1. The electric, instrumentation and control equipment, modified as proposed, will perform the necessary automatic actions of reactor scram, pressurizer isolation, emergency cooling valve operation and FFS initiation;

2. The reliability of the scram and valve actuation circuitry provides reasonable assurance that the necessary automatic actions will be performed when required; and

3. The response times for the scram action events and the safe shutdown of the reactor are reasonable for use in evaluating the status of equipment during significant seismic loadings.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

TESTIMONY OF JOSEPH A. MARTORE

Q.1. Please state your name, your present position with the Nuclear Regulatory Commission and immediately prior position.

A.1. My name is Joseph A. Martore. I am a Project Manager responsible for the overall safety and environmental project management for power reactor license applications. Prior to holding this position I was a Structural Engineer in the Division of Operating Reactors, Office of Nuclear Reactor Regulations, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, responsible for the engineering analysis and review of safety issues and design criteria related to nuclear facilities licensed for operation; including the review and evaluation of structural, seismic and mechanical analysis and design of safety related structures and components.

Q.2. Please describe your educational background and previous positions held.

A.2. I received M.S. and B.S. degrees in Civil Engineering from Massachusetts Institute of Technology in 1976 and 1975, respectively. Major fields of study and research included engineering mechanics, structural dynamics, and structural analysis and design. Currently, I am a member of both Earthquake Engineering Research Institute and American Society of Civil Engineers. I am also a registered Professional Engineer.

From April 1974 to February 1976, I was employed by North East Post-tensioning Consultants, Inc. as a field engineer and civil engineer. My duties included construction field supervision and inspection, and analysis and design of prestressed concrete structures.

From March 1976 to March 1979, I was employed by Stone and Webster Engineering Corporation as a Structural Engineer in the Engineering Mechanics Division. My responsibilities included the seismic, static, and accident analysis and design of nuclear power plant safety related structures. I was also engaged in missile impact and cask drop analyses, and in developing structural design criteria and specifications. Between the years 1977 and 1979, I was in charge of the soil-structure interaction and seismic engineering aspects of a nuclear power plant. In this capacity I had lead responsibility for the seismic analysis of all safety related structures, including the assessment of structural behavior and the determination of seismic induced stresses and displacements for use in design of the structures. In addition, I was involved in expanding the company's state-of-the art soil structure interaction modeling and analysis capabilities.

In March 1979, I joined the Nuclear Regulatory Commission. I have participated in the review and evaluation of operating license amendments involving seismic and structural issues, assessment of seismic design criteria and analysis methodology, and evaluation of mechanical and structural aspects of spent fuel pool expansions. I have also participated in the NRC sponsored confirmatory research activities related to seismic analyses and methodologies, and have established and managed technical assistance contracts involving seismic issues; including a recent study in which I co-authored a report entitled, "Equipment Response at the El Centro Steam Plant During the October 15, 1979 Imperial Valley Earthquake," NUREG/CR-1665.

Q.3. Please describe your participation in the NRC Staff review of the General Electric Test Reactor for this proceeding.

A.3. In conjunction with Dr. W. J. Hall, I prepared section C of the Staff's May 23, 1980 portion of the Safety Evaluation Report, entitled "Engineering Seismic Design Parameters" and section C of the Staff's October 27, 1980 portion of the Safety Evaluation Report, entitled "Seismic Design of GETR Structures Systems and Components Important to Safety", with the exception of the first paragraph on p.C-8 and the material relating to "Review of Represntative Time Histories for Seismic Scram Analysis at GETR" on p.C-12.

Q.4. Please summarize the extent of your review and your conclusions.

A.4. Our review of this facility is based upon the following general criteria. In the case of nuclear facilities, safety for seismic excitation implies that certain elements and components of the system must continue to remain functional. Structures, piping, and equipment may deform into the inelastic range, and some elements and components may even be permitted to suffer damage, provided that the entire system can continue to achieve and maintain a safe shutdown condition.

Given the seismic design parameters, only the following structural and mechanical requirements must be satisfied:

1. The structural integrity of the massive concrete structure which supports other systems and components important to safety must be maintained.

2. The structural integrity of the reactor vessel and canal fuel storage tanks must be assured.

3. A source of water, including the associated piping system, must be available after the seismic event to provide water to the spent fuel canal storage tanks and the reactor pressure vessel to replenish that lost through boil off and evaporation in the process of cooling the fuel.

The GETR facility, with proposed modifications, has been reanalyzed by General Electric, and reviewed by the NRC Staff and its consultants, to determine whether adequate assurance is provided that the GETR can safely withstand the effects of the seismic design events. Detailed reviews have been carried out on safety related structures, systems and components required to withstand the loadings representing the hazard defined by our seismic design criteria, including possible effects of shaking and faulting.

The seismic review analyses and design of the GETR essential structures, systems and components are in conformance with accepted codes and criteria. In the case of structures and structural components, based on the information reviewed, we find that the analyses performed are consistent with the state-of-the-art that would be used for existing nuclear facilities. It was demonstrated that allowable strengths are adequate to accommodate the effects of the seismic design criteria. Results of analyses and qualification testing of equipment and values similar to those in service demonstrate their ability to function during and after the design basis events.

Each of the three seismic design input parameters commonly associated with design or review analysis, namely earthquake magnitude, expected ground motion, and the response spectra, include reasonably high levels of conservatism which in turn are compounded one upon another as loading input in the final form of the response spectra that are to be employed in the seismic design.

Rational seismic design is based on both reasonably conservative loading and reasonably conservative physical resistance. The physical resistance is provided to accommodate the design loadings, seismic as well as those arising from other effects, and normally includes a significant margin of safety in terms of strength and/or ductility to accommodate unexpected over-loading or expected deformation.

On the basis of our evaluation of the seismic design criteria, analyses methods and criteria employed, and the results obtained, we conclude that the GETR structures, systems and components important to safety, modified as proposed, will remain functional considering the seismic design bases determined proper by the Staff.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

TESTIMONY OF CHRISTIAN C. NELSON

Q.1. Please state your name and present position with the NRC.

A.1. My name is Christian C. Nelson. I am a Project Manager in Operating Reactors Branch No. 3, Division of Licensing, U.S. Nuclear Regulatory Commission, Washington, DC 20555. I am responsible for coordinating and participating in the review and evaluation of safety and environmental considerations associated with the design and operation of power, test and research reactors licensed for operation. I have been employed as a Project Manager since August 1975.

Q.2. Please describe your educational background and previous positions held.

A.2. From January 1972 to May 1975 I was an officer in the U.S. Navy assigned to the nuclear submarine USS Bancroft SSBN 643. I participated in four deterrent partrols, associated upkeeps and shipyard overhaul. I served as Main Propulsion Assistant, Radiological Controls Officer and Reactor Controls Officer and was qualified Engineering Officer of the Watch, Officer of the Deck and in Submarines. My responsibilities included safe operation of the nuclear propulsion plant, coordinating upkeep of reactor systems and equipment, and control of ship's radioactive material

From October 1971 to January 1972 I attended the U.S. Navy nuclear power training program including Nuclear Power School at Bainbridge, Maryland and the Nuclear Propulsion Training Unit at Windsor Locks, Connecticut.

I have a B.S. degree in Naval Engineering from the United States Naval Academy in Annapolis, Maryland.

Q.3. Please describe your participation in the NRC Staff review of the General Electric Test Reactor for this proceeding.

A.3. As Project Manager, I was responsible for supervising and coordinating the work of the NRC reviewers who contributed to the Staff's SER (composed of the Staff's September 27, 1979 document modified to delete its conclusions; the Staff's May 23, 1980 document; the Staff's October 27, 1980 document as modified by the Staff's January 15, 1981 document). I also participated in the review contained in Section A of the portion of the Staff's SER dated October 27, 1980 entitled "GETR Structures, Systems and Components Important to Safety".

Q.4. Please describe the review performed by the Staff which is the subject of Section A of the portion of the Staff's SER dated October 27, 1980.

A.4. The Staff has reviewed the licensee's identification of safety related structures, systems and components as well as the proposed modifications to assure itself that the licensee has identified all the safety related structures, systems and components necessary to shut down the facility and maintain the reactor in a safe shutdown condition during and following the design basis seismic event. The Staff's analysis of the GETR as modified indicates that the principal safety related structures, systems and components are those identified in Section A.

Q.5. Please summarize the results of your review in Section A of the portion of the Staff's SER dated October 27, 1980.

A.5. 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 bases seismic events.

MR. CADY: Your Honor, at this time I would introduce Mr. John Rutherford's testimony submitted to the Board and to the reporter prior to his testimony, and ask that it be bound into the transcript as though read.

JUDGE GROSSMAN: Any objection, Mr. Bachmann?

MR. BACHMANN: No objection, sir.

MR. EDGAR: No objection.

JUDGE GROSSMAN: Admitted under those conditions.

(The document follows:)

JOHN B. RUTHERFORD
1141 Chestnut Street, #3
San Francisco, CA 94109

May 1, 1981

Earthquake Safety of the General Electric Test Reactor

I have reviewed the geologic hazard and seismic safety studies of the General Electric Test Reactor site. There appears to be general agreement that exploratory trenches dug across the site reveal several past episodes of earth movement. Some investigators attribute the movement to landslides, others to surface fault rupture. Estimates of future offset movement caused by a future earthquake, or earthquake-induced landslide, range from 18 centimeters up to a meter and a half. There are differences of opinion as to the location of the fault or landslide with respect to the reactor structure.

As a structural engineer, I cannot guarantee that a structure will resist the estimated amount of earth movement occuring beneath or directly adjacent to the structure without some structural damage. I believe that a nuclear reactor should not be operated on this site.

John B. Rutherford

JUDGE GROSSMAN: Is there a presentation, Mr. Bachmann?

MR. BACHMANN: Yes, sir.

DIRECT EXAMINATION

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BY MR. BACHMANN:

Q Mr. Nelson will give a brief overview of the scope of review that the Staff performed on the SER and other reviews.

A (Witness Nelson) This panel represents the NRC Staff's review of issue 2 of the show-cause order, which essentially was would the GETR safety-related structures, systems and components important to safety withstand the design basis seismic events.

I am representing the systems portion of that review; Mr. Burdoin, the electrical aspects; and Mr. Martore, the structural engineering or seismic design portion of that review.

Our review is essentially documented in Staff's Exhibit 1-C, which is the October 27, 1980 Safety Evaluation Report, Part 2, Sections A, B, and C.

Regarding systems, we have reviewed the safety-related equipment identified by -- and I use equipment as structures, systems and components -- we have reviewed the safety-related equipment identified by General Electric to assure ourselves that the equipment necessary to shut down the reactor and maintain the reactor in a safe shutdown condition has been identified.

This aafety-related equipment is listed in Table 1 of that Exhibit 1-C.

Regarding modifications to these systems, the principal additions to the GE Test Reactor were or are the fuel flooding system, the canal fuel storage tanks, the stand pipes above the emergency cooling check valves, the canal -- excuse me, the third floor missile impact system, the new seismic scram triggers, various seismic restraints, and anti-siphon type valve features.

Our electrical review concentrated primarily on the seismic scram system, its reliability, and the response times for actions initiated by that system.

Regarding the seismic design review, we reviewed the analyses performed by the Licensee, General Electric, using accepted codes and criteria. That review was comparable to other reviews performed of operating nuclear power plants, and the results of that review -- we assured ourselves by that review of the mechanical and structural integrity of this safety-related equipment.

I'd like to note that in doing that structural review, design input loadings, structural analyses and criteria used, employed or compounded conservatism.

I'll conclude by the results of our combined review, we have determined that the safety-related equipment for the General Electric Test Reactor in the seismic issue has been properly identified and will withstand seismic design parameters determined proper by the Staff as discussed in issue 1.

JUDGE GROSSMAN: Thank you.

Any further presentation, Mr. Bachmann?

MR. BACHMANN: No, sir.

JUDGE GROSSMAN: Mr. Cady -- oh, I'm sorry, Mr. Edgar.

MR. EDGAR: I have no questions.

JUDGE GROSSMAN: Mr. Cady?

CROSS-EXAMINATION

BY MR. CADY:

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Q Does the Staff consider any safety-related systems outside of the reactor building to be necessary -- okay, let me start over.

Does the NRC Staff consider any systems, components or equipment outside of the reactor building necessary [illegible] protect the public safety?

A (Witness Nelson) Yes, we do. The fuel flooding system portions of it are outside the reactor containment.

Q Are there any other systems or components involved with the protection of the public safety outside of the reactor building that the NRC Staff considers necessary for the protection of the public safety?

(Panel conferring.)

MR. BACHMANN: Your Honor, I would like to make an objection to that question. We have stipulated on the basis of admissions made by the Intervenors and I quote:

"All of the safety-related structures, systems, and components necessary to shut down the facility and maintain the reactor in a safe shutdown condition during and following a design basis seismic event are identified in Table 1, Section A of the SER."

And this was admitted to by Intervenors' response dated April 10th, 1981 to our request for admissions dated March 16th, 1981.

MR. CADY: Your Honor, I believe my questions do not go to the safety-related systems involved with the shutdown, but with possible other results that may happen if a seismic event does occur. It has nothing to do with the shutdown of the reactor, but as I went into yesterday, with having radioactive -- radioactively contaminated water leaving the containment building and being stored in underground containers. It's dealing with the design of these containers and other systems outside of the shutdown systems as relevant, and it was not stipulated to in the stipulation.

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: Your Honor, the Staff still maintains that the fact that we have identified the structures, systems and components completely covers the scope of the show-cause proceeding, based on the Commission's memorandum and order.

JUDGE GROSSMAN: Could you indicate again to me how you characterized the systems that you are interested in, Mr. Cady?

MR. CADY: The systems that we are interested in do not have anything to do with the safe shutdown of the reactor.

JUDGE GROSSMAN: What was the term you used before?

MR. CADY: The term that we used was that there are systems involved with the reactor itself that are outside of the shutdown situation, and therefore they should be included in the design basis for the postulated event.

JUDGE GROSSMAN: Were they safety-related? Is that the phrase you used? I don't recall now, Mr. Cady. Rephrase your question.

MR. CADY: Necessary for the public safety.

JUDGE GROSSMAN: Okay, Mr. Bachmann, do you want to respond to that? He's asking about systems that relate to the public safety, not specifically those relating to safe shutdown. Perhaps your witnesses are able to respond to the way that is characterized.

MR. BACHMANN: I still maintain my position on that. However, perhaps the witnesses can attempt to respond to that.

JUDGE GROSSMAN: Okay, why don't you respond to the question, Mr. Nelson?

WITNESS NELSON: For the purposes of this proceeding, we reviewed those equipments necessary to safely shut down the reactor and maintain the reactor in a safe shutdown condition, as the safety-related equipment, and our review concentrated on those equipments.

BY MR. CADY:

Q Plus the fuel flooding system?

A (Witness Nelson) That was included in that definition.

Q Are you familiar with the tank from which contaminated water from the sumps is pumped? Are you familiar with that underground tank?

A Yes, as it was discussed today.

Q But prior to today, or yesterday, when I discussed the matter with Dr. Kost and Mr. Gilliland, were you aware of the existence of that tank?

A I don't recall -- when it was brought up today, I didn't recognize the tanks as something I had been aware of before. That doesn't preclude the fact that it may have in the last three years come up in discussions.

Q Did the NRC Staff perform any analysis of the integrity of that tank to withstand the postulated NRC events of a .75 horizontal ground motion from the Calaveras Fault, or .6 horizontal motion as a result of the Verona Fault on that particular tank?

A No, we didn't perform any analyses of those tanks, no, on seismic resistance.

MR. BACHMANN: Your Honor, I might add at this point, and as I said, I have not withdrawn my objection -- Mr. Cady has not yet laid a foundation to establish that these particular tanks are important to safety, and that is the scope of the show-cause order.

MR. CADY: I believe the testimony yesterday from Mr. Gilliland and Dr. Kost showed that radioactively contaminated water from the -- I believe it was from the canal -- did flow down into the sump to which it was pumped into this tank, which is outside of the containment building. It is underground and from which -- from this underground tank, it was pumped to the demineralizer building to take out any impurities, and then it was recirculated back into the reactor, and I believe that is a sufficient foundation to show that it is relevant for the public safety.

JUDGE GROSSMAN: I believe Mr. Cady is distinguishing between systems necessary for safe shutdown and systems that may be damaged that would result in some effluents being released beyond the standards permitted in the various sections of the regulations.

MR. BACHMANN: Yes, sir, and I will respond exactly to that. If it's important to safety, he has not yet laid any foundation that there could be any consequences beyond the site boundary, no matter what happened to these particular pieces of equipment.

JUDGE GROSSMAN: I believe Mr. Cady is going to attempt to establish that. Is that correct, Mr. Cady?

MR. CADY: The only foundation that I could lay relative to that would be that the water that does go into these tanks is -- it does contain radioactivity and that if it does get into the underlying groundwaters that go beneath the site --

JUDGE GROSSMAN: Mr. Cady, you are not going to testify to that effect, are you? Is that something you are going to be questioning the witnesses on?

MR. CADY: Your Honor, I believe that Dr. Kost and Mr. Gilliland said that radioactive water was pumped into this tank.

JUDGE GROSSMAN: Well, I think then a sufficient foundation has been laid to question with regard to this.

You may proceed, Mr. Cady.

MR. CADY: Thank you.

BY MR. CADY:

Q Outside of the reactor building and the fuel flooding system, were any tests run to determine the seismic adequacy of any of the other buildings within the boundaries of the GETR site?

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MR.EDGAR: I will object to that question on the grounds of scope. I don't see how other facilities, other than that facility under License TR-1 can be relevant to the show-cause order.

JUDGE GROSSMAN: Yes. Mr. Cady, there are other facilities involved in the renewal proceeding. It is my recollection that at least one other facility for special handling which is involved in the renewal proceeding was not included in the show-cause proceeding, and I don't think we ought to allow questioning with regard to that here. So I will sustain that objection to that line of questioning.

MR. CADY: I have no further questions.

BOARD EXAMINATION

BY JUDGE GROSSMAN:

Q Mr. Nelson, we have had so-e indication from the Licensee's panel that the FSAR considered maintaining the integrity of the containment as necessary to ensure safety. Is that your understanding, too?

A (Witness Nelson) Yes, sir. The FSAR does consider maintaining containment integrity. I would like to make sure that we are referencing the same thing by "FSAR." I have also heard the Licensee's panel discuss their November 11th, '77, response. I just want to make sure that we are referencing the same document.

Q I am talking about the original document, not the 1977 document, yes.

Now could you tell me on what basis? Is it a legal basis? Or is it based on additional findings in which the Staff can ignore maintaining the integrity of the containment in determining whether there is a seismic threat to the facility?

A The basis for ignoring containment, or at least not requiring that it maintain its integrity, is one based on radiological consequences and the acceptability of those consequences.

Q Well, my question is this: Did you re-evaluate that at this point in time? And if so, are you permitted to do that under your interpretation?

A The answer to both is "yes." We evaluated the Licensee's response to our order, which was the November 11th, 1977, document, which assumed the failure of certain items which would not be seismically qualified, including the containment. And our evaluation, which is Section 2, Part B of our October 27th, 1980, Safety Evaluation Report, finds that those releases are within allowable limits.

Q But now didn't you have to re-evaluate everything else that is contained in the original FASR in order to downgrade the importance of that containment?

(Witnesses conferring.)

A. I'm not sure I understand your question, your Honor.

Q. Well, if the containment is considered part of the integral safety requirements originally, and it is on that basis that the facility is licensed, can you go ahead at a further point in time and determine that some of the equipment that was considered necessary, or some of the structure originally is no longer necessary in order to provide for the public health and safety?

A. We were dealing in this case with a specific event for which this containment was not necessary, or determined not to be necessary.

Q. Okay. Now there are specific events for which the containment was determined to be necessary originally. Is that not correct?

A. Yes, sir.

Q. The main event is a design basis accident, I would assume. Is that not correct?

A. Yes, sir. That is a categorization.

Q. Okay. Now can you ignore the fact that during the show-cause proceeding that a design basis accident might occur in conjunction with the seismic event that you are considering?

A. Yes, sir, I believe we can. The design basis accident assumes a core melt, and it was shown by the Licensee's analysis that a core melt would not occur as a result of the seismic event.

Q Well, that is one design basis accident. But my question is this: Couldn't some other design basis accident occur simultaneously with the seismic event? And wouldn't you have to consider that occurrence in conjunction with the seismic event?

(Pause.)

A Design basis accidents, or accidents in general, need to have a reason for occurring. The seismic event, or all potential accidents resulting from the seismic event, were postulated or were considered in a bounding one -- that being the double-ended rupture of the primary piping -- which was determined. And that is the accident that was analyzed in conjunction with breach of containment and the seismic event, or the results of the seismic event.

(Witnesses conferring.)

Q If that is the limiting event in the case of a seismic event, wasn't it also the limiting event that could have occurred originally when you considered the safety problems in the original FSAR? Or were there events that were beyond that?

A As I pointed out, I believe the design basis event assumes fuel melting.

Q That's the original design basis event for which a containment was considered necessary?

A Yes.

Q And that was the only event?

A Oh, no, sir. There were a number of events. That was the bounding event as far as release potential of radioisotopes.

Q Well, my question rea-ly is this: Did the fact that you were postulating a seismic event eliminate the possibility of there being any of those other events for which the containment was considered necessary in the first instance?

A Only by going through, as the Licensee has done and the Staff has evaluated, a determination of the worst accident associated or which could be caused by the seismic event. And that determination was a loss of coolant accident by the quickest means, the rupture of the primary piping.

Q Okay. But you keep qualifying it by saying "associated with the seismic event," and my question is: On what basis can you discount the fact that there might be a design basis accident unrelated to the particular seismic event that you are postulating that might occur simultaneously with the seismic event? I am not saying you don't have a basis; I just want to find out what it is.

A. I guess I am trying to go back on the fuel failures. The licensee has shown fuel not failing mechanically or by melting. Okay? With that demonstration by the Licensee, the next-worst accident according to the Licensee's presentation and our review and approval, was the loss of coolant accident.

It is nonmechanistic to assume the design basis event previously analyzed in the FSAR to be associated with this seismic event.

Q. Okay. Let me ask you another question, and let's go at it from a different direction. The fact that you have now postulated that there would be a breach of the -- there might be a breach of the containment in the event of the postulated seismic event, and you have decided that that does not affect the public health and safety, does that then in effect throw out what you have already determined in your FSAR as to what are necessary portions of the structure in order to promote the public health and safety, or to protect the public health and safety? Do you follow me? Does that supercede the original FSAR now?

A. No, your Honor, because the cause is different. I would have to look at all the scenarios analyzed in the FSAR, or previous Staff analyses, but the only -- the worst one, the most severe one associated with the seismic event as a cause is the rupture of the primary piping and the loss of primary coolant.

Q I take it, then, you haven't gone through every scenario that was considered in the FSAR with regard to all necessary safety measures, or safety equipment?

A No, sir. We haven't done an evaluation of all those.

Q Or a re-evaluation of all?

A Or a re-evaluation of all those.

Q You have only considered what would be the worst-case event that is associated with the seismic event? Is that correct?

A Yes, your Honor.

JUDGE GROSSMAN: Perhaps this is something that will be explained on brief. I am not sure whether it is the panel that gives the authoritative position on this, or whether it is merely argument that counsel can make.

MR. EDGAR: Mr. Chairman, we are prepared to respond on brief. The fact is, that the design basis event prior to this was the LOCA. Now you are taking the seismic event with the LOCA, and that is fairly sensible.

JUDGE GROSSMAN: Mr. Bachmann?

MR. BACHMANN: I don't want to sound as though I am testifying, but it appears to me that our original design basis event, or the worst case has now in essence been made even worse, because the mechanism for the core melt as postulated by Mr. Christian -- I mean, Mr. Nelson, we have now postulated the loss of cooland and the seismic event together. And from what he is saying, the conctainment is no longer considered necessary.

JUDGE GROSSMAN: Well, that is the part I seem to understand he is saying, and I am wondering what the effect of the Staff saying that is at this moment. Does that now supercede the FSAR and say that certain things that were considered required before are no longer required because we have re-evaluated?

WITNESS NELSON: Mr. Chairman, perhaps I could show by example how the bounding case can be different under two different circumstances. I do recall one accident analyzed, I believe, which was the C primary pump rotor, which would in effect stop the reactor coolant pump flow without a reactor scram, or with a reactor scram at sometime later, which I believe results in some fuel damage. For this event, containment is necessary.

In the review of the seismic event, the Licensee has demonstrated that the reactor will be scrammed prior to the possibility of fuel damage, and that the core will not become uncovered, the fuel will not be damaged by the seismic motions, and therefore you don't have to consider those fission products contained in the fuel as part of the -- or consider them to be released to the containment atmosphere.

BY JUDGE GROSSMAN:

Q Okay, I understand that example where the safety measures that would be in place because of the seismic event obviate the need for some of what had previously been postulated as necessary safety equipment, but there are implications from that that you have now changed the requirements with regard to what had been originally included in the FSAR.

A (Witness Nelson) No sir. I believe it is correct to say that we have outlined yet another scenario that has to be considered in the FSAR.

Q Now let me also ask you just to clarify the situation. We are -- Mr. Martore, did you have something to add to that?

A (Witness Martore) No, sir, I did not.

Q Is it the Staff position that we do have to concern ourselves with the possibility of releases beyond what is permitted by the regulations in this show-cause proceeding?

A. (Witness Nelson) The Staff used its review of radiological consequences as a check on, one, the lack of containment integrity in the seismic event, or the lack of assurance that you'll have containment integrity following a seismic event; and also on the identification of safety-related equipment.

Q. I take it, then, that your answer is generally "yes," but you've indicated the two circumstances in which you have considered that? Is that correct?

A. Yes, sir.

(Board conferring.)

JUDGE GROSSMAN: Dr. Ferguson?

(Board conferring.)

Judge grossman; We will take a five-minute recess.

(Recess.)

JUDGE GROSSMAN: Okay, we're back on the record. Unfortunately, although we would like to, we can't continue this evening. We will just have to adjourn now because we have lost the room. There is another party coming in. We will reconvene tomorrow morning, then, at 8:30.

The understanding is that Mr. Meehan will be back tomorrow morning, probably about 9:30, but we will proceed with the structural panel until he returns.

Thank you.

(Whereupon, at 5:12 p.m., the hearing was adjourned, to reconvene at 8:30 a.m., Wednesday, June 10, 1981.)

end JWB #14

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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: Tuesday, 9 June 1981

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.

Ann Riley

Official Reporter

Jane W. Beach

Official Reporter