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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the Matter of:)
PRIVATE FUEL STORAGE, LLC,)
(Independent Spent Fuel) Docket No. 72-22
Storage Installation)) ASLBP No. 97-732-02-ISFSI
)
)

DEPOSITION OF DR. VINCENT LUK

Saturday, May 4, 2002

10:00 a.m.

160 East 300 South, 5th Floor

Salt Lake City, Utah 84114

NUCLEAR REGULATORY COMMISSION

Docket No. _____ Official Exh. No. HH

In the matter of _____

Staff <input checked="" type="checkbox"/>	IDENTIFIED <input checked="" type="checkbox"/>
Applicant _____	RECEIVED <input checked="" type="checkbox"/>
Intervenor _____	REJECTED _____
Other _____	WITHDRAWN _____
DATE <u>5/9/02</u>	Witness _____
Clerk <u>V. Mansel</u>	



CitiCourt, LLC
THE REPORTING GROUP

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Salt Lake City, Utah 84144

1 MS. NAKAHARA: Let me just start over.
2 Q. (By Ms. Nakahara) Sensitivity
3 studies -- your report states sensitivity studies
4 were performed to demonstrate the adequacy of using
5 this - you are going to make me say it again -
6 discretization scheme to incorporate the depth
7 variation of soil properties such as shear wave
8 velocity and damping profiles in the soil
9 foundation submodel. Will you generally describe
10 how you conducted the sensitivity studies?
11 A. Yes. Again, I'll make reference to the
12 transmittal from Mr. Lam to me dated August 27,
13 2001. In that, we devote quite a bit of effort to
14 describe the methodology. What we simply do is
15 that we use the 1-D shake model to go through
16 different combinations of the discretization
17 procedures. That means trying to subdivide the
18 soil foundations in various combinations of
19 horizontal layers. And then try to use the shape
20 for every combination to make sure that the dynamic
21 characteristics of the soil foundations, as given
22 to us for the site-specific soil profiles, are
23 satisfied. And then we eventually come up with a
24 set of combinations of the horizontal layers that
25 we use from our model.

1 We are also trying to make sure that our
2 model is practical in nature. That means it is not
3 excessively large, which will actually -- we will
4 have to pay huge penalty for the computational
5 time. So it's more or less, at the end, it's an
6 engineering judgment. If we can preserve the
7 dynamic characteristics of the soil foundation
8 that's given to us, what is the best method that we
9 can use in our coupled finite elements model so
10 that it will still be practical. And the details
11 of the examination, as I said, is actually in the
12 submittal from Mr. Lam to me dated August 27, 2001.
13 Q. Just to clarify, is it correct that
14 Dr. Shah provided you the soil profiles for this
15 PFS site?
16 A. Yes.
17 Q. Did Dr. Shah provide you the soil
18 profile under a description of a best estimate
19 profile?
20 A. He actually provided me three sets; the
21 best estimated, lower bound, and the upper bound
22 for the site-specific soil profile data.
23 Q. Okay. So Dr. Shah categorized them into
24 the lower bound, the upper bound, and the best
25 estimate?

1 MR. TURK: I have to object. The
2 testimony is Dr. Shah provided these. You are
3 asking did Dr. Shah characterize them.
4 Q. Well, did Dr. Shah provide the soil
5 profiles defined by the lower bound, the upper
6 bound, and the best estimate?
7 A. Yes.
8 Q. Okay. On Page 9 under Section 3.4.1
9 towards the bottom of the paragraph, the report
10 states, "The stiffness proportional damping terms
11 were not implemented (i.e. set to zero) to avoid
12 very severe computational penalty associated with
13 developing the very large stiffness matrix in the
14 3-D coupled model." Will you explain what you mean
15 by that statement?
16 A. Yes. I think in order for me to answer
17 your questions, just a few sentences related to the
18 background.
19 Q. Okay.
20 A. We use rayleigh damping.
21 MR. TURK: What kind?
22 A. Rayleigh. R-A-Y-L-E-I-G-H-T damping.
23 This is a well-established damping theory.
24 Basically it has two terms. One term is related to
25 the mass proportional damping. The second term is

1 related to the stiffness proportional damping. It
2 is the choice by the analyst, and for this case it
3 is us, that we can use a parameter that
4 incorporates both terms of the damping. But we
5 went through extensive study on the sensitivity,
6 mainly because when we used damping in combination
7 of the two terms, it is going to cause severe
8 penalty computational time. Mainly it will double
9 the computational time that is required.
10 So now we are going to investigate the
11 options. And one of the options that has been our
12 practice a lot of time is that we try to find out
13 if we just use the first term, which is the mass
14 proportional damping, how much inaccuracy are we
15 inducing in the analysis results? And in our
16 sensitivity study, it indicated by just using one
17 term, which is mass proportional damping, the
18 structural response would basically remain the same
19 as for the case when we used the two-term damping.
20 The only thing that is missing in using the one
21 term mass proportional damping case is that the
22 high frequency response would probably show up and
23 would not be able to damp out.
24 So in that regard, in my conclusion of
25 the analysis methodology, we said by using one term

1 mass proportional damping, we actually underdamped
2 the structural system. So in essence, for the
3 structural response that we are considering for the
4 cask, the accuracy is not much affected at all, if
5 any, by the omission of the stiffness related
6 damping. That's what I said here.

7 Q. Okay.

8 A. And that's also the reasons why we
9 choose not to use the stiffness proportional
10 damping.

11 Q. If you will turn the page to Page 10.

12 A. Yes.

13 Q. Will you explain the basis for selecting
14 your damping ratios in each layer for Table 2?

15 A. Okay. The answer to your question is --
16 actually, if you go back to Page 9. We did try to
17 go through that starting in subsection 3.4.1. It
18 actually started in the second sentence. I'm
19 sorry. It actually started in the first sentence.
20 "The damping ratio in terms of percentage is the
21 material damping from the free field site response
22 analysis using the shaken program reflecting the
23 strength dependent soil properties for the specific
24 soil layer." And it continues.

25 Q. How did you derive your properties for

1 the soil profile in Table 2? Were those
2 provided -- for example, the Young's modulus, were
3 those provided to you in information from Dr. Shah?

4 A. Yes. All those like Young's modulus,
5 ratio density, they were given to me by Professor
6 Shah, or by Dr. Shah.

7 Q. Are you familiar with the term "contact
8 stiffness", as in reference to the contact
9 stiffness between the bottom of the cask and the
10 top of the concrete pad?

11 A. Would you like to qualify your question
12 a little bit? Of course I have heard of the term,
13 but --

14 Q. Did you use contact stiffness as an
15 input into your model?

16 A. No.

17 Q. Did your analysis assume that the pad
18 would remain horizontal or did your analysis allow
19 the pad to move with the ground motion?

20 A. The cask is free to move in whichever
21 way it will supposed to go through. The whole
22 dynamic behavior is actually governed by the
23 equations of state and the constitutive relations
24 as incorporated in the ABAQUS finite elements code.

25 MR. TURK: Could you read the answer?

(The record was read as follows:

1 "A. The cask is free to move in
2 whichever way it will supposed to go through.
3 The whole dynamic behavior is actually governed
4 by the equations of state and the constitutive
5 relations as incorporated in the ABAQUS finite
6 elements code.")

7 Q. Is the pad free to move also in the
8 model?

9 A. Yes.

10 Q. Did you account for the natural
11 frequency of the pad vibrations in your model? You
12 don't understand my question.

13 Did you plot the acceleration time
14 history in the vertical direction from soil cement
15 interaction effects at D prime, if you look on Page
16 33?

17 A. Yes.

18 Q. And if you can find it, can you point --

19 A. It's on the following page, isn't it?
20 Page 34. So I don't want to ask the question
21 again, but that's the question. You refer to the
22 accelerations at the D prime locations?

23 Q. In vertical -- is it the vertical
24 direction, or are these in the horizontal

1 direction?

2 A. This is in the horizontal directions.
3 We did not plot the time history in the vertical
4 directions.

5 Q. In your opinion, what would you expect
6 if you had plotted it in the vertical direction, if
7 you can render an opinion?

8 A. Probably not, because the model is
9 highly nonlinear and the results are also highly
10 nonlinear and it is also very dynamic. Anyway, to
11 speculate the results would probably degrade the
12 quality of the analysis results.

13 Q. Can you determine the frequency of
14 response of the pads in the vertical direction?

15 MR. TURK: Could I hear the question
16 again?

(The record was read as follows:

17 "Q. Can you determine the frequency of
18 response of the pads in the vertical
19 direction?")

20 MR. TURK: I object. Are you asking can
21 he determine it independently or are you asking can
22 you determine it from looking at his report?

23 Q. From your report. Can you point to
24 somewhere?
25

1 back and derive through your computer model?
2 A. No, not from the analysis.
3 MR. TURK: And for clarification just to
4 be sure, as I understand the question and answer,
5 Dr. Luk is saying he doesn't have the printouts, he
6 doesn't have something he can hand you that says
7 this is how it looks, correct?
8 THE WITNESS: Yes.
9 Q. (By Ms. Nakahara) Have you calculated
10 the maximum shear strain for the soil underlying
11 the cement-treated soil?
12 A. Can you repeat the question?
13 Q. Have you calculated the maximum shear
14 strain for the soil underlying the cement-treated
15 soil? I guess in this case it would be the soil
16 cement underneath the concrete pad.
17 MR. TURK: I'm sorry. Would you ask the
18 question again?
19 Q. (By Ms. Nakahara) Have you calculated
20 the maximum shear strain in the soil beneath what's
21 characterized in your report as soil cement
22 underneath the storage pad?
23 A. Yes. As I said, you know, all those
24 informations are available as output of the
25 computer program. We did investigate in detail the

1 shear strain in the soil cement layer as well as
2 the soil foundations As intermediate steps to
3 investigate the integrity of the soil cement layer
4 as well as the soil foundation. In that regard,
5 the shear strain in both soil cement layer and soil
6 foundations are very small. As a matter of fact,
7 it is the requirement for the 10,000-years return
8 seismic calculations we have to make sure that the
9 shear strain is within the range that's given
10 because of the nature of the seismic input.
11 MR. TURK: Just for clarification,
12 you're staying shear strain or shear strength?
13 THE WITNESS: Strain.
14 Q. (By Ms. Nakahara) What did you mean by
15 within the range given?
16 A. Because as a requirement the damping as
17 well as the sheer modules is a function of the
18 shear strain in the foundations. And that is the
19 characteristic for the 10,000 years seismic event.
20 MR. TURK: Again, that was sheer strain.
21 THE WITNESS: Yes, sheer strain.
22 Q. (By Ms. Nakahara) In your model, how
23 did you allow sliding to occur? Strike that. How
24 is sliding allowed in the model, in your model for
25 the soil elements?

1 A. Can you repeat the question?
2 Q. In your model, how did you allow sliding
3 -- how did you allow the soil elements to slide?
4 Or how did you model the soil elements that are
5 allowed to slide?
6 A. When two bodies are in contact, sliding
7 is permitted with the model that we have with
8 adequate explicit is only allowed at the interface
9 when counterelements have been used. So in that
10 regard, since the soil foundation model itself does
11 not have any interfaces in it, they will act as a
12 continuum.
13 Q. Look at Figure 20a on page 36. Is it
14 correct that this is a response spectra in Figure
15 20a?
16 A. Yes.
17 Q. For what return interval is this
18 response spectra?
19 A. This is for 2,000 years.
20 Q. Will you explain what this response
21 spectra shows at 0 period for point D'?
22 MR. GAUKLER: Are you talking about
23 Figure 20a?
24 Q. (By Ms. Nakahara) Yes.
25 A. Okay. This is response spectra and the

1 independent variable is period. If you say that --
2 can you repeat, what is the frequency level that
3 you want?
4 Q. At the 0 period or right after the 0
5 period.
6 A. Okay. Right after 0 0 period, that
7 means when the period is more the frequency is very
8 high. Okay. So it's right next to the Y axis.
9 Q. Go ahead. Sorry.
10 A. And whatever we plot is the values.
11 Q. So is it correct that this response
12 spectra is showing accelerations in excess of 10 Gs
13 just after the 0 period?
14 A. Yes.
15 MR. TURK: In excess of 10 Gs?
16 MS. NAKAHARA: Yes.
17 MR. TURK: The plot only goes up to 10
18 Gs.
19 Q. (By Ms. Nakahara) That's why it doesn't
20 look like it stops at 10 Gs.
21 A. Yes.
22 Q. Can you explain, if it does, how this
23 response spectra Figure 20a relates to Figure 17?
24 A. Yes. Can I elaborate a little bit on
25 Figure 17?

1 Q. Yes, please.

2 A. Because it will directly answer your
3 question. Two things. One is that, as I described
4 earlier, that we only used one turn, which is the
5 mass proportional damping in our three-dimensional
6 coupled finite element method. So in that regard
7 we know some of the high peak will not be able to
8 damp out because that's by very nature of the input
9 that we omit the stiffness proportional damping.

10 In that regard, if you look at the
11 Figure 17, we know the green plots, which is
12 actually the free field point, free field locations
13 on the free field surface which is actually A',
14 there is actually for some in just a little bit
15 more than five seconds for the green, there's a
16 plot of 1.34. And we know in reality for the free
17 field behavior on top of the soil foundation the G
18 value is only of the order like .7.

19 What that simply indicated to us is that
20 simply because this is unfiltered raw data directly
21 from the analysis that some of you think that we
22 actually expect to show up in the raw data, it did
23 show up. So what this simply mean is that if you
24 look at the high G value for the A', that 1.34 G at
25 that time is not real. But the whole purpose of

1 derived directly -- Figure 20a is the response
2 spectra obtained directly from the raw data from
3 Figure 17. And that's actually for that regard, we
4 know all the high frequency response will show up.
5 But again, the intent of the whole exercise in this
6 area is to demonstrate there is a significant
7 contribution to the dynamic behavior of the cask
8 with regard to the SSI effect.

9 And also, if you don't mind me to
10 elaborate a little bit more, there's always the
11 danger when people do finite element calculations,
12 if people's interest are focused on the structural
13 response, it is very dangerous to pick values from
14 a single node. A single node, a node is a point in
15 a finite elements mesh grid because the very nature
16 of the nonlinear dynamic behavior will have peaks
17 at various isolated locations, but that's not the
18 intent that we try to demonstrate here. We just
19 want to pick one node at the free surface of the
20 soil foundation and compare with one locations that
21 is at the center of the pad base and try to find
22 out is there any difference. And the answer is
23 yes, there's significant differences.

24 Also, can I substantiate a little bit
25 because I feel, okay, if people's focus is actually

1 the Figure 17 is to demonstrate whether there's SSI
2 effect and if it does have the effect, how
3 significant are they, okay? And is also by
4 intention we did not go through the filtering
5 because we want to see the SSI effect is important
6 in this class of problems.

7 MR. GAUKLER: You did not go through
8 what?

9 THE WITNESS: We did not go through the
10 filtering to use a different frequency level
11 because in that sense you can actually filter out
12 all the nonessential things. Essential only to the
13 structure of the response is important. And also
14 in that regard, when you look at the G value
15 response with respect to the point D, which is at
16 the center of the pad at the base of it, the G
17 value is as high as 2.95. But that's by the same
18 nature as unfiltered raw data, does not real
19 indicated that anything more than we try to show
20 there is an amplification by the pure presence of
21 the structure on top of the soil foundations.

22 MR. TURK: You said point D. Did you
23 mean point D'?

24 THE WITNESS: Yes, I'm sorry, point D'.
25 And is also in the light of this, Figure 20a is

1 try to get the structural response from the finite
2 elements results, for example, you have to go
3 through some kind of averaging, okay? Mainly try
4 to reduce the certain peaks happen in any node
5 because structural behavior is very -- is quite
6 different from the mathematical models, and the
7 only way to have a structure to respond in
8 appropriate manner within the principle of physics
9 is that if you try to go through some averaging.

10 Q. (By Ms. Nakahara) Do you have an
11 opinion on what the average amplification of the
12 free field ground motion would be from soil
13 structure interaction effects?

14 A. Can you repeat the question?

15 Q. Would you read it?

16 (Pending question read.)

17 THE WITNESS: From the way that the
18 analysis results indicated to us, anyway, the range
19 of the amplification due to the SSI effect on the
20 base of the pad changes from locations on the pad,
21 but I think that it ranges from 20 percent and
22 maybe up to 45 percent. But that's location
23 dependent.

24 Q. (By Ms. Nakahara) It's location
25 dependent. Can you expand on that? For example,

1 where would approximately a 20 percent
2 amplification occur?
3 A. Well, that, those sets of values also
4 dependent on the input of the time history of the
5 seismic accelerations, but I think for here, I
6 think the -- I want to make reference to the plots
7 that we actually have this things in mind is to
8 look at, for example, the locations C and D on
9 Figure 16 and the results actually show up in
10 Figure 18 on page 34. If you compare the actual
11 pad to the center of the pad you more or less will
12 be able to get some range of variations because
13 they do represent the other two extreme. And also
14 because of the dynamic nature of the phenomena the
15 amplification is also a function of time. So in
16 that regard it's very difficult to answer your
17 question with just a value because that is actually
18 the reason why we plot out a time history so people
19 will have a better understanding of this.
20 MS. NAKAHARA: Just to clarify, Sherwin,
21 we have the electronic histories that are plotted
22 out here, correct?
23 MR. TURK: I gave you a disk with the
24 input type histories.
25 MS. NAKAHARA: Not with the output?

1 MR. TURK: As we discussed before, those
2 outputs would be massive. We don't have them
3 ourselves. They don't have a copy of those. We
4 would have to run the computer to generate them for
5 you.
6 MS. NAKAHARA: But he has already
7 plotted these?
8 THE WITNESS: Maybe off the record.
9 MS. NAKAHARA: Off the record.
10 (Discussion held off the record.)
11 THE WITNESS: For that, back on the
12 record, that was the purpose for us to -- we submit
13 the input file to NRC and if it is choice of
14 anyone, you get hold of the input file and execute
15 the model yourself and get the output. For us to
16 repeat any run, of course it's possible, but then
17 it will be cumbersome to submit the output file
18 because it's as large as 2.5 gigabytes.
19 MR. TURK: Just for point of reference,
20 how many pages would it take to print out?
21 THE WITNESS: I don't think anyone going
22 to actually want to print out.
23 MR. TURK: We're talking many thousands
24 of pages?
25 THE WITNESS: I have no idea. Nobody

1 has ever tried to get an output like that because
2 all those are just pure numbers, do not have any
3 sense.
4 MR. TURK: You're talking about a finite
5 element analysis in which thousands of loci,
6 individual locust points are plotted.
7 MS. NAKAHARA: I understand that.
8 MR. TURK: And then you're looking for a
9 microsecond for each locust point. You're talking
10 about a vast amount of information.
11 Q. (By Ms. Nakahara) He's already plotted
12 these histories. You don't have a electronic file
13 of, for example, Figure 17?
14 A. Yes, we have that. But I don't have it
15 here.
16 Q. And how large of a file would that be?
17 A. Well, it -- for that is very small
18 because we literally convert this to the work
19 format. What that simply mean is that the file
20 size is very small. And as a matter of fact, the
21 only reason why I say that is that I submit the
22 whole report electronically to NRC and you actually
23 have that. That means if that's all you want is to
24 have electronic copy of the plots, you have it.
25 DR. SOLER: She wants the data that went

1 in the plot, you know, time, X1, X2, X3, that's
2 what they want.
3 THE WITNESS: Okay. I think for that,
4 you actually -- well, first, I don't have it here,
5 and if you actually want, I think we have to rerun
6 the case and then take that piece of information
7 explicitly out and then look at it.
8 Q. (By Ms. Nakahara) So you don't have it
9 stored somewhere, you would have to rerun the model
10 to obtain it; is that correct?
11 A. Yes, yes. But this is the importance of
12 the -- well, maybe that is the whole reason for a
13 plot like this. We plot the raw data. That means
14 there's nothing that has been done to it. That
15 means if I give you that file you can generate this
16 figure.
17 MR. TURK: Just for reference, Dr. Luk
18 is pointing out to page 34 of the report on which
19 Figure 17 and 18, particularly Figure 17 is
20 depicted.
21 THE WITNESS: Yeah. Because, you know,
22 we were thinking that if we did go through some
23 filtering, then I think similar questions would be
24 raised, what have we done to the original analysis
25 result. But this Figure 17 and Figure 18, those

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1 are the raw data.
2 MR. TURK: Without any change or
3 modification by you?
4 THE WITNESS: Correct.
5 Q. (By Ms. Nakahara) This is a naive
6 question. If you'll look at Figure 16 on page 33,
7 this figure illustrates various points in which you
8 show acceleration time histories, correct?
9 A. Yes.
10 Q. And it's --
11 MR. TURK: I'm sorry, Figure 16?
12 THE WITNESS: Yes.
13 Q. (By Ms. Nakahara) And your model
14 actually applies --
15 MR. TURK: Wait. You said it shows time
16 histories. It does not show time histories.
17 MS. NAKAHARA: Points.
18 MR. TURK: This shows different points.
19 Q. (By Ms. Nakahara) Points in which he
20 showed acceleration time histories elsewhere in the
21 report, but it does not imply that those are the
22 only points that you applied accelerations,
23 correct, or that experienced accelerations?
24 A. Okay.
25 Q. I'm not asking this very well, but

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1 basically you have a finite element model that
2 experiences the accelerations at a variety of
3 points in your model. And this is just for
4 illustrations for your time history plots?
5 A. This serve nothing more than try to
6 accomplish two things; to demonstrate the
7 significant effect due to the SSI. And second, is
8 there any amplification through the depth of the
9 soil foundations. So we pick a few points either
10 across the board on the free surface of the soil
11 foundations or at various depth of the soil
12 foundations.
13 And also, by the way, the results we
14 used to illustrate this true phenomenon has nothing
15 to do with the structural response, in term of
16 structural response of the cask in terms of its
17 translation and rotations because we did not go
18 through any averaging. We used a single node. And
19 as I say before, there is a danger if you -- if
20 people are focused to investigate the structural
21 risk points, people should never use the results at
22 a single node. But for demonstrated two effects
23 that we have in mind, this will serve the purpose.
24 MR. TURK: May I just ask for
25 clarification? Right now you're speaking about

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1 Figures 17 and 18 with respect to single points?
2 THE WITNESS: Yes, 17, 18 and 19.
3 MR. GAUKLER: So those are figures of
4 just a single node?
5 THE WITNESS: Yes. Because there was
6 also indicated on Figure 17, all those are the
7 single node points.
8 Q. (By Ms. Nakahara) Just to correct,
9 Figure 16 identifies the locations, correct?
10 A. Yes, yes.
11 Q. Dr. Luk, have you compared your results
12 in cask response with experimental data, such as
13 shake table data?
14 A. Can you substantiate a little bit?
15 Q. Have you constructed a physical model, a
16 physical model, experimental model that compares
17 the results in your computer model with the results
18 obtained in an experimental model?
19 MR. TURK: May I ask, are you asking if
20 he physically built a model and subjected it to a
21 shake test to see if it responded to the way he
22 predicted it would respond?
23 Q. (By Ms. Nakahara) Yes, that's a much
24 better question.
25 A. Within this project, no.

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1 Q. Have you constructed such a model with
2 respect to your other NRC cask -- analysis of
3 freestanding casks, such as at the Hatch plant or
4 San Inofre?
5 A. No. I would say as my last answer is
6 that I consider all the site-specific analysis as
7 well as the generic analysis. The whole effort is
8 within this project for us. Yes, we have not have
9 any physical models.
10 Q. Dr. Luk, how do you ensure that the soil
11 structure interaction motions of the soil
12 foundation are not masking the actual cask response
13 on top of the soil?
14 MR. GAUKLER: Repeat the question again.
15 (Pending question read.)
16 THE WITNESS: We know the SSI effect is
17 very important in this class of problems that
18 involve freestanding structures. That's the reason
19 why I went through the pain to identify the experts
20 in this area, okay? Mr. Lam has more than 20 years
21 of experience in performing soil structure
22 interaction calculations, okay? And also, once we
23 associated with the project and went through all
24 the detailed steps, we are very much aware of the
25 fact that we will not have any test data to

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1 validate our model. It's for that reason that we
2 actually go through the details to make sure that
3 all the procedures leading to the final execution
4 of the 3-D finite elements model we have done
5 everything we know how to make sure that we can
6 enhance the integrity and accuracy of the finite
7 elements results.
8 MS. NAKAHARA: If we can take a five
9 minute break, I may have no more questions.
10 (A recess was held.)
11 MS. NAKAHARA: Dr. Luk, thank you very
12 much. I have no further questions at this time.
13 THE WITNESS: Okay, thank you.
14 MS. NAKAHARA: I believe Mr. Gaukler has
15 some.
16 EXAMINATION
17 BY MR. GAUKLER:
18 Q. Good afternoon, Dr. Luk. I'm Paul
19 Gaukler, I'm counsel for Private Fuel Storage, the
20 applicant in the licensing proceedings. I just
21 have a few questions for you.
22 First of all, looking at your report
23 March 31, 2002 report, are Figures 17 -- 17, 18,
24 19, 20 through 22b, are they all for the 2,000-year
25 return period at PFS?

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1 A. Yes, sir.
2 Q. Now, you were talking about these are
3 figures for just various nodes as identified on the
4 figures themselves?
5 A. Yes.
6 Q. And the location of the nodes that's
7 given by Figure 16?
8 A. Yes.
9 Q. Now, I just want to clarify a couple of
10 the locations. Figure D' --
11 DR. SOLER: Point D'.
12 Q. (By Mr. Gaukler) Point D', that's at
13 the soil excuse me, that's at the pad and cement
14 soil interface, is it at the bottom of the pad or
15 the top of the cement-treated soil?
16 A. It's at the base of the pad, at the
17 interface between the pad and soil cement layers.
18 Q. Is that the interface between -- so
19 would it be a point on the bottom of the pad or a
20 point --
21 A. It's a point on the base of the pad.
22 Q. On the base of the pad as opposed to the
23 top of the cement-treated soil?
24 A. Yes.
25 Q. Now, if you look at Figures 7, 8, 9

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1 through Figure 15, these are data for the
2 free-field analysis results?
3 A. Yes. It's only applied to portion (c)
4 of all those data.
5 Q. It only applies to portion (c)?
6 A. Yes.
7 Q. So (c) is a figure of the free-field
8 analysis results from your running your program?
9 A. Yes.
10 MR. TURK: And just for clarification,
11 Dr. Luk, you're talking about on each page of the
12 report there's an (a), (b) and (c)?
13 THE WITNESS: Yes.
14 MR. TURK: You're looking at the charts
15 at the figure (c) on each page?
16 THE WITNESS: For all the figures from
17 Figure 7 through Figure 15, only the (c) portion of
18 all those figures are referred to as the time
19 history of the free-field analysis results.
20 Q. (By Mr. Gaukler) So basically if I look
21 at (a), figure (a) in each one of those is the
22 original time history input report?
23 A. Yes.
24 Q. (b) is the time history at the base of
25 the soil column?

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1 A. Yes.
2 Q. And then (c) is the results back up at
3 the surface from running your program?
4 A. Yes, yes.
5 Q. And then going back to Figure 16, what
6 is point A', point A' is the point at which you get
7 the results?
8 A. Point A' is exactly indicated, that's
9 the locations in Figure 16. It's a single node.
10 Q. Single node?
11 A. Yes.
12 Q. And that would correspond to the
13 free-field results, the node on which you had the
14 free-field results for your program?
15 A. Yes. We -- yes, yes.
16 Q. So in other words, if I look back at
17 these figures that we've talked about, Figure 7
18 through 15, if I look at --
19 A. Interesting point, they do not actually
20 represent the same results in the following sense.
21 I will -- if you don't mind I will repeat what I
22 said before, okay? All the figures related to the
23 locations as described in Figure 16 are using the
24 results at a single node on the model. And all the
25 part (c) results that has been included in Figures

1 7 through 15 actually go through an averaging
2 scheme. And averaging scheme is falling because
3 this results has everything to do with the
4 structural response.

5 As I say before, it's really important
6 to not use single points results if you are
7 involved in doing the structural response
8 evaluations. And the average scheme to come up
9 with the plots for part (c) in figures 7 through 15
10 is that if you look at the -- this is the top view
11 of the top of the coupled model. The outside -- if
12 you look at this from the top, the outside box will
13 represent the out of boundary of the soil
14 foundations. And then there's in the box also
15 rectangular in shape which represents the geometry
16 for the cask. Okay? And if you join corners from
17 the outside box to the inner box and take the mid
18 point, that will be one point and will go through
19 all four corners and go through the averaging of
20 all those four nodes. That is the results that we
21 include in figure (c) in Figure 7 through 15. And
22 that is actually the reason why most of the peaks
23 disappear because that is how -- is the well
24 accepted engineering practice when people try to go
25 through the evaluation of the finite elements

1 results in case people want to evaluate the
2 structural response.

3 Q. Thank you. Going back to Figure 17, if
4 I understood Figure 17, first of all, that was a --
5 those are accelerations at particular nodes that
6 are not averaged, correct?

7 A. Yes.

8 Q. Also, if I understood you correctly,
9 these figures are the result of the way you
10 calculated your damping of the soil; is that
11 correct?

12 A. Yes. We only use the single term mass
13 proportional damping in the model.

14 Q. And you didn't use the term for
15 stiffness in the damping in your models, is the way
16 I had understood you?

17 A. Yes.

18 Q. And because you didn't use the stiffness
19 in the damping for your model, you didn't damp out
20 higher frequency, is what I understood you to say?

21 A. Yes.

22 Q. And I take it further that if you had
23 put that term in your model you would have damped
24 out higher frequency or damped higher frequency?

25 A. Yes.

1 Q. And if you had put that term in the
2 model, what effect would that have had on, say,
3 Figure 17?

4 A. I think quite likely because we did go
5 through some sensitivity study that that may or may
6 not be explicitly implied to this case, but we went
7 through some evaluations to try to find out the
8 effect of -- or to compare the results of cases
9 using one term mass proportional damping versus the
10 case when both term -- both terms of damping are
11 involved. And yes, most of the high spikes that's
12 related to the single term case disappear.

13 Q. So you would expect for example this
14 point 4 D' that's approximately 2.9, you expect
15 that to disappear, that high spike at that point?

16 A. Yes.

17 MS. NAKAHARA: Do you mean disappear or
18 would be reduced?

19 THE WITNESS: Well, when I say -- maybe
20 I used a nonprofessional term, that it disappear.
21 That means the spike will actually have sizable
22 reduction in amplitude.

23 Q. (By Mr. Gaukler) And be up in the
24 nature of some of the other spikes that you see
25 higher up in the graph; is that correct?

1 A. Yes.

2 Q. You also were talking about filtering
3 certain frequencies, if you filter certain
4 frequencies you would get a certain effect. Is
5 that the same thing we're talking about now or is
6 that something different?

7 A. It's -- filtering with different cutoff
8 of frequency is an engineering practice procedure
9 if people are interested in some peculiar portion
10 of the structural response. For example, if people
11 are trying to evaluate more or less related to the
12 rigid body dynamics for some problem, you probably
13 want to eliminate all the high frequency content
14 portion of the results. And then you go through a
15 specific filtering scheme with prescribed cutoff
16 frequency.

17 Q. And if you were to filter the values in
18 Figure 17, what frequency would you filter that if
19 you were interested in, like you said, the
20 structural response?

21 A. Well, I think if you don't mind me go
22 back, if we are interest in using some results like
23 this in evaluating the structural response, we
24 would not use point results. I have to apologize I
25 keep on repeating the same message. If people

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1 interest in evaluating structural response you
2 never use the single node results. That means I
3 will never go through that.
4 Q. Good enough.
5 A. Okay. That is actually the reason why I
6 think in Figure 20, 20a that we did not actually
7 apply the filtering because it's not good
8 engineering practice that we lost sight that we're
9 going to go through the filtering with the single
10 node result.
11 Q. You would do the averaging and then if
12 you felt any filtering was appropriate you would do
13 the filtering after you had done your averaging?
14 A. Yes.
15 MR. TURK: Excuse me one second.
16 (Discussion held off the record.)
17 MR. TURK: For clarification, may I ask,
18 does that mean that figures -- I believe you're
19 talking about Figure 20a?
20 THE WITNESS: Yes. 20a, b, 21a, b, 22a,
21 b.
22 MR. TURK: Do those have any filtering
23 in them?
24 THE WITNESS: No.
25 Q. (By Mr. Gaukler) Dr. Luk, in addition

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1 to running the cases for the 2,000 and 10,000-year
2 earthquakes for the PFSF site, you also ran the
3 case for the 1971 Pacoima Dam, correct?
4 A. Yes.
5 Q. And what information did you gain from
6 that run that -- well, strike that. What
7 additional information did that run provide you in
8 terms of evaluating the cask response for the PFSF
9 site?
10 A. Since we went through the study to look
11 at the dynamic characteristics of the time history
12 of the seismic accelerations for both 2,000-year
13 return seismic event as well as the 1971 San
14 Fernando earthquake Pacoima Dam record, the results
15 from executing the seismic analysis based on the
16 1971 San Fernando earthquake, the Pacoima Dam
17 record, indicates that the results actually
18 confirmed the analysis results that we got by using
19 the 2,000-years return seismic.
20 Q. So you used a different time history for
21 one thing and confirmed the results?
22 A. But it's more important, there is a
23 difference between the two seismic inputs. The
24 1971 San Fernando earthquake/Pacoima Dam record is
25 an actual seismic event and the other, the

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1 2,000-years return seismic, is an artificial one.
2 So we actually used a actual earthquake record to
3 confirm the results that we got for an artificial
4 seismic event.
5 Q. Now, you're saying the 2,000 and 10,000
6 year are artificial. In what sense do you mean
7 artificial?
8 A. Artificial means there is
9 well-established procedures' criteria come up with
10 those artificial seismic -- seismic-related
11 response spectra as well as the time histories of
12 seismic acceleration. That means it's more or less
13 going through a vigorous mathematical model.
14 Q. To produce them?
15 A. Yes.
16 Q. In accordance with the requirements of
17 the guidance of the Standard Review Plan?
18 A. Yes.
19 Q. You also mentioned that you did --
20 strike that. You stated that you modeled the soil
21 cement around the pads, around the concrete pad?
22 A. Yes. I would like to make reference to
23 one of the figures in the drawing -- I mean in the
24 report which is actually Figure 6 on page 17. The
25 answer to your question is is that we model soil

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1 cement layers adjacent to the concrete pad as well
2 as underneath the pad.
3 Q. And in modeling the soil cement layers
4 adjacent to the pad, you modeled the interaction
5 between the pads and the soil cement during the
6 earthquake?
7 A. If you'll refer to the vertical boundary
8 between the soil cement layer and the concrete
9 pads.
10 Q. Yes.
11 A. We did not come up -- we did not
12 incorporate interface at the vertical boundary
13 between this two structural sub elements.
14 Q. And what do you mean --
15 MR. TURK: I'm sorry, are you going to
16 ask?
17 Q. (By Mr. Gaukler) I was going to ask
18 what you mean by not including the interface there.
19 A. We just have the -- okay. We have a
20 boundary between the vertical wall of the concrete
21 pad and the soil cement layer.
22 MR. TURK: Adjacent to it.
23 THE WITNESS: Right.
24 MR. TURK: In the horizontal direction?
25 THE WITNESS: Also in the vertical