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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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

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 ✓ IDENTIFIED ✓

Applicant ______ RECEIVED ✓

Intervenor ______ REJECTED ______

Other ______ WITHDRAWN ______

DATE 5/9/02 Witness ______

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CitiCourt, LLC
THE REPORTING GROUP

50 South Main, Suite 920
Salt Lake City, Utah 84144

801.532.3441 TOLL FREE 877.532.3441 FAX 801.532.3414

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

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

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

related to the stiffness proportional damping. It is the choice by the analyst, and for this case it is us, that we can use a parameter that incorporates both terms of the damping. But we went through extensive study on the sensitivity, mainly because when we used damping in combination of the two terms, it is going to cause severe penalty computational time. Mainly it will double the computational time that is required.

So now we are going to investigate the options. And one of the options that has been our practice a lot of time is that we try to find out if we just use the first term, which is the mass proportional damping, how much inaccuracy are we inducing in the analysis results? And in our sensitivity study, it indicated by just using one term, which is mass proportional damping, the structural response would basically remain the same as for the case when we used the two-term damping. The only thing that is missing in using the one term mass proportional damping case is that the high frequency response would probably show up and would not be able to damp out.

So in that regard, in my conclusion of the analysis methodology, we said by using one term

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mass proportional damping, we actually underdamped the structural system. So in essence, for the structural response that we are considering for the cask, the accuracy is not much affected at all, if any, by the omission of the stiffness related damping. That's what I said here.
Q. Okay.
A. And that's also the reasons why we choose not to use the stiffness proportional damping.
Q. If you will turn the page to Page 10.
A. Yes.
Q. Will you explain the basis for selecting your damping ratios in each layer for Table 2?
A. Okay. The answer to your question is -- actually, if you go back to Page 9. We did try to go through that starting in subsection 3.4.1. It actually started in the second sentence. I'm sorry. It actually started in the first sentence. "The damping ratio in terms of percentage is the material damping from the free field site response analysis using the shaked program reflecting the strength dependent soil properties for the specific soil layer." And it continues.
Q. How did you derive your properties for

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the soil profile in Table 2? Were those provided -- for example, the Young's modulus, were those provided to you in information from Dr. Shah?
A. Yes. All those like Young's modulus, ratio density, they were given to me by Professor Shah, or by Dr. Shah.
Q. Are you familiar with the term "contact stiffness", as in reference to the contact stiffness between the bottom of the cask and the top of the concrete pad?
A. Would you like to qualify your question a little bit? Of course I have heard of the term, but --
Q. Did you use contact stiffness as an input into your model?
A. No.
Q. Did your analysis assume that the pad would remain horizontal or did your analysis allow the pad to move with the ground motion?
A. The cask is free to move in whichever way it will supposed to go through. The whole dynamic behavior is actually governed by the equations of state and the constitutive relations as incorporated in the ABAQUS finite elements code.
MR. TURK: Could you read the answer?

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(The record was read as follows:
"A. The cask is free to move in whichever way it will supposed to go through. The whole dynamic behavior is actually governed by the equations of state and the constitutive relations as incorporated in the ABAQUS finite elements code.")
Q. Is the pad free to move also in the model?
A. Yes.
Q. Did you account for the natural frequency of the pad vibrations in your model? You don't understand my question.
Did you plot the acceleration time history in the vertical direction from soil cement interaction effects at D prime, if you look on Page 33?
A. Yes.
Q. And if you can find it, can you point --
A. It's on the following page, isn't it? Page 34. So I don't want to ask the question again, but that's the question. You refer to the accelerations at the D prime locations?
Q. In vertical -- is it the vertical direction, or are these in the horizontal

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direction?
A. This is in the horizontal directions. We did not plot the time history in the vertical directions.
Q. In your opinion, what would you expect if you had plotted it in the vertical direction, if you can render an opinion?
A. Probably not, because the model is highly nonlinear and the results are also highly nonlinear and it is also very dynamic. Anyway, to speculate the results would probably degrade the quality of the analysis results.
Q. Can you determine the frequency of response of the pads in the vertical direction?
MR. TURK: Could I hear the question again?
(The record was read as follows:
"Q. Can you determine the frequency of response of the pads in the vertical direction?")
MR. TURK: I object. Are you asking can he determine it independently or are you asking can you determine it from looking at his report?
Q. From your report. Can you point to somewhere?

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

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

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

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

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Q. Yes, please.
A. Because it will directly answer your question. Two things. One is that, as I described earlier, that we only used one turn, which is the mass proportional damping in our three-dimensional coupled finite element method. So in that regard we know some of the high peak will not be able to damp out because that's by very nature of the input that we omit the stiffness proportional damping.
In that regard, if you look at the Figure 17, we know the green plots, which is actually the free field point, free field locations on the free field surface which is actually A', there is actually for some in just a little bit more than five seconds for the green, there's a plot of 1.34. And we know in reality for the free field behavior on top of the soil foundation the G value is only of the order like .7.
What that simply indicated to us is that simply because this is unfiltered raw data directly from the analysis that some of you think that we actually expect to show up in the raw data, it did show up. So what this simply mean is that if you look at the high G value for the A', that 1.34 G at that time is not real. But the whole purpose of

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the Figure 17 is to demonstrate whether there's SSI effect and if it does have the effect, how significant are they, okay? And is also by intention we did not go through the filtering because we want to see the SSI effect is important in this class of problems.
MR. GAUKLER: You did not go through what?
THE WITNESS: We did not go through the filtering to use a different frequency level because in that sense you can actually filter out all the nonessential things. Essential only to the structure of the response is important. And also in that regard, when you look at the G value response with respect to the point D, which is at the center of the pad at the base of it, the G value is as high as 2.95. But that's by the same nature as unfiltered raw data, does not real indicated that anything more than we try to show there is an amplification by the pure presence of the structure on top of the soil foundations.
MR. TURK: You said point D. Did you mean point D'?
THE WITNESS: Yes, I'm sorry, point D'. And is also in the light of this, Figure 20a is

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derived directly -- Figure 20a is the response spectra obtained directly from the raw data from Figure 17. And that's actually for that regard, we know all the high frequency response will show up. But again, the intent of the whole exercise in this area is to demonstrate there is a significant contribution to the dynamic behavior of the cask with regard to the SSI effect.
And also, if you don't mind me to elaborate a little bit more, there's always the danger when people do finite element calculations, if people's interest are focused on the structural response, it is very dangerous to pick values from a single node. A single node, a node is a point in a finite elements mesh grid because the very nature of the nonlinear dynamic behavior will have peaks at various isolated locations, but that's not the intent that we try to demonstrate here. We just want to pick one node at the free surface of the soil foundation and compare with one locations that is at the center of the pad base and try to find out is there any difference. And the answer is yes, there's significant differences.
Also, can I substantiate a little bit because I feel, okay, if people's focus is actually

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try to get the structural response from the finite elements results, for example, you have to go through some kind of averaging, okay? Mainly try to reduce the certain peaks happen in any node because structural behavior is very -- is quite different from the mathematical models, and the only way to have a structure to respond in appropriate manner within the principle of physics is that if you try to go through some averaging.
Q. (By Ms. Nakahara) Do you have an opinion on what the average amplification of the free field ground motion would be from soil structure interaction effects?
A. **Can you repeat the question?**
Q. Would you read it?
(Pending question read.)
THE WITNESS: From the way that the analysis results indicated to us, anyway, the range of the amplification due to the SSI effect on the base of the pad changes from locations on the pad, but I think that it ranges from 20 percent and maybe up to 45 percent. But that's location dependent.
Q. (By Ms. Nakahara) It's location dependent. Can you expand on that? For example,

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where would approximately a 20 percent amplification occur?

A. Well, that, those sets of values also dependent on the input of the time history of the seismic accelerations, but I think for here, I think the -- I want to make reference to the plots that we actually have this things in mind is to look at, for example, the locations C and D on Figure 16 and the results actually show up in Figure 18 on page 34. If you compare the actual pad to the center of the pad you more or less will be able to get some range of variations because they do represent the other two extreme. And also because of the dynamic nature of the phenomena the amplification is also a function of time. So in that regard it's very difficult to answer your question with just a value because that is actually the reason why we plot out a time history so people will have a better understanding of this.

MS. NAKAHARA: Just to clarify, Sherwin, we have the electronic histories that are plotted out here, correct?

MR. TURK: I gave you a disk with the input type histories.

MS. NAKAHARA: Not with the output?

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MR. TURK: As we discussed before, those outputs would be massive. We don't have them ourselves. They don't have a copy of those. We would have to run the computer to generate them for you.

MS. NAKAHARA: But he has already plotted these?

THE WITNESS: Maybe off the record.

MS. NAKAHARA: Off the record.

(Discussion held off the record.)

THE WITNESS: For that, back on the record, that was the purpose for us to -- we submit the input file to NRC and if it is choice of anyone, you get hold of the input file and execute the model yourself and get the output. For us to repeat any run, of course it's possible, but then it will be cumbersome to submit the output file because it's as large as 2.5 gigabytes.

MR. TURK: Just for point of reference, how many pages would it take to print out?

THE WITNESS: I don't think anyone going to actually want to print out.

MR. TURK: We're talking many thousands of pages?

THE WITNESS: I have no idea. Nobody

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has ever tried to get an output like that because all those are just pure numbers, do not have any sense.

MR. TURK: You're talking about a finite element analysis in which thousands of loci, individual locust points are plotted.

MS. NAKAHARA: I understand that.

MR. TURK: And then you're looking for a microsecond for each locust point. You're talking about a vast amount of information.

Q. (By Ms. Nakahara) He's already plotted these histories. You don't have a electronic file of, for example, Figure 17?

A. Yes, we have that. But I don't have it here.

Q. And how large of a file would that be?

A. Well, it -- for that is very small because we literally convert this to the work format. What that simply mean is that the file size is very small. And as a matter of fact, the only reason why I say that is that I submit the whole report electronically to NRC and you actually have that. That means if that's all you want is to have electronic copy of the plots, you have it.

DR. SOLER: She wants the data that went

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in the plot, you know, time, X1, X2, X3, that's what they want.

THE WITNESS: Okay. I think for that, you actually -- well, first, I don't have it here, and if you actually want, I think we have to rerun the case and then take that piece of information explicitly out and then look at it.

Q. (By Ms. Nakahara) So you don't have it stored somewhere, you would have to rerun the model to obtain it; is that correct?

A. Yes, yes. But this is the importance of the -- well, maybe that is the whole reason for a plot like this. We plot the raw data. That means there's nothing that has been done to it. That means if I give you that file you can generate this figure.

MR. TURK: Just for reference, Dr. Luk is pointing out to page 34 of the report on which Figure 17 and 18, particularly Figure 17 is depicted.

THE WITNESS: Yeah. Because, you know, we were thinking that if we did go through some filtering, then I think similar questions would be raised, what have we done to the original analysis result. But this Figure 17 and Figure 18, those

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are the raw data.
MR. TURK: Without any change or modification by you?
THE WITNESS: Correct.
Q. (By Ms. Nakahara) This is a naive question. If you'll look at Figure 16 on page 33, this figure illustrates various points in which you show acceleration time histories, correct?
A. Yes.
Q. And it's --
MR. TURK: I'm sorry, Figure 16?
THE WITNESS: Yes.
Q. (By Ms. Nakahara) And your model actually applies --
MR. TURK: Wait. You said it shows time histories. It does not show time histories.
MS. NAKAHARA: Points.
MR. TURK: This shows different points.
Q. (By Ms. Nakahara) Points in which he showed acceleration time histories elsewhere in the report, but it does not imply that those are the only points that you applied accelerations, correct, or that experienced accelerations?
A. Okay.
Q. I'm not asking this very well, but

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

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

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

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validate our model. It's for that reason that we actually go through the details to make sure that all the procedures leading to the final execution of the 3-D finite elements model we have done everything we know how to make sure that we can enhance the integrity and accuracy of the finite elements results.
MS. NAKAHARA: If we can take a five minute break, I may have no more questions.
(A recess was held.)
MS. NAKAHARA: Dr. Luk, thank you very much. I have no further questions at this time.
THE WITNESS: Okay, thank you.
MS. NAKAHARA: I believe Mr. Gaukler has some.

EXAMINATION

BY MR. GAUKLER:
Q. Good afternoon, Dr. Luk. I'm Paul Gaukler, I'm counsel for Private Fuel Storage, the applicant in the licensing proceedings. I just have a few questions for you.
First of all, looking at your report March 31, 2002 report, are Figures 17 -- 17, 18, 19, 20 through 22b, are they all for the 2,000-year return period at PFS?

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A. Yes, sir.
Q. Now, you were talking about these are figures for just various nodes as identified on the figures themselves?
A. Yes.
Q. And the location of the nodes that's given by Figure 16?
A. Yes.
Q. Now, I just want to clarify a couple of the locations. Figure D' --
DR. SOLER: Point D'.
Q. (By Mr. Gaukler) Point D', that's at the soil excuse me, that's at the pad and cement soil interface, is it at the bottom of the pad or the top of the cement-treated soil?
A. **It's at the base of the pad, at the interface between the pad and soil cement layers.**
Q. Is that the interface between -- so would it be a point on the bottom of the pad or a point --
A. **It's a point on the base of the pad.**
Q. On the base of the pad as opposed to the top of the cement-treated soil?
A. Yes.
Q. Now, if you look at Figures 7, 8, 9

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through Figure 15, these are data for the free-field analysis results?
A. **Yes. It's only applied to portion (c) of all those data.**
Q. It only applies to portion (c)?
A. Yes.
Q. So (c) is a figure of the free-field analysis results from your running your program?
A. Yes.
MR. TURK: And just for clarification, Dr. Luk, you're talking about on each page of the report there's an (a), (b) and (c)?
THE WITNESS: Yes.
MR. TURK: You're looking at the charts at the figure (c) on each page?
THE WITNESS: For all the figures from Figure 7 through Figure 15, only the (c) portion of all those figures are referred to as the time history of the free-field analysis results.
Q. (By Mr. Gaukler) So basically if I look at (a), figure (a) in each one of those is the original time history input report?
A. Yes.
Q. (b) is the time history at the base of the soil column?

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

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

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

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results in case people want to evaluate the structural response.

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

A. Yes.

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

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

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

A. Yes.

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

A. Yes.

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

A. Yes.

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

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

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

A. Yes.

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

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

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

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A. Yes.

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

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

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

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

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

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

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

cement layers adjacent to the concrete pad as well as underneath the pad.
Q. And in modeling the soil cement layers adjacent to the pad, you modeled the interaction between the pads and the soil cement during the earthquake?
A. If you'll refer to the vertical boundary between the soil cement layer and the concrete pads.
Q. Yes.
A. We did not come up -- we did not incorporate interface at the vertical boundary between this two structural sub elements.
Q. And what do you mean --
MR. TURK: I'm sorry, are you going to ask?
Q. (By Mr. Gaukler) I was going to ask what you mean by not including the interface there.
A. We just have the -- okay. We have a boundary between the vertical wall of the concrete pad and the soil cement layer.
MR. TURK: Adjacent to it.
THE WITNESS: Right.
MR. TURK: In the horizontal direction?
THE WITNESS: Also in the vertical