June 7, 2002

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
PRIVATE FUEL STORAGE L.L.C.	)	Docket No. 72-22
	)	
(Private Fuel Storage Facility)	)	ASLBP No. 97-732-02-ISFSI

REBUTTAL TESTIMONY OF WEN S. TSENG ON SECTION D OF UNIFIED CONTENTION UTAH L/QQ

I. REBUTTAL TO TESTIMONY OF STATE OF UTAH WITNESS DR. FARHANG OSTADAN

Q1. In his answer to questions 25, 26 and 31 in the "State of Utah Testimony of Dr. Steven F. Bartlett and Dr. Farhang Ostadan on Unified Contention Utah L/QQ (Dynamic Analyses)" ("Bartlett/Ostadan Direct Testimony"), and in his oral testimony at the May 8, 2002 hearing (Tr. 7455-7472), Dr. Ostadan raises the concern that PFS incorrectly assumes that the reinforced concrete pads upon which the storage casks rest behave rigidly under earthquake loadings. Dr. Ostadan disputes the validity of this assumption, claiming that there is evidence that the pads exhibit significant flexibility under seismic loadings. What is your response to Dr. Ostadan's claim?

A1. PFS has demonstrated using the methodology in a recognized industry technical paper by Iguchi and Luco that the effect of flexibility on the foundation stiffness and damping properties of the pad is insignificant in the frequency range of importance to the cask response. The calculation that demonstrates this result is included in the record as PFS Exhibit MM. In addition, as discussed in my testimony, an analysis of the maximum dynamic displacement of the pad in the vertical direction as computed by ICEC at various nodes on the pad (these are reported in Table D-1(d) at page 234 of the ICEC Calculation G(PO17)-2, Rev. 3) shows that the maximum local deformation of the pad for the nine cases shown on Table D-1(d) is on the order of 0.01 ft, or approximately 1/8 of an inch. Such a small local displacement would produce only secondary effects on the global dynamic response of the system.

Q2. In his oral testimony at the May 8 and May 9, 2002 hearings, Dr. Ostadan disagreed with your conclusion that a maximum pad deformation of 1/8 of an inch establishes pad rigidity for global dynamic response purposes. Dr. Ostadan testified (Tr. 7464-7470) that what is significant is not so much the amplitude of the displacement but the relative motion of various points on a pad with respect to each other, so that if you effectively have a rippling effect of the pad, this will tend to decrease the radiation damping available from the pad. Do you agree with Dr. Ostadan's position?

A2. No. The results of ICEC calculation G (PO17)-2, Rev. 3, which include the effect of pad flexibility, indicate that there is generally only one-half of a wave length, or ripple, in the pad's vertical deflection over the length of the pad. Therefore, there are not multiple "ripples" in the pad vertical displacement. Furthermore, as explained in the response to the previous question, the PFS assessment using the published results of Iguchi and Luco (PFS Exhibit MM) demonstrates that pad flexibility has a relatively insignificant effects on the pad foundation stiffness and radiation damping for the frequency range important to the cask response.

Q3. What is the basis for your conclusion that, contrary to Dr. Ostadan's contention, there will be no deformation ripples" in the pad that will cause it to behave as a flexible, rather than a rigid body?

A3. PFS Exhibit 227 demonstrates that Dr. Ostadan's contention is incorrect. The exhibit is an electronic message from PFS counsel to counsel for the State dated April 28, 2002 and a three-page attachment prepared under my supervision. As described in the e-mail, the attachment consists of a Figure 1, which is a model of a cask storage pad showing node points and the two sections selected for plotting pad displacements; a Figure 2, which shows a plot of dynamic vertical response displacements at 5.285 seconds of the pad along the longitudinal section; and a Figure 3, which shows a plot of dynamic vertical response displacements of the pad at 5.285 seconds along the transverse section. These two plots show the maximum local deformation observed for the pad for the asymmetrical loading of two casks.

Figure 2 of the Exhibit plots vertical displacements on the vertical axis against location at various points on the pad in the long direction of the pad, identified in feet and by node number, with the "Node 7" on the left corresponding to the middle lower edge of the pad and "Node 293" corresponding to the upper middle edge. This plot shows that the maximum pad displacement is about minus 0.01 foot, or about $1/8^{th}$ of an inch, and it occurs at about 52 feet from the lower edge of the pad, or 18 feet from the upper edge. This location is between nodes 253 and 255 on the grid, and as expected is the location where the dynamic loadings act on the two casks.

The plot shows that, at time 5.285 seconds, the displacement along the pad is virtually zero for roughly the left half of the pad and then there is one slowly changing set of displacements starting at about 35 feet off the lower edge of the pad , achieving a maximum at 52 feet or so, and then returning to almost zero at the other edge of the pad.

Q4. What is the significance of these results?

A4. These results show that there is a small displacement of the pad at the point of application of the seismic loadings, which then slowly decreases as you move away from the point of application of the force. There are no multiple "ripples" of the type postulated by Dr. Ostadan. In fact, this plot shows that only one-half of a ripple (wave-length) is present in the dynamic vertical displacement due to pad flexibility.

Q5. Would you turn to Figure 3 of Exhibit 227 and indicate what it means?

A5. That figure represents the vertical displacements against location in the pad along the centerline of the casks in the short direction of the pad, going from Node 248 at the edge of the cask on top of the page to node 260. The vertical downward displacements on the pad shown in this plot increase linearly from 0 on Node 248 to a little less than minus (downward) 0.02 feet on Node 260. Such a smooth and near linear increase in vertical displacement demonstrate near rigid vertical motion of the pad in the short direction of the pad.

Q6. In answer 28 of the Bartlett/Ostadan Direct Testimony, Dr. Ostadan testifies that a critical shortcoming in the ICEC pad design calculation is that ICEC obtained the dynamic forces acting on the pad from the Holtec Report HI-2012640. At the May 8, 2002 hearing (Tr. 7532), Dr. Ostadan further testified that ICEC analysis does not include the inertial seismic loading on the pad, which should have been provided by Holtec. As a result, Dr. Ostadan asserts, ICEC used .7g times the weight of the pad to compute that loading, a procedure that probably underestimated the pad accelerations. Are these criticisms valid?

A6. No. For purposes of structural design of the pad, the earthquake inertial loading on the pad itself is insignificant. For a pad of constant thickness, such as the PFSF pads, the earthquake inertial loading is uniformly distributed and produces no in-plane stresses and very insignificant out-of-plane bending stresses in the pad. Therefore, for the pad's structural design purpose, the earthquake inertial loading on the pad itself has very little influence on the pad design and, thus, is not a significant loading parameter. The earthquake inertial load on the pad does increases the soil shearing and bearing stresses but this inertial loading has been explicitly included when checking the pad's sliding and overturning stability.

Q7. In answer 31 of the Bartlett/Ostadan Direct Testimony, Dr. Ostadan testifies that "The horizontal reaction forces are reported in the ICEC calculation. By dividing the reaction forces by the weight of the casks and the pad, one can clearly observe the effective acceleration experienced by the cask and the pad system. This acceleration is less than 0.60 g. This is for the case where 8 casks are placed on a pad with a coefficient of friction of 0.8. The effective acceleration is less than the peak ground acceleration and is clearly much less than the design motion at the natural frequency of the system. This simple calculation shows that the dynamic loads given to ICEC for the design of the pad are deficient and do not represent the total dynamic load of the cask and the pad." At the hearing, Dr. Ostadan clarified at Tr. 7537 that the table to which he referred in his direct testimony was Table D-1(a) of Calculation G(PO17)-2, Rev. 3. Is the calculation performed by Dr. Ostadan correct?

A7. No. Dr. Ostadan sought to compute the effective acceleration experienced by the cask and the pad system by dividing the average horizontal reaction force on the casks and pad due to dynamic loading shown as Qxd in Table D-1(a) as having a value of 2212 kips by the combined weight of the eight casks and the pad. That computation yields an acceleration of 2212/(2880+950) = 0.59.

Dr. Ostadan's calculation, however, is incorrect. The maximum dynamic soil reactions presented in Tables D-1(a) through D-1(d) of Calculation G(PO17)-2, Rev. 3, include only the effects of cask dynamic loadings acting on the pad, as provided by Holtec and do <u>not</u> include the inertial loadings of the pad. Therefore, in order to account for the total seismic effect on soil reactions beneath the pad, the inertial load of the pad needs to be added to the dynamic soil reactions provided in the above mentioned tables. The horizontal inertial loading on the pad, based on pad maximum acceleration equal to the maximum horizontal ground acceleration of 0.7g, is 630 kips (= 0.7g x 905 where 905 is the weight of the concrete pad). Thus, the numerator of Dr. Ostadan's calculation should be (2,212+630) = 2,842 kips, and the effective horizontal acceleration is 0.75g (2,842/ (2,880+905), where 2,880 is the weight of the 8 casks on top of the pad and 905 is the weight of the concrete pad. Such an acceleration is reasonable considering that the casks on top of the pad, for the case of high cask/pad friction coefficient, will start tipping due to rocking at a cask response acceleration of 0.57g (= 1.0g gravity × one-half diameter of cask (132.5/2 = 66.25 inches) / height of center of gravity of cask (231.25/2=115.625 inches)). Thus, for the case of cask/pad friction coefficient greater than 0.57, the casks will tip but not slide. Tipping results in lower horizontal seismic inertial loading on the pad from the casks. For the case of a cask/pad friction coefficient lower than 0.57, the casks will not tip but will slide at a lower acceleration value equal to the cask/pad friction coefficient value.

Q8. In answer 33 in the Bartlett/Ostadan Direct Testimony Dr. Ostadan contends that Holtec failed to assure itself that it selected appropriate soil spring and damping values for the analysis of the pad and cask movement. In his oral testimony at the May 9, 2002 hearing (Tr. 7565-7587) Dr. Ostadan summarized his concern by saying at Tr. 7576 that Holtec has not demonstrated that the values of soil spring and damping it used represent the peak values at the natural frequency of the pad. Does the concern raised by Dr. Ostadan present a significant problem?

A8. No. Because of the non-linear seismic response of the casks, which requires non-linear time history analyses, approximate but appropriate frequency-independent (constant) soil spring and damping values have to be used. Selection of those values can be accomplished by several methods. One method is to select the values from the frequency-dependent impedance functions that correspond to the fundamental natural frequency of the cask/pad/soil coupled system (as suggested by Dr. Ostadan). Use of this method requires knowing the system frequency beforehand. Due to the non-linear response of the casks caused by sliding and tipping, the system's natural frequencies are not unique and are amplitude dependent. Therefore, the iterative solution suggested by Dr. Ostadan may not work.

The method used by Holtec in its analysis was to select the soil mass, spring and damping parameters using formulae published in a well-recognized technical treatise, Newmark, N. M., and Rosenblueth, E., **Fundamentals of Earthquake Engineering,** Prentice-Hall, Inc., Englewood Cliffs, N.J., 1971. The combination of soil mass and spring parameters produces approximate frequency-dependent foundation impedance functions that cover the frequency range important to the cask response. Use of this method, coupled with the use of three sets of soil properties (best estimate, lower bound, and upper bound) ensures that a sufficiently large range of frequencies of the cask/pad/soil system is considered.

Furthermore, the analyses performed by Holtec have demonstrated that, despite the large variations of soil parameters used and the performance of analyses in which the soil spring values were deliberately adjusted to "tune" them to the frequency of the peak of the design response spectrum and the damping value was set to an artificially low value of 1%, there are sufficient margins to maintain the sliding and tipping response of the casks within acceptable levels. Such margins have been further confirmed by the analyses performed by the Sandia National Laboratories for the NRC, which did not use soil springs and dampers, but represented the soil by a detailed finite element model.

Q9. Does this conclude your testimony?

A9. Yes.

MR. GAUKLER: Dr. Tseng in his rebuttal testimony refers to an exhibit, PFS Exhibit 227, which I think is self-explanatory in terms of the testimony in the document itself. I would move for the admission of that exhibit into evidence.

JUDGE FARRAR: What is that exhibit?

MR. GAUKLER: It's a --

JUDGE FARRAR: It's an e-mail that's attached?

MR. GAUKLER: Yeah. It's an e-mail from me to Ms. Chancellor forwarding some information from Dr. Tseng.

JUDGE FARRAR: And you want that marked as what?

MR. GAUKLER: PFS Exhibit 227. I think the court reporter's already marked it.

(APPLICANT'S EXHIBIT 227 MARKED.)

JUDGE FARRAR: And now you're moving its admission?

MR. GAUKLER: Yes.

JUDGE FARRAR: State, any objection?

MS. NAKAHARA: No objection, your Honor.

JUDGE FARRAR: Staff?

MR. TURK: No objection, one question. This will not be bound into the record but simply put in the exhibit file?

JUDGE FARRAR: Right. This is an exhibit.

(APPLICANT'S EXHIBIT 227 WAS ADMITTED.)

MR. GAUKLER: I have two very brief additional rebuttal questions.

Q. (By Mr. Gaukler) Dr. Tseng, you were here yesterday when Dr. Ostadan was discussing the Luk report and Figure 20B of the Luk report. Do you have that?

A. Yes.

Q. Will you take a look at that very briefly, page 36.

A. Yes.

Q. You heard Dr. Ostadan say with respect to this Figure 20B that with respect to the 6 g's at 5 Hz that the casks would see this sitting on the pad. Do you agree with that statement?

A. Well, the 6g's shown on this Figure is certainly rigorous acceleration spectral value of approximately 22 seconds. That's what we were referring to. And as I understand it, response spectral value is the value of a single degree of freedom subject to the motion that have been calculated. So it is a response of the single degree of freedom at the damping which was calculated for this response spectra. Now, the damping calculated for this response spectra is not labeled here, so we do not know what kind of damping value for that single degree of freedom.

Q. And single degree of freedom means that you have a mass attached to a spring?

A. Yes. This is a linear yardstick system with one single mass, single linear spring with certain damping value which we are now missing here.

Q. So the only way the cask would see that response is if it were anchored to the pad?

A. It's generally a way of characterizing motion, but -- frequency contents of the motion, but it is not necessarily reflected in the response of the casks.

Q. You are aware that later in this proceeding we will be introducing rebuttal testimony of Mr. Paul Trudeau where he says that a reasonable long-term estimate of the pad might be something on the order of long-term settlement -- long-term static settlement of the pad would be on the order of a half inch. Is that your understanding?

A. Yes, I understand that was the case.

Q. And assuming that to be the case, what type of impact would that have on the dynamic motion of the pad, that long-term -- a long-term static settlement of approximately a half inch?

A. I do not see, unless the settlement change any of the soil properties, I do not see any effect on the dynamic motion of the pad.

MR. GAUKLER: That's all I have.

JUDGE FARRAR: Staff?

MR. TURK: Yes, your Honor.

CROSS-EXAMINATION

BY MR. TURK:

Q. Let me start with the series of rebuttal questions that Mr. Gaukler just asked you. Looking at Figure 20B of Dr. Luk's report.

A. Yes.

Q. You describe this as a single degree of freedom, that this portrays a single degree of freedom. For the record, could you explain what that term means?

A. It's a single mass attached with a single linear spring with a damper attached to it which provide the damping for a single degree of freedom. Generally characterizes certain fraction of critical damping, and generally they're 1 percent damping ratio, 2 percent damping ratio, et cetera.

The frequency of a single degree of freedom is the horizontal axis thought as a period which is 1 over the frequency. So if it's 1, 2 second would then mean 5 Hz frequency of the single degree of freedom.

Q. And it's not a time history. Do you know where the time history -- do you know if there is a time history input to this chart?

A. That's correct.

Q. And is that correct that that would be Figure 17 that provides the time histories for it?

A. So far the label is center point B prime, and the time history on Figure 17 label is center of pad point D. That would mean the time history.

Q. So you would agree that because the time histories in Figure 17 are unfiltered and reflect only a single term of damping, that it's the values from Figure 17 that then went into plotting out what you see in Figure 20B? Is that consistent with your understanding?

A. My understanding, of course, is using the time history in Figure 17, and with a single degree of freedom prescribed a certain damping ratio, then you could plot, calculate and plot the response spectra value on Figure 20B. The empirical nature of the time history is quite clear from the response spectra, the very short period range is very high spectral value.

Q. I'd like to turn to your written testimony.

A. Yes.

Q. On page 3 of your testimony in the last paragraph of answer 3 --

A. Yes.

Q. -- you indicate that displacement along the pad is virtually zero for roughly the left half of the pad and then there is one slowly changing of displacements, and it goes on. Can we tell from the documents you've submitted what the maximum amount of displacement is?

A. From that Exhibit 227, they plot, we can identify that to be of the order of .01 feet, which amounts to about one eighth of an inch.

Q. Now, also answer 7, at the end of the last paragraph, this appears at the top of page 5, there's a discussion that indicates that acceleration will "start tipping due to rocking and a cask response acceleration of 0.57 g." Do you see that?

A. Yes, I do.

Q. When you say "start tipping," do you mean starting to tip over?

A. No, not tip over. Start to have -- through the base start to have zero compression in the wave.

Q. Start to rotate off --

A. To start to --

Q. Off its vertical axis?

A. Yeah, of the pad, yeah, on one end.

Q. And the same, later in that paragraph I see the word "tip" and "tipping" again. That's the same sense in which you used the word "tipping"?

A. That's correct.

Q. In answer 8 at the end of the first paragraph -- well, in that paragraph you discuss the concern expressed by Dr. Ostadan as to the need to describe the soil springs and damping. In Dr. Luk's analysis, as you understand it, are soil springs and damping utilized?

A. As I understand, it is a representation of the soils.

Q. So that does not include springs and dampers?

A. Not include the springs.

Q. And in fact, however, that would account for the effects that are discussed by Dr. Ostadan, correct? I'll read you that last sentence. You say, "Due to the nonlinear response of the casks caused by sliding and tipping, the system's natural frequencies are not unique and are amplitude dependent, and therefore the iterative solution suggested by Dr. Ostadan may not work." That iterative solution would be to do what? To model the soil springs and dampers as they change over time?

A. The approach suggested by Dr. Ostadan is a usual procedure if you have a linear system that will work. So you know the system frequency, then you would go to the frequency dependent impedance functions which include soil spring function as well as damping function. Then you go to the frequency of the system and pick out the value.

And then if your initial guess is not quite right but on the frequency, then you can recalculate the frequency and go back to the function so you can enter it that way. And I think that is a very common procedure a for linear system. The problem with the nonlinear system is you really don't have a unique or well defined frequency very well, so you are chasing a number which really is a running target. So in many cases it may work, in many cases it may not work.

Now, in the case of Dr. Luk's analysis, he's representing the soil by series of finite elements, and he really bypass the need of going through these procedures.

Q. And with respect to the comment you made about the moving target or, as some people have used that term as a constantly changing value for frequency, is that in part because if there is any motion in the cask, as that motion is experienced the frequency will change?

A. For example, you get a slide frequency certainly will change. If it's not slide but tipping, then frequency will change to rocking.

MR. TURK: Okay, that's all I have.

Oh, I'm sorry. May I have one moment, your Honor?

JUDGE FARRAR: Yes, you may.

Q. (By Mr. Turk) If you would turn to PFS

Exhibit 227. There is a point -- first of all, let me see if I understand this correctly. At the third page of this exhibit you plot out for node No. 2 -- I'm sorry, for -- this presents Figure 2, which is entitled Dynamic Vertical Response Displacements of Cask Storage Pad at 5.285 Seconds Longitudinal Section.

A. Okay, that's the second page?

Q. No, the third page.

A. Yeah, third page.

Q. It's entitled Figure 2.

A. Entitled Figure 2, yes.

Q. I see node 7 at the top of this, at the left-hand margin of this chart. Node 7 appears at zero, node 293 occurs at approximately 67. Those are the nodes that represent the one end of the pad versus the other end of the pad 67 feet away?

A. That's correct. If we turn to the page before that, there is a plot of the model for the pad. It has the nodal numbers showing on that Figure, and we can identify a node No. 7. That will be the center line of the pad in a longitudinal or long direction. And the end of that's underlined to be node 293.

Q. There's a series of squares that appears on this Figure 2 commencing at approximately perhaps 36 feet into the pad.

A. Yes.

Q. Extending down to approximately 50 feet or something of that order?

A. Right.

Q. Do you see there's sort of a downward slope of that line of squares?

A. That's correct.

Q. And if I look over to the left-hand margin of this -- I'm sorry. I'm looking at this on its side, so what is now the left-hand margin used to be the bottom. That's the vertical displacement axis?

A. Yes.

Q. That's a measurement in feet of the vertical displacement --

A. That's correct.

Q. -- of that axis? So this slope that we see commencing at about 36 or so going down to about 50 or so, that represents the deflection in the pad in the longitudinal direction?

A. That's correct.

Q. And that's approximately -- goes down from .00 to approximately .01 feet?

A. .01 feet, correct.

Q. And that's the maximum displacement you mentioned before about the .01 --

A. The particular time histories, yes.

Q. Thank you. And just for clarity, the next page, which is Figure 3, that shows the horizontal direction of the storage pad?

A. Shows directions.

Q. The 30-foot direction.

A. Right.

Q. And again, to the left side, node 248, that begins at one side of the pad?

A. That's correct.

Q. And node 30, that's the other side 30 feet away?

A. That's correct.

MR. TURK: Thank you very much. That's all I have.

JUDGE FARRAR: All right, Mr. Turk. State?

MS. NAKAHARA: Thank you, your Honor.

CROSS-EXAMINATION

BY MS. NAKAHARA:

Q. Good afternoon, Dr. Tseng.

A. Good afternoon.

Q. To follow up on the questions referring to Dr. Luk's report, do you still have that?

A. Yes.

Q. If you look at Figure 20B on page 36.

A. Yes.

Q. In your opinion, is the acceleration shown in this Figure too high or too low to cause the pad to move?

A. Acceleration of the pad itself?

Q. Yes.

A. If I want to look at acceleration of the pad, I would then look at Figure 17 that corresponds to Figure 20B. And the question -- do you want me to continue to answer your question?

Q. How about if I withdraw that last question.

MR. TURK: I would ask that he continue, because I'm going to have to ask him in recross. So I'd ask him to complete his answer.

MS. NAKAHARA: That's fine.

THE WITNESS: Well, this acceleration, given that the high frequency is so high without filter out, I really can't tell the actual, I would say response acceleration. I would suspect the actual acceleration would be lower than this. But irrespective of what acceleration value, my testimony have indicated, when you have a cask which has a maximum coefficient of friction of .8, then achieving, when the casks respond up to .8 g, you would expect it would start to slide. Sliding certainly would not increase the cask acceleration.

In the meantime, if coefficient of frequency is very high so that a cask is not sliding, then the tipping, without vertical acceleration the tipping will start at about .57, so you would expect that your cask vertical -- horizontal acceleration would not be many -- very high, either, just because as soon as you start to tip, the inertia response is so reduced because you won't have the -- it doesn't behave like the anchored casks where you have a sufficient stored energy to amplify the cask response.

MR. GAUKLER: Just so the record is clear: I think you mentioned -- you went through two cases there, one for sliding and one for tipping, and I think you mentioned a coefficient of .8 when you were talking about the first case with respect to sliding. Did you mean to say that?

THE WITNESS: Well, .8, because the fact

that tipping will start earlier than .8 coefficient of friction, so I would expect it was a tipping response rather than sliding.

MR. GAUKLER: I wasn't talking about the friction, I was talking about the case where the cask slid. What coefficient of friction did you mean to say in that case? When you were talking about your two cases on top of the pad.

THE WITNESS: Well, I understand that Holtec has analyzed coefficient of friction varying from .2 to .8. So for a low coefficient of friction case, for example, .4, .5, then I would expect the cask to slide first before tipping.

MR. TURK: Just for clarity: the figure .8, was that a g force, acceleration force, or was that a coefficient of friction you were referring to when you said if the maximum equals .8? I thought you said at .8 g you would expect it to start to slide.

THE WITNESS: Yes, .8 g, yes.

MR. TURK: So that was not a coefficient of friction value?

THE WITNESS: Well, it tied to coefficient of friction. And a case without vertical acceleration, then .8 g would be equal to a weight times -- measure of force would equal to .8 coefficient of friction times the weight of the casks.

Q. (By Ms. Nakahara) Dr. Tseng, if you look at Figure 20B again, and at 0.2 seconds what's the acceleration in the center of the pad at point D prime?

A. Well, again, by looking at this response spectra value, I cannot tell. And the high frequency -- normally if the high frequency is not so high, you would have a zero period of acceleration on the response spectra, and I can infer from zero period spectra of acceleration. But unfortunately, the high frequency is so high that you cannot really get that zero period acceleration to be the pad acceleration.

Q. At 0.2 seconds what's the acceleration?

A. The 0.2 spectra acceleration is about around 6.5.

Q. 6.5 g's, correct?

A. At 6.5 g's, that's the spectra acceleration.

Q. At 0.2 seconds and 6.5 g's, in your opinion is the motion of the pad at 0.2 seconds too high or too low?

MR. TURK: Objection. I don't understand. Objection to the form of the question.

Q. (By Ms. Nakahara) Do you understand, Dr. Tseng?

MR. TURK: Well, the record will be unclear whether he understands or not.

JUDGE FARRAR: I think the problem is, too high or too low versus what?

MR. TURK: Or what terms.

MS. NAKAHARA: I can try and clarify.

JUDGE FARRAR: Yes, please.

Q. (By Ms. Nakahara) Dr. Tseng, is it correct that you testified that Figure 20B is a way to show the motion of the pad?

A. It characterize the motion of the pad.

Q. Characterize the motion of the pad. Thus, at 0.2 seconds, how would you characterize the motion of the pad?

A. Well, this goes back to earlier on where if you have a single degree of freedom in linear system with certain damping value which is not clear here on this Figure, that will respond to that 6.5 g and the motion of the pad.

Q. How would you characterize the motion in the pad? As too high or too low?

MR. TURK: Objection.

MR. GAUKLER: Objection.

MR. TURK: Same question, same problem.

MR. TRAVIESO-DIAZ: Also lacks foundation. He hasn't testified that the pads move at all.

Q. (By Ms. Nakahara) In your opinion would the pad move at 0.2 seconds?

MR. TURK: I'm sorry. DR. SOLER stated that it's a way of characterizing the motion of the pad. He didn't state that the pad moves.

MS. NAKAHARA: I didn't ask him that. I withdrew that question, and now I'm asking in his opinion would the pad move at 0.2 seconds.

MR. GAUKLER: 0.2 seconds?

MS. NAKAHARA: At 0.2 seconds on Figure 20B.

A. If I want to answer your question straight, I would have to recompose the time history of the pad into frequency components, and to take 0.2, which is 5 Hz window and look at the motion, filter out that window and look at that acceleration. That information is not readily available here.

Q. In your opinion, would the information, unfiltered information in Figure 20B be an indication that maximum acceleration of the pad could be high?

A. Well, with the unfiltered it shows high. On the other hand, we really don't know how much unfiltered result would affect us, because as you can see, normally a response spectra you would come down at close to zero period, you come down to peak acceleration value, and if you do look at the unfiltered time history at Figure 17, the maximum here, even with this unfiltered results, is about 3. Then the zero period value would be reduced on to 3, and yet I have not seen that spectra value reduced on to 3. So I think there's a lot of filtering need to be done or corrections or something need to be done before we can even look at this Figure and say whether that number was high or low.

Q. Would filtering affect the motion at 5 Hz?

A. Well, it depend on how you filter it. If you filter the motion outside of significant earthquake energy range, which generally below 33 Hz, then you would not affect the 5 Hz frequency. But whether you affect the spectra response calculation, I have no answer at this time.

Q. Thank you. With respect to your testimony regarding long-term settlement and Mr. Trudeau's testimony, how do you define long-term settlement of the pad?

A. I'm not a soil engineer, but I take it literally as the settlement experience through time for foundation and load.

Q. Would long-term settlement include elastic settlement of the pad?

A. Long-term settlement would have also initial elastic, and then of course, continuing on, you have continuous element. That's my understanding.

Q. Would long-term settlement include primary consolidation settlement?

A. I would say so.

Q. And would long-term settlement include secondary compression?

A. I wouldn't know the detail of all the component according to long-term settlement.

Q. Dr. Tseng, are you familiar with what's been marked as State's Exhibit 168, which has not been admitted? It's a page out of the Safety Analysis Report, Chapter 2, Revision 22, and I apologize for reading over your shoulder, page 2.6-50.

MR. TURK: Could we have a moment to try to find the document? And off the record.

(Discussion off the record.)

Q. (By Ms. Nakahara) Dr. Tseng, have you seen this document before?

A. I may have seen it, but it's not very -- don't have a lot of impression of this document.

Q. The title of the section, is it correct that it reads "Static Settlements of the Cask Storage Pad"?

A. Correct.

Q. And then the bullets, do they read "Elastic Settlement 0.5 inches"?

A. Correct.

Q. The next bullet, "Primary consolidation settlement, 0.8 inches"?

A. Correct.

Q. "Secondary compression, 0.4 inches"?

A. Yes.

Q. And for a total of maximum total settlement 1.7 inches?

A. Yes, that's what it states here.

Q. If the maximum total settlement or

long-term settlement was in fact 1.7 inches as predicted by PFS in their Safety Analysis Report versus the 0.5 inches you considered, would you change your opinion you gave earlier to Mr. Gaukler?

A. Well, the opinion earlier was operating with any long-term settlement effect dynamic response of the pad. And my response was, as long as the soil dynamic property is not transferred to this long-term settlement, then you wouldn't have any effect on it. And that, I think I still stand by that response.

MS. NAKAHARA: Your Honor, I believe Utah Exhibit 168 is relevant on this issue, although we maintained it was relevant earlier. I move for admission of Utah -- or State 168.

JUDGE FARRAR: Any objection?

MR. GAUKLER: I think the objection that we made at the time was that long-term settlement was outside the scope of the case. I think your Honor should have moved to the contrary on that and maintained our original objection. Other than that, we have no objection.

JUDGE FARRAR: And why didn't -- seeing how the transcript's here, why didn't we admit it at that time?

MS. NAKAHARA: I didn't offer it, your Honor.

JUDGE FARRAR: That's a good reason. Mr. Turk?

MR. TURK: I think you had ruled me out on this one. I'll restate the objection I made at the time. You may recall I had supported the Board's -- or had made statements supporting the Board's consideration of the issue of the long-term settlement that in the Staff's testimony had addressed it. I then realized I had erred and I came back with actually some transcripts from depositions noting that the only time the State had raised that issue was not in connection with the issue of differential settlement of the pads -- I'm sorry. That the only way they had raised the issue was with respect to the impact on adjacent soil cement. I don't oppose the admission of this exhibit, because this seems to me to go to the issue of the pad's settlement effect upon the soil cement, if I'm reading it correctly.

JUDGE FARRAR: Well, then --

MR. TURK: If I'm reading it incorrectly, perhaps somebody else can tell me.

JUDGE FARRAR: Then we will admit the document.

(STATE'S EXHIBIT-168 WAS ADMITTED.)

MS. NAKAHARA: Thank you, your Honor.

MS. CHANCELLOR: If it helps your record keeping, it was offered at page 5598.

JUDGE FARRAR: Thank you, Ms. Chancellor.

Q. (By Ms. Nakahara) Dr. Singh, with respect to your written rebuttal testimony, your response to question 1 refers to PFS Exhibit MM. Based on the testimony that you've heard in this proceeding or read in this proceeding or based on your rebuttal testimony, have you changed any of your prefiled testimony or oral testimony with respect to PFS Exhibit MM?

A. Well, Exhibit MM deals with flexibility of the pad. And I think the result still stand that, based on the parameter they have calculated for that pad, the effect on the foundation stiffness and damping is very small effect to the pad.

Q. So is it correct that you have not changed -- today you have not changed any of the opinions that you've given in prefiled testimony or orally in this proceeding?

A. No.

Q. In the first sentence you refer to the frequency range of importance to the cask response.

A. Yes.

Q. What is the frequency range?

A. That's 1 to 5 Hz.

Q. I believe this is already on the record, but clarify, what is basis for the 1 to 5 Hz?

A. Since it's nonlinear response, so the basis of 5 Hz, 1 to 5 Hz was calculated really by Geomatrix consultants using the cask response motion under the earthquake input. And then the ratio that calculated full spectra ratio to the input motion, there you can identify what's the significant amplified range of motion of the pad. And from that full spectra ratio you can identify this 1 to 5 Hz is the amplifying motion for the casks.

Q. You state that the frequency of the system is a moving target?

A. As far as the entire pad -- cask/pad and soil interaction, the fact that the cask is experiencing nonlinear response under earthquake input, there is not a single unique frequency that you can identify unless there is no sliding or uplifting, then of course the whole system is still linear. But that would be at a lower level, low level excitation.

MR. TURK: Ms. Nakahara --

Q. Lower level excitation corresponds to what frequency?

A. If the earthquake capacity is lower so that doesn't cause any sliding or rocking appeared in response of the casks, then you will have a linear system. In that case, there will be a station -- or the constant stationary system frequency.

Q. And in your opinion that the frequency of the system is a moving target, would it also be moving from 1 to 5 Hz?

MR. TURK: May I interject? That was my characterization, that was not the witness's. I used the phrase "moving target," and I said as the State has used that term. I don't know if we can ascribe to DR. SOLER the term that I utilized.

JUDGE FARRAR: Can you -- understanding the background, can you answer the question?

THE WITNESS: Yes. I think the 1 to 5 Hz already was calculated under the condition that the casks already experiencing nonlinear response. So that would be already in that range but is not a single value. That's what I'm trying to say.

Q. (By Ms. Nakahara) In your response to question 1 towards the end of page 1, you state that the maximum local deformation of the pad for the nine cases shown on Table D-1(d) is on the order of 0.01 feet or approximately one eighth of an inch, correct?

A. That's correct.

Q. In your prefiled testimony, will you clarify, in response to answer 70, in response to answer 70 you state, "Further, the displacements in the table --" if you look at the question -- strike it. Make this clear since I don't have a copy for you. Question 70 asks, Dr. Ostadan also refers to Table D-1(d) at page 234 of your calculation, which appears to be the same table that you're referring to --

A. Yes.

Q. -- in your rebuttal testimony. But in your response to answer 70 you state, the largest displacement -- the very last sentence. The very last sentence in your response to question 70 states, "These --" The second to the very last sentence, sorry. "Thus, the largest displacements are on the order of three eighths of an inch." Can you explain the discrepancy between three eighths and one eighth?

A. Well, the one and one eighths is really the deviation from say like, you know, rigid body average motion. But if you count the rigid body, of course there will be additional --

(Off the record briefly.)

THE WITNESS: If you count the rigid body component of motion. But we are talking about flexibility of the pad, so we have to use the number deviate from rigid body motion.

Q. In response to answer 3 of your rebuttal testimony, the last sentence of the first paragraph you state, "These two plots show the maximum local deformation observed for the pad for the asymmetrical loading of two casks," correct?

A. That's correct.

Q. What position were these two casks located?

A. At the end of the pad, one end of the pad.

Q. Did you analyze the maximum deformation for any other loading combinations?

A. We did analyze the case for four casks on one side of the pad as well as the four casks -- eight casks on the pad.

Q. For the four casks on one side do you recall what the maximum differential was?

A. Well, I couldn't recall right now, but as we look at the differential case, the two casks on the one end appears the largest differential.

Q. And that's between the two casks on one end and four casks on one side or eight casks?

A. For the case of eight casks full loading, you produce mainly rigid body motion, raise more amount of deviation. Then you start to get more, as you get four casks on one side, then it produce the most when you have two casks.

Q. Did you look at two casks on opposite ends of the pad?

A. You mean two on one end and two on the opposite end?

Q. No, two casks total. Are you familiar with the location numbers that Dr. Soler has used in his various reports?

MR. TRAVIESO-DIAZ: Ms. Nakahara, if I could make a suggestion to help you?

MS. NAKAHARA: Use the exhibit?

MR. TRAVIESO-DIAZ: Yes. Look at Figure 1 that has the cask number.

MS. NAKAHARA: Thank you.

THE WITNESS: Now, the cask number on Figure 1 is the same as Dr. Soler's numbering, correct?

Q. (By Ms. Nakahara) Did you consider two casks placed at cask location 1 and cask location 8?

A. No.

Q. Did you consider any other configuration other than -- strike that. Did you consider -- did you analyze casks placed at location 1 and location 7?

A. No.

Q. In your opinion, would either of those situations of casks located in position 1 and 8 or 1 and 7 create more deformation?

A. Since I haven't analyzed it, I don't know whether you will or not. But based on my engineering looking, there probably would be -- you've got a symmetrical conditions at the middle and then you will work similar to the two casks on one end, except that you would now create two dishes, two deformed shape, symmetrical. As this

Figure of Figure 2, you'll have four casks on one end, you'll have this deformed shape on one end, and the other end is virtually flat. And you would now have this similar deformed shape on the other hand.

Q. Would you then get, then being in a --

A. Perhaps the total deflection could be increased from what they have now, but differential would probably be similar.

Q. And that would be for both cases, a cask located at location 1 and a cask located -- strike that. That would be for both cases where two casks are located at position 1 and position 8 and position 1 and 7?

A. In terms of magnitude, I would say probably similar. Of course the shape will be somewhat different.

Q. Would the shape caused by the alternative locations that you did not analyze, would that create more of a ripple effect as you consider a ripple in your response to answer 2?

A. Well, the loading certain -- well, the deflect shape reflect where the load is placed. So if you have a load placed there, you would expect there will be some deflections.

Q. Would a ripple effect -- not to beat a dead horse, I'm sorry -- with respect to casks loaded in position 1 and 7 generate more than half a wavelength, in your opinion?

A. Well, it would be one side half wavelength, the other side have one half wavelength.

Q. Would that be the same situation for a cask loaded in position 1 and position 8?

A. I would expect similar, except there will be some transverse turning or twisting differently.

Q. Did you consider the cask combination of three casks?

A. For the final design calculation we did not. But very early on actually we have investigated one through eight cask cases, and looking at the results, they were not really as much different. I mean, in terms of design purpose, you try to capture the maximum response. We have determined that two, four, and eight would capture the maximum pad internal force response.

Q. And would capturing the maximum internal response also include capturing the maximum --

A. Deflection.

Q. Yes. Dr. Tseng, you have shown a vertical displacement at 5.285 seconds along the length of the pad, correct?

A. That's correct.

Q. Is this displacement based on the forces provided to you by Holtec?

A. That's correct.

Q. Why did you select 5.285 seconds?

A. That's the maximum deflection.

Q. At any point in time on the pad?

A. Well, underneath the loads, so in that region of pad. And that would be the maximum deflection.

Q. Because the casks are moving, the location of the forces acting on the pads -- strike that. Because the casks are moving, are the location of the forces acting on the pad changing with time?

A. Well, for the case we are looking at, it's a frictional coefficient of .8, so as far as pad response is concerned, internal force generated maximum by the maximum amount of tipping and rocking response, rather than by sliding. So for a case of pad design, not sliding but maximum rocking response are the controlling cases. So there is really no moving of the forces.

Q. Will you explain on Figure 1 of Exhibit 227 where you would find the forces?

A. The forces were applied for each cask represented by a circle of the four points, four quadrants of the circle. Each quadrant would have one force and function. And I think earlier on this morning Dr. Soler testified that that's the important time history that they supplied to us.

Q. In your opinion, at a coefficient of friction of 0.8 are the casks sliding?

A. The initial force of 0.8, yes. But since tipping response will start at a lower g value, it would then start to tip. Once it tipped, then it will response in tipping.

Q. Just to clarify, once the cask starts tipping, in your opinion the cask will not also slide? There would be no sliding of the cask; is that correct?

A. Unless the vertical acceleration is such that it reduce the effective load down to smaller. And that will be a very small time steps -- I mean, time distance. And there will be maybe a very sharp time distance where one vertical acceleration goes up, goes down, that reduce the contact force between the casks and the pad.

Q. Just to clarify: you did not move the location of the forces acting on the pad?

A. In our design, we do not move.

Q. Did you request the acceleration response of the pads from Holtec for your calculation?

A. Well, I think in the very beginning we did, but the acceleration was not calculated then. So in their final design we did not request. Then, as you know, Dr. Soler testified this morning, I think the raw acceleration cannot be directly used. I think you need to process them in certain way before it can be used.

Q. You indicated that you initially asked for acceleration. What was the basis for your request?

A. Since they're calculating the entire system, certainly we would like to have not only the forces but acceleration, not only just pad but the casks too. But realizing that there is a limit amount of output that they have calculated, since they have calculated so many cases, restriction vary from .2 to .8 with many, many different variation. So to minimize the amount of data transfer, we have eventually reduced down to asking just the sufficient loading information that we need to perform our analysis and design for the pad.

Q. Are you aware of any calculations performed by NRC staff or PFS that provides the acceleration response of the pad?

A. Other than this earlier report, Staff Exhibit T, I'm not aware of any other reports.

MR. TURK: For clarity: that would be Dr. Luk's report?

THE WITNESS: Yes.

Q. (By Ms. Nakahara) Although the accelerations provided in Dr. Luk's report are unfiltered, have the accelerations shown in that report caused you to reconsider any portion of your pad structural analysis?

A. Well, for pad per se, no. Horizontal total acceleration really does not cause much for the pad itself. It does change the soil reaction force that the pad stability calculation have to be include. But as far as pad's own forces, you have -- you can apply an acceleration onto a pad horizontally and it behave like implant rigid, so you put -- and uniform inertia didn't really produce any differential stresses in the pad.

Q. Do you agree in-plane rigid means response of one node compared to others are about the same?

A. Yes.

Q. Do you agree with Dr. Luk's opinion that response may change from one node to another?

A. Well, in-plane rigid, if you said infinitely rigid, then it will be identical, but if you are just rigid they would have some differential, depending on how much.

Q. Would you characterize that as a significant change?

A. I don't think I understand character exact.

MS. NAKAHARA: Could you re-read Dr. Singh's last answer, please?

(The record was read as follows:

"Well, in-plane rigid, if you said infinitely rigid, then it will be identical, but if you are just rigid they would have some differential, depending on how much.")

Q. (By Ms. Nakahara) Can you quantify some differential differences from node to node if it's characterized as just rigid, if the pad is characterized as just rigid?

A. Well, I think it's just intuitively, if you have a pad like this, that in plane, in plane direction it will be really quite rigid. Other plane direction is really the best direction, and I think for quantifying a number, I don't think it's really necessary.

Q. And the response at nodes -- at different nodes for a pad such as the PFS pad would not be significantly different?

MR. TURK: Objection. Are you talking in plane or not in plane?

MS. NAKAHARA: In plane.

THE WITNESS: If in-plane rigid, then the response would be quite similar to each other at component of points, yes.

Q. (By Ms. Nakahara) Dr. Tseng, if you'll look at your response to question 7. In the second paragraph you refer to a maximum horizontal ground acceleration of 0.7 g's; is that correct?

A. That's a number used for this calculation.

Q. What is your basis for using 0.7 g's in this calculation?

A. That's a maximum ground surface acceleration. I think the correct specific number, it could be .711, but for the purpose of this discussion, we just rounded off to .7.

Q. Is that the acceleration response of the pad?

A. That's assumed to be if the pad's response the same as is one surface acceleration. And that's assumption for this calculation.

Q. On page 5, continuing your response to question 7, you state, "Thus, for the case of cask/pad friction coefficient greater than 0.57, the casks will tip but not slide," correct?

A. Yes.

Q. Have you reviewed the results of Holtec's cask sliding analysis for the 2,000-year design-basis earthquake?

A. I have not reviewed in detail, but I have reviewed some of the report. I think the calculation on this particular answer is trying to offer a ballpark Figure for us to feel at what g value we expect what kind of response of the casks. Rather than trying to portray that it will be a particular g value, that the response, realizing that under earthquake loading, mean time history, there are much more complex response than this. But with all the complex response, it has to follow certain physical parameter. And these are the static physical parameter that you would expect, and dynamic response would be then vary just plus-minus of these values.

Q. Dr. Tseng, this is a Holtec report, Holtec Cask Response at PFS ISFSI from 2,000-year seismic event, Revision 2, Report No. HI-2012640 dated August 20th, 2001. Are you familiar with this document?

A. I think I've seen this document.

Q. If you'll turn to page 28.

MR. TURK: For clarification, this is Utah Exhibit 173?

MS. NAKAHARA: Yes.

MR. TURK: Thank you.

THE WITNESS: Page --

Q. (By Ms. Nakahara) Page 28. For cask No. 2, and Dr. Tseng's copy has a circle, the data that's circled which show the displacement of 1.2 inches, do you agree that that's for cask No. 2 in the Y direction at the bottom of the cask, or a coefficient of friction of 0.8?

A. I take it that cask No. 2 is referring to the order of the output of these casks, which correspond to the order of the casks?

Q. Yes.

A. And the circle one is the one that shows Y displacement for, parentheses, bottom, equal to minus 1.2? That's the number you're referring to?

Q. Yes. And this is at a time of 5.5 seconds, correct?

A. Correct.

Q. For a coefficient of friction of 0.8, correct?

A. Correct.

Q. Now, will you look at page 30 of PFS -- of State Exhibit 173 for cask No. 8.

A. Yes.

Q. What is the displacement at the bottom of the cask in the Y direction?

A. That's the last number that you were referring to?

Q. Yes.

A. Minus 1.2.

Q. Now, if you'll turn to Dr. Luk's report. We're back to Exhibit P on page 30. Is this the displacement for a best estimate model Type 2 with a coefficient of friction 1 equal to -- strike that. What is the displacement for the best estimate model 1 for coefficient of friction 1 equals 0.8 and mu 2 equal to 1.0 at the base of the cask in the horizontal direction?

A. Referring to U1, 1.46 inch.

MR. TURK: I'm sorry. Again, I wasn't sure which one he's addressing. He's looking at mu 2 for best estimate?

A. U1 on this table. With -- am I correct, best estimate normal, type 1?

Q. Yes.

A. With coefficient of friction, mu 1 equal to 0.8 and mu 2 equal to 1.0. And then on the row that's marked as base. Am I correct?

Q. Yes.

A. And then under U 1 column is 1.46 inch.

Q. Based on the results of Holtec and Dr. Luk for a coefficient of friction of 0.8, do you agree that Holtech and Dr. Luk showed that the cask will slide at a coefficient of friction of 0.8?

A. That's correct.

Q. In your response to question No. 8, in the second paragraph you state, the method used by Holtec in its analysis was to select the soil spring -- strike that. You state, "The method used by Holtec in its analysis was to select the soil mass, spring and damping parameters using formulae published in a well-recognized technical treatise, Newmark, N.M., and Rosenblueth, E., Fundamentals of Earthquake Engineering." Is that correct?

A. That's correct.

Q. Have you reviewed Holtec's calculations of soil mass, spring and damping parameters?

A. Have I reviewed?

Q. Yes.

A. I have seen -- I have -- the number were included this report, yes.

Q. Have you reviewed the calculations themselves for their accuracy?

A. I did not check the calculation.

Q. Were you present when Dr. Soler testified that the force time history given to ICEC did not include the forces in the dash pots earlier?

MR. GAUKLER: I think that mischaracterizes the testimony of Dr. Soler.

MS. NAKAHARA: I'll withdraw the question.

Q. (By Ms. Nakahara) In your response to question 8 in the first paragraph, isn't it true you indicate that the natural frequency of the system varies, and due to cask sliding or tipping, the method proposed by Dr. Ostadan may not work?

A. That's correct.

Q. Do you have a copy of the ICEC calculation?

MS. NAKAHARA: If I may have a moment, your Honor.

JUDGE FARRAR: Go ahead.

Q. (By Ms. Nakahara) Look at page 171.

A. Yes.

Q. The graph for the lower bound soil.

MR. GAUKLER: Would you repeat that page again, please?

MS. NAKAHARA: 171, for lower bound soil.

MR. TURK: Which exhibit are we in?

MS. NAKAHARA: I don't believe it's an exhibit. It's ICEC's calculation entitled Storage Pad Analysis and Design Calculation No. GP 017-2 dated April 5th, 2001.

MR. GAUKLER: That is PFS Exhibit 85, portions of it are. That particular page is part of PFS Exhibit 85.

MR. TURK: Utah Exhibit 170, which appears to be from the same calculation.

MS. NAKAHARA: Pardon?

MR. TURK: Utah Exhibit 170 appears to be the same calculation.

MR. TRAVIESO-DIAZ: I think PFS Exhibit 85 has more of it.

Q. (By Ms. Nakahara) For the lower bound soil, do you see a foundation frequency of about 5 Hz?

A. I see a peak of this transfer function of 5 Hz, yes.

Q. And on page 181 for the best estimated soil?

A. Yes.

Q. Do you agree the foundation shows a frequency of 8 Hz, around 8 Hz?

A. Well, the peak of the transfer function is 8 Hz.

Q. And on page 193 for the upper bound soil, do you agree the transfer function shows a frequency of 11 Hz?

A. Somewhere between 10 and 11, yes.

Q. Isn't it true they calculate spring and damping at those frequencies?

A. Well, this is only the pad on soil subject to force and function. So what frequency you are referring to here will be pad/soil frequency, not pad -- cask/pad/soil frequency.

Q. Soil springs and dash pots represent pads, the pad and soil?

A. Well, in our pad designing calculation, since we design the pad, we're only concerned with loading come from the casks. So we model the pad on soil. On the other hand, for Dr. Soler's cask response calculation he would have to include the casks, the pad and the soil. So there are two different purpose and different system frequency of concern.

Q. Could you use these frequencies as a check on the soil springs and dash pots used by Dr. Soler, by Dr. Soler in the Holtec analysis?

A. It could be used as a way to see whether a range of frequencies that Dr. Soler's three bounds would be approximately same as in this frequency range.

Q. Based on your knowledge, have Dr. Soler's soil springs and dash pots been checked against the method using the natural frequencies?

A. He has not used the method No. 1 here, I call it, using this selected frequency and then choose the soil springs and so on. Rather I think he uses a soil mass which, as you know from testimony, that if you have the stiffness mass, soil mass is frequency square, it will produce some kind of frequency variation of the impedance function, and that would cover in the range I believe is up to about 10 Hz or 11, depending on where the lower bound will come from. That's without the cask mass on it. With cask mass on it, that frequency would drop, certainly. Then, depend on which particular case he is analyzing, then that frequency would then further drop for different values.

So really couldn't be a unique value. Would depend on whether two casks, one cask, or four or eight casks. And even if you have the same number of casks because the nonlinear response, again, the unique frequency cannot be quite defined.

JUDGE FARRAR: Ms. Nakahara, let me interrupt for a minute. Just in terms of planning, how much longer do you think you have?

MS. NAKAHARA: Just this one question.

JUDGE FARRAR: I spoke too soon.

Q. (By Ms. Nakahara) Isn't it true you testified that you could use Dr. Ostadan's method, iterative method with the soil impedance function at the soil impedance function frequencies on pages 171, 181, and 193 in the ICEC calculation as a check on --

A. On soil alone.

Q. Are you aware of whether that that was in fact -- that was in fact checked?

A. I'm not aware whether they have especially checked it, but I think their wide range of coverage covers some of this frequency range.

Q. And the frequencies calculated by ICEC on pages 171, 181, 193, those are calculated after you applied the forces provided by Holtec, correct?

A. No, it was a frequency under the single point load application for that case that we were talking about. It does show the natural frequency of the system irrespective of whether there is a point load or many point load.

Q. Do you agree that it's important to ensure that the spring damping is appropriate for the natural frequency of the system?

A. I agree of course for a soil-structure interaction system you have, you know, you have to get good frequencies. But in the meantime, it all also depend on how much variation of parameter you have, you cover. If you are not -- and this is general, if you use a simplified model, generally you would like it to vary in the wider range so that some of the approximations used can still be covered by the wide variation of parameters. I think all calculation to some degree are approximations, it's just how refined or how crude. And I agree that in any calculation you have to have the right frequencies.

MS. NAKAHARA: Thank you, Dr. Tseng. I have no further questions.

JUDGE FARRAR: Judge Lam has one.

JUDGE LAM: Dr. Tseng, good afternoon.

THE WITNESS: Good afternoon.

JUDGE LAM: Going to be good evening. Dr. Tseng, the way I read your rebuttal testimony, I understand that you provide testimony in response to three essential claims by Dr. Ostadan. One had to do with the pad's flexibility; two had to DO with the way your company handled dynamic forces; and finally, the appropriate use of soil spring and damping values. Is that correct?

THE WITNESS: Yes.

JUDGE LAM: And furthermore, you provide in detail your reasoning about why Dr. Ostadan is incorrect or the concern that he had raised is insignificant. Is that correct?

THE WITNESS: For the issue discussed here.

JUDGE LAM: Now, if I may categorize your response together with Dr. Ostadan's concern as a dispute, then I basically see three disputes here. And what I would like to ask you to do is to take a step back and think about, without addressing the merits of your response or Dr. Ostadan's claim, can you prioritize for this licensing board as to the importance of these disputes?

Now, if I may clarify my question by giving you an analogy. Let's say you are about to buy a used car. There is a claim that there is a rusty spot on the fender; there's a claim that perhaps the windshield wiper needs replacement; and then finally, there is a claim that the transmission may be about to be gone. And we are not certain of these claims, and let us call them, these are disputes between you and the salesman. Now, to me, if you're lucky all three disputes will be resolved to your satisfaction and all is well. But one clearly is more important than the other two. I mean, the transmission issue would be a lot more important than if there is a rusty spot on the fender or not.

So my question is asked in that spirit. I see three disputes here. Are they all created equal, by which I mean presenting the most critical and serious challenge to the Applicant's application, or do they -- or maybe they don't matter.

THE WITNESS: Well, I could answer from my perspective not necessarily in trying to see whether -- which one is more important.

I think some of the concern or claim raised by Dr. Ostadan certainly from a point of view of analysis, every project you can raise the same question. It's a matter of whether a particular project, some of the parameters become important, some other parameter may be more important for other project. Now, for this particular project he had to raise many of the issues, of course, within the range of my area where the pad design, and then maybe because there is interaction between the pad design and also

Dr. Soler's --

JUDGE FARRAR: I think Judge Lam is just talking in your area.

THE WITNESS: Okay, in my area. Well, I was going to say that because interface, there is a little bit sort of extend to Dr. Soler's area, but I will -- in my area.

I think the pad flexibility certainly is a legitimate issue, but then it depends on whether it affects your response, important or not. In this case the important, the pad response is for design, our design issue.

On the other hand, I think for the project the most important is also the cask response. I think that's the major response we're talking about. And I think the fact that the casks and pad has a, if you will, have a surface of discontinuity where you can allow the slide or uplifting, I think many of these parameters are raised may become not so important. Just because many of these parameter variation creates some variation of motions, some variation of maybe acceleration values and so on, go across that surface of discontinuity where you're allowed to slide and uplifting will make it not such an important issue.

Now, important issue will be then whether the cask's motion, and there is always wide variation of parameters that they will have enough margin to accommodate these motions and the casks will be stable. Then of course on our pad design and all this wide variation of forces, do we have a conservative design of the pad with the quantitative forces anticipated.

So I don't know whether I answered your question or not, but that's my attempt of trying to answer your question.

JUDGE LAM: Yes, Dr. Tseng, but if I may ask you among the three issues in the order of importance of one, two, and three, one being the most important issue here, which one would you call number one? Pad flexibility, dynamic forces and soil spring?

THE WITNESS: I think dynamic forces is the most important in terms of pad design, because that certainly controls our selection of how many rebars and shear rebars, no shear rebars. So as far as pad design is concerned, dynamic forces will be the number one.

JUDGE LAM: Then which one is the number

two?

THE WITNESS: Number two then of course is the casks -- let me rephrase it. Your number three is referring to --

JUDGE LAM: Soil spring value and damping.

THE WITNESS: The soil spring will be the number two issue, I would say. The case of PFS wide variation has been considered, so I think that issue also have been addressed extensively.

JUDGE LAM: And Dr. Tseng, let me also ask you a final question. You had read and listened to Dr. Ostadan's testimony, I presume, in this proceeding. Is that correct?

THE WITNESS: Yes.

JUDGE LAM: Based on what you had read and heard, may I ask you to do the same type of analysis, without addressing the merits of Dr. Ostadan's claims, which one of his numerous claims would you urge this licensing board to give our most serious attention?

THE WITNESS: Well, again, I will limit myself on the pad design --

JUDGE LAM: Yes, indeed.

THE WITNESS: -- and whether there is

effect on the cask. I will not address the soil portion or soil cement treated or soil cement area, which is not my expertise.

JUDGE LAM: I fully recognize that you're on the opposing side of Dr. Ostadan, and therefore I think that your answer would be extremely helpful.

THE WITNESS: Well, as I mentioned, I think many of the concern raised certainly is a worthwhile parameter that every engineering project --

JUDGE FARRAR: Wait, wait. Give him the answer. He wants to know which of -- it's ten minutes after five; give him the answer.

THE WITNESS: Okay. I think, in my opinion, the pad flexibility is not such an important issue as far as pad design as well as the cask motion is concerned. Pad-to-pad interaction, even though today Dr. Soler has shown a model which produce result, given very significant forces between pads, but I believe Dr. Soler's model was designed or created to maximize or to address certain particular issue. If you really want to model this somewhat more properly, my belief is that the pad-to-pad interaction would also not be such a big issue in terms of the motion of the pad itself. I'm not addressing the effect on the cement treated soil or anything like that. More on demand side rather than capacity side. And I couldn't quite recall an important area that we need really to look at.

JUDGE LAM: Okay, thank you for your answer, Dr. Tseng. Appreciate it.

JUDGE FARRAR: Mr. Gaukler, do you want to have redirect?

MR. GAUKLER: No, I do not.

MR. TURK: I have a couple of limited follow-up questions. Do you want to go forward with another witness today?

JUDGE FARRAR: Well, I would assume Mr. Gaukler was going to have some redirect. I was about to excuse your other witnesses, but maybe we can do something. How long will you take, Mr. Turk? Because everyone needs a break right now. If you have a couple quick questions.

MR. TURK: Five to seven minutes. But if you want to take a break, we can come back. We're going to be here regardless the same amount of time.

MS. CHANCELLOR: Your Honor, Dr. Ostadan

is going to have to leave very shortly.

JUDGE FARRAR: All right. Go ahead, Mr. Turk.

RECROSS-EXAMINATION

BY MR. TURK:

Q. I want to come back to Dr. Luk's report, Staff Exhibit P. Do you recognize that Figure 20B?

A. Yes.

Q. Represents a characterization of single nodal points?

A. Yes, I believe that's --

Q. That chart also bears one axis which is labeled Spectral Acceleration. Could you give us your understanding of that term and how that differs from seismic acceleration?

A. Well, spectral acceleration again is the response of a single degree of freedom with that particular selected spectral frequency and spectral damping values.

Q. Isn't that the equivalent of seismic acceleration?

A. It's not equivalent to seismic -- or maximum acceleration. Although if we were to have time history, you can infer the maximum acceleration from the response spectra plot.

Q. And that would be assuming that the spectral acceleration plot was properly filtered and properly representative of actual conditions that you had experienced in the real world?

A. From numerical -- if there were corruptions.

Q. Including -- it would require that you have proper filtering and damping, correct?

A. Yeah, that's correct.

Q. Also, at some point --

MS. NAKAHARA: May I interrupt? Sorry. Dr. Ostadan needs to leave to catch his plane. Can he be excused?

JUDGE FARRAR: Certainly. Dr. Ostadan, will we see you again?

DR. OSTADAN: If needed, sir.

DR. BARTLETT: I've got to drive him, so I'm going to leave too.

JUDGE FARRAR: Thank you for your contribution here. We appreciate it.

MS. NAKAHARA: Thank you, your Honor. Sorry.

Q. (By Mr. Turk) There was some discussion about whether nodes in the same plane would experience the same accelerations. What if the nodes were not in exactly the same plane? How would your answer differ?

A. I guess we're referring to nodes in soil?

Q. Well, for instance, in Dr. Luk's model he modeled the soil as well as the cement treated soil, the soil cement between pads, the pads and the cask. For any of those systems, if we're looking at nodes for some part of the structure, whether it's in soils or in casks or in the pad, if the nodes were not exactly in the same plane, would the accelerations experienced by those nodes be different?

A. In general they will be different.

MR. TURK: No other questions.

JUDGE FARRAR: Thank you, Mr. Turk. Does that finish this witness? Thank you, Dr. Tseng. Appreciate your contribution.

Let's take a -- do you want -- let me ask, do you want to try to get some more business done?

MR. GAUKLER: I would like to get Mr. Ebbeson on if we could.

MS. CHANCELLOR: I've got like half a

dozen, eight questions. I think we can get Mr. Ebbeson done today.

JUDGE FARRAR: It's late in the day. It's 5:15. Let's break until 5:25.

(A recess was taken.)

JUDGE FARRAR: All right, we're coming down the home stretch here in Salt Lake City. What do you have here, Mr. Gaukler?

MR. GAUKLER: I have something marked to be 225, I believe D.

JUDGE FARRAR: D as in dog?

MR. GAUKLER: Yes, PFS 225 D. And I'd like to have Dr. Soler very briefly explain what this is. This relates to the previous Exhibit 225 C, I believe.

(APPLICANT'S EXHIBIT 225D MARKED.)

JUDGE FARRAR: Dr. Soler, we are on a word limit here. Tell me in the shortest possible time what this is.

THE WITNESS: What I have done is, the first page simply repeats the exhibit that was submitted this morning. The four succeeding pages, pages 2 and 3 are simply the first graph on the lower right of the first page split into two components, and pages 4 and 5 are simply the first graph in the top right-hand corner split into two components so that each one is separate.

JUDGE FARRAR: Thank you. Does that satisfy the State's concern?

MS. NAKAHARA: It does, your Honor, and we appreciate --

JUDGE FARRAR: Okay, then this will be -- without objection, this will be admitted.

MR. TURK: We probably wouldn't object, but we don't have a copy.

MR. GAUKLER: And I guess we'd like to have the record note that there's actually the word "225 B" on the exhibit. You can correct it. It should be 225 D.

JUDGE FARRAR: The reporter has marked that. Then that exhibit will be admitted

(APPLICANT EXHIBIT 225 D WAS ADMITTED.)

JUDGE FARRAR: Now, we want to do --

MR. TURK: 225 C then is withdrawn?

MR. GAUKLER: Just in the record.

JUDGE FARRAR: Do we want Mr. Ebbeson?

BRUCE E. EBBESON,

called as a rebuttal witness, having previously been sworn, was examined and testified as follows:

DIRECT EXAMINATION

BY MR. TRAVIESO-DIAZ:

Q. Mr. Ebbeson, good afternoon.

THE WITNESS: Your Honor, are you telling me I'm sworn in?

JUDGE FARRAR: Yes. You've been sworn and consider yourself still under oath. Thank you, sir.

Q. Mr. Ebbeson, do you have in front of you a document entitled Rebuttal Testimony of Bruce E. Ebbeson on Section B of Unified Contention Utah L/QQ?

A. Yes.

Q. Dated June 7th, 2002?

A. Yes, I do.

Q. Was this document prepared by you under your supervision?

A. Yes.

Q. Is this document complete and correct, to the best of your information and belief?

A. Yes, it is.

Q. Do you adopt it as your rebuttal testimony in this proceeding?

A. Yes, I do.

MR. TRAVIESO-DIAZ: I will move that

this document be admitted into evidence and accepted into the record, bound into the record.

JUDGE FARRAR: Any objection?

MS. CHANCELLOR: No objection?

JUDGE FARRAR: Mr. Turk?

MR. TURK: We're conferring for a brief second. We have no questions, your Honor.

JUDGE FARRAR: No objection?

MR. TURK: I'm sorry. Oh, sorry. No objection to binding in the record, no.

JUDGE FARRAR: Okay, this will be bound into the record as if read.

(Rebuttal testimony of Bruce E. Ebbeson follows:)

June 7, 2002

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of	)	
	)	
PRIVATE FUEL STORAGE L.L.C.	)	Docket No. 72-22
	)	
(Private Fuel Storage Facility)	)	ASLBP No. 97-732-02-ISFSI

REBUTTAL TESTIMONY OF BRUCE E. EBBESON ON SECTION D OF UNIFIED CONTENTION UTAH L/QQ

I. REBUTTAL TO TESTIMONY OF STATE OF UTAH WITNESS DR. FARHANG OSTADAN

A. Dynamic Interaction Between Soil Cement and CTB Mat Foundation

Q1. In his answer to question 40 in the "State of Utah Testimony of Dr. Steven F. Bartlett and Dr. Farhang Ostadan on Unified Contention Utah L/QQ (Dynamic Analyses)" ("Bartlett/Ostadan Direct Testimony"), and in his oral testimony at the May 9, 2002 hearing (Tr. 7656-63), Dr. Ostadan raises the concern that PFS has failed to analyze the dynamic interaction of the soil cement with the CTB mat foundation. Is this a valid concern?

A1. No. Dr. Ostadan appears to be treating the soil cement around the CTB as an adjacent structure capable of significant dynamic interaction with the building. However, the layer of soil-cement around the CTB is not as massive as another building; it is, at most, equivalent to a layer of very stiff soil. The free-field ground motion, developed by Geomatrix, considered the soil-cement as another soil layer atop the clay. The ground motion thus already considers the effects of the soil cement. The impedance functions for the CTB were developed using the soil profile and properties below the basemat elevation, in accordance with Section 3.3.4.2.4 of ASCE 4-86.

Dr. Ostadan makes reference (Tr. 7658-7660) to a paper by Wong and Luco as supporting the proposition that the soil cement cap around the CTB will reduce the radiation damping effect of the soil under the building. He asserts that the soil cement will "trap" the energy that would normally be dissipated through radiation damping. However, the Wong and Luco paper cited by Dr. Ostadan addresses the effect on radiation damping of having two adjacent rigid rectangular foundations. The soil cement around the CTB is, however, not a rigid structure. That soil cement will have a Young's modulus much lower than concrete, has no reinforcing steel, has no stiffening walls, and as Dr. Ostadan and Dr. Bartlett have repeatedly pointed out, may exhibit cracking at a number of locations. Thus, the soil cement is unlike the structures cited in the Wong and Luco paper, and therefore the results of that paper are inapplicable.

Even if one were to assume that the soil cement around the CTB is equivalent to having another building in the CTB's proximity, there is no need to consider structure-to-structure interaction in the dynamic analyses. Section 3.3.1.5 of ASCE 4-86 states "structure-to-structure interaction may be generally neglected for overall structural response but shall be considered for local effects due to one structure on another, such as required in Section 3.5.3 for walls." Since the soil-cement does not extend above the bottom of the CTB walls, there is no need to consider structure-to-structure interaction between the soil-cement and the CTB. The Commentary to Section 3.5.3 of ASCE 4-86 states "Explicit treatment of structure-to-structure interaction need not be done in the analysis under the assumption that variability in response due to structure-to-structure interaction is encompassed by parameter variation considerations...". As a matter of fact, every nuclear power plant site has a number of buildings adjacent to each other, and yet each building is typically analyzed without taking into account the potential dynamic effects of other buildings.

Q2. In the same answer in his direct testimony, Dr. Ostadan indicates that the presence of a stiff soil cement perimeter around the CTB impacts the soil spring and damping parameters and kinematic motion of the building mat foundation. What is your response to this concern?

A2. The soil spring and damping parameters for a structure are a function of the soil beneath the basemat and, if present, the embedment formed by any soils around the sides of the building. For a rigid mat sitting at the surface of the soil, only the soil beneath the mat has an effect. There are no kinematic interaction effects for such a mat assuming vertically-propagating seismic waves. As the depth of embedment increases relative to the dimensions of the mat, the effect of the soil around the building becomes more significant. For the CTB, which has a very large plan area (240' by 279.5') and a shallow embedment (5'), the effects of the embedment are small and can be neglected. Section 3.3.4.2.4 of ASCE 4-86 states that for shallow embedments the effect of embedment may be neglected in obtaining impedance functions provided the soil properties below the basemat elevation are used for the impedance calculations. This was done in the case of the CTB SSI analysis.

Q3. In the same answer, Dr. Ostadan concludes that the shortcomings he identifies in the calculations can "easily" reduce the 1.1 factor of safety against sliding to values less than 1, "indicating instability of the CTB for sliding". Do you agree?

A3. No. As discussed above, I do not agree that the shortcomings alleged by Dr. Ostadan actually exist. In addition, even if the calculated factor of safety against sliding of the CTB were to be reduced below 1.0, this would not mean that the building would in fact slide in the event of a design basis earthquake. There are substantial conservatisms included in the CTB sliding stability calculation, which provide additional margins of safety against sliding. For instance, the sliding stability calculation conservatively used the static shear strength of the clay below the CTB. As described in the testimony of Paul Trudeau, the dynamic shear strength of the soil at the PFSF would be expected to be 50-100 % greater than the static shear strength. Furthermore, the sliding stability calculation used the largest accelerations from the three soil cases used in the CTB seismic analysis. These largest accelerations resulted from using the upper bound soil properties, and are considerably greater than those from the best estimate and lower bound soil cases. The upper bound soil properties were developed by using a shear modulus 50% greater than the best estimate value (shear wave velocity 22% greater than the best estimate). As described in the testimony of Dr. Youngs, the shear wave velocity measurements at the PFS site show little variation across the site. Therefore, the accelerations calculated, and used in the sliding stability calculations, are conservatively high. Because of these conservatisms, it is unlikely that the building would actually experience sliding even if the calculated factor of safety were to drop somewhat below 1.0. And, as I have previously testified, even if the CTB were to slide, no adverse safety consequences would occur.

B. CTB Mat Rigidity

Q4. In the next paragraph of his response to the same question in his direct testimony, Dr. Ostadan criticizes PFS for failing to address the potential flexibility of the CTB mat during a seismic event. He states: "Stone & Webster should have all the necessary data from the structural analysis and design of the mat to make a determination on the validity of the assumption for rigidity of the mat." Have you made such a determination?

A4. Yes. As discussed in Answer 24 of my prefiled direct testimony on Section D of Utah Contention L/QQ, we performed a calculation that shows that, for the loading combination with the full peak vertical earthquake acceleration acting downward and 40% of the peak accelerations acting on the two horizontal directions, the maximum variation of vertical displacement along the centerline of the building in the N-S direction is .163 inches over the length of 279.5 ft., which represents a less than 0.005% deflection. The maximum variation of vertical displacement in the E-W direction is .333 inches over the length of 240 ft., or about 0.01% deflection. The results of that calculation are presented in PFS Exh. YY. Such small displacements over an area of 67,200 square feet (240 feet times 280 feet) demonstrate that the CTB basemat acts like a rigid body under earthquake loadings.

Q5. In his oral testimony on May 9, 2002 (Tr. 7664-74), Dr. Ostadan discounted the significance of such small displacements in terms of demonstrating that the CTB basemat is rigid. He testified at Tr. 7668 that "[f]or the purpose of radiation damping, it's not important how big or small amplitude of displacement is as opposed to how many times it occurs. If I have this variation of, say, .164 taking place every few feet, then the pad -- mat is flexible. But if it's taking place only at two extreme points and in between, I don't see that, then it tends to be more rigid." How do you respond?

A5. I cannot imagine how a 5-foot thick mat could experience such relative displacements over a length of a few feet. It is clear from a review of PFS Exh. YY that the displacements do not take place over short distances, as Dr. Ostadan assumes, but in fact occur over a distance of about 65 feet, and there is only one such occurrence, at the south end of the mat; the north end of the mat is quite rigid. This can be seen on the third page of PFS Exh. YY, where the maximum displacement (designated as MX) and the minimum displacement (designated as MN) are quite far apart. Thus, even applying Dr. Ostadan's suggested approach of concentrating on changes in displacement over small lengths, the conclusion is reached that the CTB basemat is rigid.

I would also note that assuming that the CTB mat is rigid is appropriate in view of the physical configuration of the mat (five foot reinforced concrete, stiffened by shear walls connected to it), which provides the mat with significant resistance to deformation in either the vertical or the horizontal directions. Assuming that the CTB mat is rigid is also fully consistent with Section 3.3.1.6 of industry code ASCE 4-86, which states: "The effect of mat flexibility for mat foundations and the effect of wall flexibility for embedded walls need not be considered in the SSI analysis." Assuming the mat to be rigid is also consistent with the practice in the nuclear industry, which is to treat foundations for safety-related structures similar in design to the CTB at nuclear power plants as rigid.

Q6. Does this conclude your testimony?

A6. Yes.

MR. TRAVIESO-DIAZ: Mr. Chairman, a very quick procedural clarification. A copy of this testimony that you have with you, there is also attached another document. This other document is PFS Exhibit YY. This document was already admitted into evidence.

JUDGE FARRAR: So this is just a courtesy copy?

MR. TRAVIESO-DIAZ: Well, yes, but there's more.

MS. CHANCELLOR: The State withdraws its objection to Exhibit YY. We reserved an objection, your Honor.

MR. TRAVIESO-DIAZ: The exhibit is in evidence but there was a pending objection that was raised during the testimony of Mr. Ebbeson, and she's withdrawing that objection.

JUDGE FARRAR: So you say we had already admitted subject to the objection, and the objection being withdrawn, the record will be clear on that.

MR. TRAVIESO-DIAZ: Thank you. Mr. Ebbeson is available for further examination.

JUDGE FARRAR: All right. Mr. Turk, you indicated you had no questions?

MR. TURK: Correct.

JUDGE FARRAR: Ms. Chancellor?

MS. CHANCELLOR: Very few, your Honor.

CROSS-EXAMINATION

BY MS. CHANCELLOR:

Q. Good evening, Mr. Ebbeson. At last you get to testify.

A. Good evening. I'm ready.

Q. Where you come from, I'm sure it is. On page 2 of your testimony there's a reference to energy being trapped that would normally be dissipated through radiation damping, and this is something that Dr. Ostadan brought up. Did you quantify whether, and if so, how much energy would be trapped in the situation of the soil cement barrier around the CTB acting as a cap?

A. My use of the word "trapped" there is quoting Dr. Ostadan. I think you asked me that in my testimony. In the transcript I asked the question, what do you mean by trapped, and I never got an answer. So I don't quite understand what he's talking about by trapping. I believe he's trying to assert that the soil cap will prevent energy from radiating away from the base of the canister transfer building.

Q. If you assume that the soil cement would act similar to a second building or second foundation, would that help?

A. First off, later in my testimony I don't think the soil cement acts like another building, for reasons I elaborate on below.

Secondly, I think you referred to a paper by Luco and Wong, and they demonstrate that there is another adjacent building next to a building. There may be some changes in the impedance parameters. They never used the term "trap," so I don't know what Dr. Ostadan means by the word "trap."

Q. If you consider the soil cement as you would a second building as they do in the Wong and Luco paper, would you be able to quantify how much energy may not be dissipated as radiation damping?

A. No. There's no way to quantify that. If you're talking about how much energy, you're talking about a percentage or the number of joules? There's no -- radiation damping isn't measured in quantities of energy.

Q. I'll move on. In the stability analysis of -- this relates to question two, I believe. In the stability analysis of the CTB, do you know whether the passive resistance or the passive resistance of soil cement was used in the stability analysis?

A. Yes, it is.

Q. Does this mean that soil cement is moving with the CTB or resisting a CTB load?

A. Well, the soil cement on one side of the building is resisting.

Q. If it is resisting, will there be any kinematic interaction?

A. There will be interaction. Kinematic interaction is a complex term, and I'm not sure how you're using it here.

Q. We're using it as Dr. Ostadan would use it.

A. The judges have asked a number of times for a definition of kinematic interaction, a wide variety, and I'm not sure how it applies in this case. Kinematic interaction in this case I believe is referring to how the soil cement cap changed the motion of the -- under the canister transfer building, which is kind of related to the first question about, if you want to call it trapping energy. It amounts to changing the impedance functions of the canister transfer building and changing the motion underneath the canister transfer building. And then again, as I've said in my testimony and in this rebuttal, I think the soil cement cap around the building behaves more as a soil than it does as another building, in which case I believe that would actually increase the radiation damping, not decrease it.

Q. Okay. In answer 3 in the first couple of sentences, the question I'm going to ask relates to the first couple of sentences in answer 3. In your earlier testimony you indicated you use 5 percent eccentricity to include accidental torsional loads for the CTB, correct?

A. Correct.

Q. How did you include this load for the stability analysis of the CTB building?

A. Torsional loads have a negligible effect on the stability analysis of the CTB.

Q. But did you include --

A. By the way, I did not do the stability analysis on the CTB. Mr. Trudeau did.

Q. Do you know whether Mr. Trudeau included the torsional loads in the stability analysis of the CTB?

A. I'm quite sure he did not, because they do not contribute to sliding or overturning or bearing.

Q. In answer 3 in about the middle of the -- middle of page 3 it states, "These largest accelerations resulted from using the upper bound soil properties," et cetera. Isn't it a common practice to envelope results of three soil cases for design?

A. Yes, it is, which is why we do that. When Mr. Trudeau did his canister transfer building stability analyses, he gave the -- he used the forces and moments that we provided it to him from our seismic analysis, which is Calculation SC 5 there, tabulated in there. And the numbers that are tabulated are the largest of the three soil bases.

Q. Oh, I understand. Okay, thank you.

A. What I'm going on to say there is that based on the testimony of Dr. Youngs, the upper bound soil properties probably overestimate the highest range it could be, so our accelerations are probably higher than they would be expected to be.

Q. Okay. And the next to last sentence on page 3 states, "Because of these conservatisms, it is unlikely that the building would actually experience sliding even if the calculated factor of safety were to drop somewhat below 1.0." My question is -- do you see that?

A. Yes.

Q. Do you agree that the factor of safety of stability of the -- if the factor of safety of stability of the CTB is less than 1 -- scrub that question. Let me start again. This writing is terrible.

A. Can't read your own writing?

Q. No, nor can I read anybody else's. If the factor of safety -- would the factor of safety of stability of the CTB be less than 1 if soil resistance is not considered?

A. Soil cement resistance.

Q. Soil cement resistance is not considered?

A. Did you say the factor of safety or the calculated factor of safety? There's a --

Q. Why don't you give your answer for both cases.

MR. O'NEILL: Are we referring to factor of safety against sliding?

MS. CHANCELLOR: Of the stability of the

CTB, yes, against sliding.

A. Okay, if you read that last -- the sentence you're talking about, I'm saying the building would not slide even if the calculated factor of safety were below one, because the calculated number is a conservative number. So what I'm saying is if we had no conservatism in our calculations and we had everything exactly right, if it went below 1, yes, the building would slide. But I'm saying, even if we calculate a number, say .95, but we know we have these other conservatisms in, so in real life the building would not slide.

Q. But if soil cement resistance is not considered in calculating the factor of safety against sliding, would that factor of safety be less than one?

A. The way it's calculated, yes. If we were to go back and take the other conservatisms out, it's conceivable it would work without soil cement. We would not need it.

Q. Then in also in answer 3 where you refer to Mr. Trudeau's testimony and the dynamic shear strength of soils at PFS would be expected to be 50 to 100 percent greater than the static shear strength. Do you see that?

A. Yes.

Q. Do you know whether testing of the Bonneville clays has been performed by PFS to demonstrate the claimed 50 to 100 percent increase in strength?

A. It has not. That is why we're not taking credit for it.

Q. You're not taking credit, but you're saying that there's extra conservatism because of it. Is that correct?

A. Yes. And I think that's been agreed upon by State's witnesses also. I know that from reading the testimony.

Q. In your opinion is it good engineering practice to introduce a potentially nonconservative design input without verifying the value?

A. No. That's why we do not do that.

MS. CHANCELLOR: Okay, thank you. I have no further questions.

JUDGE FARRAR: Any the board has none. Any redirect?

MR. TRAVIESO-DIAZ: No.

JUDGE FARRAR: Thank you, Mr. Ebbeson. You waited a long time. Thank you for your contribution.

THE WITNESS: Enjoyed seeing this beautiful city.

CROSS-EXAMINATION

BY MR. TURK:

Q. Could I ask for one clarification? In the oral testimony you just gave you indicated that Dr. Young's upper bound probably overestimated the actual upper bound?

A. No. Well, the upper bound that was used in the analysis where we follow the recommendations of ASCE-4 where we increase the shear modulus by 50 percent to account for unknowns in the soil properties, during Dr. Young's testimony he said that looking at the results across the site, there's little variability and we wouldn't expect to see a value 50 percent higher than the best estimate.

Q. So the oral testimony you gave relates to that statement on page 3, answer 3 of your testimony where you discuss this 50 percent greater than --

A. Right. In other words, we --

Q. I just wanted to clarify.

A. Yes.

Q. That's the same reference you're making, same piece of your testimony?

A. Right.

MR. TURK: Thank you.

JUDGE LAM: Let me ask just one quick question. Mr. Ebbeson, in your response to question 3, at the bottom of page 3 you indicated even if the calculated factor of safety were to drop below 1 you would not expect the building would slide, and even if it were to slide there's no safety consequences, right?

THE WITNESS: Yes.

JUDGE LAM: And the question is, why, if that's the case, why do you need all of these treatment of the soil?

THE WITNESS: Again, that was -- there was a discussion on that this afternoon. That's to meet the regulatory requirement of 1.1 for the factor of safety against sliding. And there was some discussion between Mr. Turk and others about whether that's a strict requirement or it's a requirement for a nuclear power plant but not for ISFSIs or it's a requirement for buildings and not storage pads. But we elected to meet the 1.1 factor and not let the building slide, so we went and put the soil cement in.

JUDGE LAM: Okay, thank you.

RECROSS-EXAMINATION

BY MS. CHANCELLOR:

Q. One follow-up question. As an engineer is it common practice to meet a factor of safety of 1.1 in designing a building?

A. A nuclear building or a regular building?

Q. Regular building, any building.

A. Building codes typically have factors of safety of I believe it's 1.1 for both earthquake and wind. But again, the loads they design for are much smaller.

MS. CHANCELLOR: Thank you.

RECROSS-EXAMINATION

BY MR. TURK:

Q. One last clarification. When you say regulatory requirement of 1.1, again you're referring to the NUREG 0800 regulatory guidance, correct?

A. Yes, section 3.815.

MR. TURK: Thank you.

JUDGE FARRAR: Thank you, Mr. Ebbeson. I assume Mr. Trudeau will not be that short?

MR. TRAVIESO-DIAZ: I believe he could be very short, but I'm not the determining factor here.

JUDGE FARRAR: Are you all -- without your experts are you prepared to cross-examine him?

MS. CHANCELLOR: Let me take a quick look. No, I don't think -- I think I'll be floundering.

JUDGE FARRAR: What about your rebuttal to Mr. Ebbeson?

MS. CHANCELLOR: Don't have any, your Honor.

JUDGE FARRAR: Mr. Trudeau, were you planning to be in DC?

MR. TRUDEAU: Yes, sir.

JUDGE FARRAR: Sitting here all this time, being there will not be an extraordinary hardship?

MR. TRUDEAU: Correct.

JUDGE FARRAR: Ordinarily we might try to squeeze you in, but it's late, almost six o'clock on the sixth day of the week, and the State does not have its experts here.

MR. TRAVIESO-DIAZ: Mr. Chairman, the only problem with the questioning of Mr. Trudeau will be to fit him in the already crowded schedule we have for Washington.

JUDGE FARRAR: Well, let's talk about that. We were going along fine before with direct testimony, and the rebuttal has been -- has added a significant amount of time. We'd like the parties to talk amongst themselves about how we might plan to structure rebuttal in Washington at a faster pace than we had today. If someone puts in two pages of rebuttal, and all parties were equally guilty of this, I'm not sure we need an hour -- I mean, there needs to be some limits on cross-examination of simple rebuttal. And we're coming -- it seemed to us we've heard a lot of these things before, and we've got to have a way that rebuttal doesn't consume, overly consume us in DC. So if you all would put your heads together and come up with a plan for how we can with fairness to everybody make sure rebuttal is efficient.

If you fail to come up with such a plan, I will -- let's go off the record.

(Discussion off the record.)

JUDGE FARRAR: Back on the record. We can come up with a plan to make sure that -- I think we talked the other day about convergence, and we need to have direct, and I think that cone, Mr. Travieso-Diaz, I think you mentioned, making sure we head for the right end of the cone rather than the wrong end. I'm not sure the sides of that cone are converging quickly enough, so let's see what we can do about that.

I take it we are -- oh, we'll have Jack send you all an e-mail Monday about exactly what you have to have. I think I know in terms of security for the headquarters building, but I don't want to give any information and have it be wrong. So give the name, address and social security number and/or date of birth and so forth.

MS. CHANCELLOR: Should we use Mr. Whetstine as our contact?

JUDGE FARRAR: Yes. We'll have him send e-mail and you just send everything back to him, or whoever he tells you.

We are going to -- to make sure we're prepared, we're starting at 9:30 on Monday, the 17th, with the soil cement people. That's still the plan, you haven't changed that?

MS. CHANCELLOR: That's correct.

MR. GAUKLER: That's correct.

MR. TURK: Correct.

JUDGE FARRAR: And you do want to go on Friday that week, or at least hold that open?

MR. TRAVIESO-DIAZ: I think we should leave it open, given the additional amount of things that have to go.

JUDGE FARRAR: All right. Then we should probably try to start, since we can only go until two that day, maybe start at eight that day and have it be almost a full day. And then no hearing on Monday, the 24th. Is that --

MR. GAUKLER: That's the current plan. We might want to hold that in reserve in case we have problems, but --

JUDGE FARRAR: Well, the Board will be available.

MS. CHANCELLOR: I've decided to stay over, so --

JUDGE FARRAR: Let us know and we can, you know, on the 17th. And no matter what else happens, we're doing aircraft on the 1st, 2nd, and 3rd?

MR. GAUKLER: Yes.

JUDGE FARRAR: So doesn't matter if we finish seismic, don't finish; we're doing aircraft the 1st, 2nd, and 3rd?

MR. GAUKLER: That's right.

JUDGE FARRAR: And who will the first witnesses be?

MR. GAUKLER: It will be the completion of our rebuttal.

JUDGE FARRAR: That will be the generals and the officers --

MR. GAUKLER: Yes.

JUDGE FARRAR: -- with their addition and --

MR. GAUKLER: Yeah, I think it's already been introduced, but it will be -- I don't know if they have anything more to say on that or not. Can't speak to that specifically at this point in time.

JUDGE FARRAR: And meanwhile the State has been analyzing those additional reports that came in, so you will be prepared to cross-examine them, and I assume --

MS. NAKAHARA: Yes, your Honor.

JUDGE FARRAR: -- then Col. Horstman will want to take the stand and give his review?

MS. NAKAHARA: Yes.

MR. GAUKLER: Just for, your Honor, as planning, I think we also have agreed among the parties after soil cement we then would do the cross- examination of Dr. Bartlett with respect to the Luk report and deal with any issues with respect to the Luk report.

MS. CHANCELLOR: But our goal for that week is to get through soils.

MR. GAUKLER: And then we go back to soils.

JUDGE FARRAR: Okay, great.

MS. CHANCELLOR: And then we need to get to Dr. Bartlett's direct testimony on Part E seismic exemption.

MR. TURK: Not necessarily that week, but that's something else to accomplish.

MS. CHANCELLOR: That's the goal. We would like to get -- we would like Dr. Bartlett not to have to make two trips. He has -- his wife's birthday is on Saturday. He has to come back to Salt Lake.

MR. TURK: I'm sorry, which --

JUDGE FARRAR: Or not come back.

MS. CHANCELLOR: Or yes, stay out of

town.

MR. TURK: He has to go back to Salt Lake the week between the 21st and 24th?

MS. CHANCELLOR: Correct.

MR. TURK: And I do have that problem with scheduling of Dr. Luk. And I've not been able to reach him. I'll try again today. I'm sorry -- not scheduling him but scheduling the cross-examination on his report.

MR. GAUKLER: And one other date that we set, just for purposes of planning witness, is we set June 26th I think for radiation dose consequences.

JUDGE FARRAR: Right.

MR. TRAVIESO-DIAZ: And that will have the additional complication of setting a date for Mr. Trudeau's rebuttal that was left over from today.

JUDGE FARRAR: Is his rebuttal all that you need to finish on part D?

MR. TRAVIESO-DIAZ: Correct. That's the only thing left from part D.

MS. CHANCELLOR: I don't think it will take long. I just didn't feel quite ready.

JUDGE FARRAR: That's quite all right.

All right, is there any other business we need to transact?

MR. GAUKLER: I can't think of anything else, your Honor.

MS. CHANCELLOR: Head for the hills.

JUDGE FARRAR: We've enjoyed our time in Salt Lake City. The proceedings we've indicated have taken longer than the lawyers predicted, but it's been very complicated and we again commend the parties for their diligence and effort in working through difficulties and helping us do it as efficiently as possible.

So we will see everyone at 9:30 on Monday, the 17th, in our hearing room in NRC headquarters in White Flint in beautiful Rockville, Maryland. So thank you all, and we'll see you there.

(Proceedings were concluded for the day at 5:55 p.m.)

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CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Private Fuel Storage, LLC

Docket Number: Docket No. 72-22-ISFSI

ASLBP No. 97-732-02-ISFSI

Location: Salt Lake City, Utah

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

/S/ Diana Kent

Diana Kent
Official Reporter
Neal R. Gross & Co., Inc.