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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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

U. S. Nuclear Regulatory Commission
Sheraton Hotel, Wasatch Room
Salt Lake City, Utah 84114

On June 3, 2002 the above-entitled matter came on for hearing, pursuant to notice, before:

MICHAEL C. FARRAR, CHAIRMAN
Administrative Judge
Atomic Safety & Licensing Board Panel

DR. JERRY R. KLINE
Administrative Judge
Atomic Safety & Licensing Board Panel

DR. PETER S. LAM
Administrative Judge
Atomic Safety & Licensing Board Panel

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I N D E X

E X A M I N A T I O N

E X H I B I T S

June 3, 2002 10:00 a.m.

P R O C E E D I N G S

JUDGE FARRAR: Morning, everyone. We're back in Salt Lake City for a full week of seismic hearings today through Saturday. Good to see all of you back.

Before we get started, a couple of preliminary things. For Staff counsel, each one of us seems to have left the Staff's cross-examination plan of Dr. Arabasz home or somewhere and we don't have it. So before tomorrow night, if you could get ahold of Mr. Turk and get another copy sent out here just to the hotel, just get us a copy of that.

MR. O'NEILL: Okay.

JUDGE FARRAR: Second -- off the record.

(A discussion was held off the record.)

THE COURT: Back on the record. Any other preliminary matters before we get started?

MS. CHANCELLOR: I had one preliminary matter, Your Honor, dealing with exhibits.

JUDGE FARRAR: All right.

MS. CHANCELLOR: We offered Mr. Solomon's testimony into evidence, but we can't find any reference to Exhibit 91, which is Mr. Solomon's curriculum vitae, and I would request that that be entered into the record. It was given to the reporter to have marked, and if the reporter doesn't have a copy, I can provide another copy.

JUDGE FARRAR: All right. Let's check that during the course of the day. And it would not have been bound in as part of the testimony, it would have been a separate exhibit?

MS. CHANCELLOR: It was a separate -- an exhibit separate from the testimony, that's correct, and Ms. Braxton has checked and it wasn't bound into the record.

JUDGE FARRAR: All right. I'm sure there was no objection, so we'll have that admitted at this time. And the reporter will check and see if they have copies and if not, you can resubmit it to them.

MS. CHANCELLOR: Thank you, Your Honor.

JUDGE FARRAR: Ms. Gaukler.

MR. GAUKLER: One other preliminary matter. We had sent an E-mail to the Board concerning aircraft crash. I was just wondering what the Board's thinking was in that respect.

JUDGE FARRAR: We had gotten several

E-mails, one on May 22nd from your co-counsel, one on the 24th from you and one on the 30th from Ms. Chancellor, and all of them seem to make sense as far as we were concerned. So we were going to proceed on the basis outlined in those documents, unless you told us otherwise. But at some point this week, we'll have an off the record discussion just to make sure we're all in the same page.

And again, thank you all for -- I know as we get closer towards the end, the harder it is to make these arrangements in an efficient fashion, and it looks like you've done a marvelous job of it. So thank you.

If there are no other preliminary matters, then we were going to resume Mr. Gaukler with your continued cross-examination of the Ostadan/Khan panel, which consists of Dr. Khan.

CROSS EXAMINATION (Continued)

BY MR. GAUKLER:

Q. Good morning, Dr. Khan.

A. Good morning.

Q. Welcome back.

A. Thank you.

Q. The last time we were talking about the use of SAP2000, and I'd like to follow up with some questions on use of SAP2000 and its capabilities.

I believe you said that SAP2000 was very focused and very good for the evaluation and the analysis of structures; correct?

A. That's correct.

Q. And it couldn't handle non geometric linearities?

A. It can -- what the present capabilities are --

MR. SOPER: Could we get a little more volume of the system today, Your Honor, I think we're all having a little trouble.

JUDGE FARRAR: Until the sound technician gets here, let's make sure everyone talks loudly and clearly and right into the microphones.

DR. KAHN: Okay. SAP2000 handles nonlinear analysis, which is limited in its scope. It's not as exhaustive as some other programs in the industry would be. But it is capable of performing sliding analysis. It is capable of performing impact analysis.

Q. (By Mr. Gaukler) Now, I thought you said it could not handle geometric nonlinearities, though?

A. Geometric nonlinearities where you have the large changes in like large rotations, for example, it is limited at this present time.

Q. And that also would include large deformations?

A. No.

Q. No. It would include large displacements?

A. No. It would handle large displacement. If something slides 300 inches, it will show 300 inches.

Q. I'd like to hand out -- I'm not going to mark it as an exhibit but I'd like to hand out portions of the SAP2000 user manual. And I have the complete manual here, Dr. Khan, if you want to look at it.

A. Thank you.

Q. I'd like to have you look at the last page that I handed out. First of all, do you recognize this as excerpts from the SAP2000 user manual?

A. That's correct.

Q. And the last page that I handed out is Page 329 from the excerpt I've handed out. Do you see that?

A. Yes, sir.

Q. And there it says that the SAP2000 method of nonlinear time-history analysis is an extension of the Fast Nonlinear Analysis method developed by Wilson, and it gives us a cite and then it says, "The method is extremely efficient and is designed to be used for structural systems which are primarily linear elastic, but which have a limited number of predefined nonlinear elements. In SAP2000, all nonlinearity is restricted to the Nllink elements."

So if I understand correctly, SAP2000 is primarily a linear elastic program?

A. SAP2000 was originally developed primarily for linear elastic analysis. Then like any other program, nonlinear effects are included and all those nonlinear effects are defined in terms of their nonlinear Nllink element, which has compression, sliding and also some rotations. But limits is not defined.

Q. And the nonlinear analysis uses the method developed by Wilson; is that correct?

A. That's what this says, so I believe it.

Q. And do you know at what point the

nonlinear method by Wilson may break down in terms of nonlinearity?

A. Well, if the program was not written for where the object is changing its rotational behavior and that becomes important to the physics of the problem, then it would not. But, let's say, if you take a cask and it's just looked at simple sliding, in that case, it should give pretty accurate solution.

Q. But I guess I was asking specifically about your information and knowledge concerning the Fast Nonlinear Analysis method developed by Wilson, and if you knew specifically under what conditions or circumstances that Fast Nonlinear Analysis would break down? Do you know? Do you know?

A. No, I don't.

Q. Now, it says here that all -- in SAP2000, all nonlinearity is restricted to the Nllink elements; correct?

A. Yes.

Q. And I'd like to have you go back to the -- I think it's probably the fourth page that I handed out. It's the first page of Chapter XIV.

A. Okay.

Q. And do you recognize that as the first page of the chapter of the SAP2000 users manual concerning Nllink elements?

And for the court reporter, Nllink, is N-L-L-I-N-K.

A. This is page 243?

Q. Yes.

A. Yes, that's right.

Q. And here it says, specifically the first sentence, "The Nllink element is used to model local structural nonlinearities such as gaps, dampers, isolators and the like."

Did I read that correctly, the first sentence?

A. Yes.

Q. And so doesn't it say that the Nllink element is to model local nonlinearities?

A. How do you define local nonlinearities?

Q. Well, is 40 feet a local nonlinearity linearity when it's 40 feet?

A. Yes, for sliding, yes. Slide nonlinearities is for being two elements in a finite element model, okay. It could be a gap between two objects, it could be frictional force between two objects, it could be sliding within the two objects. Those are all defined as local nonlinearities.

Q. Now, you say between two finite elements, I take it you were modeling an element on the cask vis-a-vis a point on the ground in your analysis in terms of measuring displacement?

A. No, it would be simply a rigid member extending from the base to a certain height, and if you are looking at pure sliding, yes, that would be the nonlinearities between two surfaces or between two points.

Q. And one point would be at the original location of the cask?

A. It's starting. It has to start from some point.

Q. So that would be a point that you would be measuring it from, the nonlinearity from, is the initial location?

A. That's how it is done.

Q. And so you're measuring a nonlinearity at the point of the cask at some point in one of your analysis, you got 40 feet away from the cask; correct?

A. The program automatically calculates that figure.

Q. And that still is a local nonlinearity, that local structural nonlinearity in your mind, that 40-feet displacement?

A. That's local because of local effects, what happens to a response is that's what you incorporate.

Q. Local effects as opposed to the displacement, but isn't the -- you're starting from a point where basically the two points are virtually together or within that same point; right?

A. Yes, sir.

Q. And so you're measuring some nonlinearity at those two points which are very close together when you begin your program; right?

A. Yeah, physically not connected, that's how define it.

Q. And at the end you're measuring some nonlinearity between those two points that's approximately 40 feet apart; is that right?

A. It's a relative displacement.

Q. Yeah. If you go to the next page, this is Page 244 of the handout and it gives some examples at the bottom of Page 244 of types of nonlinear behavior that might be modeled by this Nllink element.

A. Yes, sir.
Q. And the one I see is viscoelastic damping; correct?
A. Yes, sir.
Q. And gap and hook tension only?
A. That is correct.
Q. I take it the gap compression is only when you are looking at a gap and seeing whether it closes?
A. That's correct.
Q. And a hook, you're looking to see whether -- hook tension, you're looking to see whether something pulls apart?
A. Yes.
Q. Locally, it's a local point?
A. Yes.
Q. And what you're interested there is to do two things, pull apart or to stay together; correct?
A. That is correct.
Q. And with the gap compression, you're interested in something relatively close with the gap in where they actually hit at some point in time; correct?
A. No. All it does, it's between -- it's

starting two points, that is a compression between two surfaces, and as they move, that compression could change during the nonlinear behavior.

Q. And then the other one is uniaxial plasticity.

A. Okay.

Q. And then there's biaxial-plasticity base isolator?

A. Yes, sir.

Q. And then there's friction-pendulum base isolator?

A. That's correct.

Q. And those are the examples it gives; correct?

A. That's correct.

Q. Now, do any of these examples involve displacements in the order of 40, 50 feet?

A. That is a theory on which all these nonlinear programs are based, and no program that I know of will give you an example where an input motion was applied and displacement of 50 inches, 60 inches or 30 inches were obtained and compared with the test data. And that has been my question all along.

Q. I don't think you answered my question.

Do any of these examples involve displacements on the order of 30, 40 feet in these type of examples where you would expect displacement, your nonlinear displacements or movements to be in the order of 30, 40 feet? Can you answer the question?

A. Yes, you could have.

Q. You could have?

A. Yes.

Q. That's your testimony?

A. Yes, sir.

Q. Is there any limit in the displacement in the Nllink element beyond which the solution would break down, to your knowledge?

A. The only limitation that you have -- as far as sliding displacement is concerned, there was no limit, okay. As long as it continues to move. Where limit could be is as the program says is where the geometry due to rotation is going to be such that it will introduce inaccuracy. But otherwise, the limit is not imposed. You know, if a solid object is moving, it moves 10 inches or 50 inches, it would depend upon the input motion that somebody applies, what the stiffness is between two surfaces interacting and the physics of the problem.

Q. And so the displacement could be 400 feet?

A. If you apply a large input motion, in other words, if you keep on increasing the intensity of the earthquake, your inertial force will increase and your friction is very small, yes, you could have -- and it's all inertial balance that program writes an equation of motion and solves it at a given set of time. It is no different for sliding problem. I said again, it is no different than any structural nonlinear analysis program.

Q. So it could be 400 feet or 4,000 feet, the program could handle it, is what you're saying, there's no limitation on the capability of the program to handle that, even though it doesn't handle a nonlinear geometric -- geometric nonlinearities, excuse me?

A. Geometric nonlinearity. If you are using a compression element that allows it to slide, depending upon what input motion you apply and what input parameters you have, it will give you solution what any other program would do.

Q. And what if you introduce a situation where in addition to just sliding, you have lift-off two feet? Now, that's a geometric nonlinearity; correct?

A. That's where the compression only element is used.

Q. Well, no, my question is, you have sliding, you talk about sliding 40 feet. Now, in addition to sliding, you have the cask going up --

A. Yes.

Q. -- two or three feet. Now, doesn't that introduce a geometric nonlinearity when you combine the two together?

A. If it purely lifts up vertically, then the C gs are still within the limit. Where you will introduce significant nonlinearity is if you have a significant amount of rigid body rotations. Okay. Rigid body rotations. And that's when significant -- what you call kinematics type of nonlinearity becomes effective.

Q. So if I lift up and go five feet or 10 feet, even though I have a large angle, significant angle between my point of origin and the point where the cask is, there's no geometric nonlinearity involved in that, is there?

A. For translational displacement, which means -- translational displacement, means it moves sideways, it moves up. That is not a change in the center of gravity of the object. Therefore, that is only -- that's not a kinematic nonlinearity. Kinematic where you have a motion of the rigid bodies. That is not related to the nonlinearity you're talking about where you may have large rotations.

Q. So you don't consider that to be a geometric nonlinearity as you used the term before?

A. The program basically uses a solution, and it uses compression only stiffness and it incorporates the changes in the X, Y and Z coordinate system of the moving objects, and basically keeps track of it. Where you may have, let's say, difficulties, is if not only changing X, Y, Z coordinates, it also starts changing the, because of rotations, large rotations, the center of gravity of a structure. So that could introduce some inaccuracy in the solution, and it depends on how much rotations you have. For a small rotation, you will see probably nothing.

Q. So I take it the answer to my question, just going up two, three feet and going out five, 10 feet, you would not consider that to be a geometric nonlinearity?

A. The program does not consider that as a geometric nonlinearity.

Q. And would you consider that to be a geometric nonlinearity?

A. No. The program does not consider that.

JUDGE FARRAR: Mr. Gaukler, if you'd wait a minute while we check the sound system here.

(A discussion was held off the record.)

JUDGE FARRAR: Mr. Gaukler, sorry for the interruption. However, we're getting the sound things -- sound system working better. Go ahead, if you would.

Q. (By Mr. Gaukler) Now, if the casks were to start to tip over, that's when you would begin to have a geometric nonlinearity as you consider that term; correct?

A. Not the start. If you have large rotations, which could change the geometry to a point where it starts equation -- affecting the equations of motions, yes, I would consider those.

Q. And now, with a friction coefficient of 0.8, wouldn't you expect a cask to tip over before it would move 40 feet? Just as a physical matter.

A. There are a few things. I've got some time history that PFS provided. I've got those time histories. And I wanted to show that how sensitive your vertical motion could be, and if the cask lifts up due to these motions, then you basically have no effect of coefficient of friction at that inset of time, and its ground is just moving with respect to the casks. So when you got three motions acting simultaneously at that time, anything is possible. And I think one thing that we should recognize is nobody can predict the nonlinear behavior exactly.

Q. So what you're saying is that you wouldn't, with a coefficient of friction of 0.8, you wouldn't expect -- necessarily expect a cask to tip over before it moved 40 feet, is what you're saying?

A. Anything is possible. Actually, what my calculation did was, it selected a range of parameter to show that such a thing is possible if there was a case like this. Okay. So all that shows is not a fixed value. It's a range of values that one could observe during the analysis.

Q. My question was, a coefficient of friction of 0.8 means the cask doesn't slide very well; correct?

A. No, that doesn't mean -- it depends what vertical motion is doing to the cask. If it's lifting, then coefficient of fiction has no effect.

Q. I'm saying, it doesn't slide very well, it would be prone to tip as opposed to sliding, is that correct?

A. No.

Q. You don't think so?

A. It would depend on where the cask equations of motions are at that time. There is no way one would be able to predict if vertical motions exciting the cask, jumping up and down, what is the most effective coefficient of friction? It could be .6, it could be .5, it could be .9. You could have a range of values that could give you a higher number than one would predict.

Q. Now, you ran this model -- this ground was .8 coefficient of friction; correct?

A. Yes, either from .2 to .8.

Q. And you ran this one with .8, the one case we're talking about; right?

A. Yes, sure.

Q. So therefore, I'm focusing on that, and my question was simple. Wouldn't you expect a cask of .8 to tip before it would slide?

A. It depends on the vertical motion.

Q. Now, what have you done -- when you got these results of 30 to 40-feet displacement and two feet up in the air, what, if anything, did you do to confirm or reconcile that the limitations on SAP2000 in some way did not affect those results? Did you do anything in terms of trying to evaluate whether the limitations on SAP2000 somehow corrupted or contaminated those results?

A. Well, what do you -- could you explain?

Q. Well, you got a result of 40 feet, and you have a program that says, you know, it's primarily a linear elastic program with some nonlinearities. Did you do anything to evaluate whether or not your model had exceeded the limitations of the program and that was the reason you were getting 30 to 40-feet displacement. Did you do anything in that respect?

A. No.

MR. GAUKLER: I'd like to hand out and have marked as PFS Exhibit -- could I go off the record for a second, Your Honor.

JUDGE FARRAR: Yes.

(A discussion was held off the record.)

(EXHIBIT-219 MARKED.)

JUDGE FARRAR: We're back on the record with the pre-marked but not yet presented aircraft crash reports going up through PFS 218. That is those numbers being reserved for those aircraft reports. This will be Exhibit 219. And, Mr. Gaukler, you did say that the manual we've been talking about, you do not want marked?

MR. GAUKLER: That's correct.

JUDGE FARRAR: All right, our reporter has marked this latest diagram as PFS 219, so go ahead -- for identification.

Q. (By Mr. Gaukler) From the previous discussion we've had, Dr. Khan, I understand it's your position that the contact spring constant variable that one would use to establish a static equilibrium position bears no relation to the proper contact stiffness that one would use in simulating a dynamic problem. Have I fairly characterized your position?

A. Could you please repeat it.

Q. Basically, my understanding is that it's your position that the contact stiffness value that one would associate with static equilibrium position bears no relation to the proper contact stiffness value that one would use in simulating a dynamic problem?

A. No. What I said is -- let me repeat. One should look at the designed spectra, okay. Looking at the designed spectra, you look at the amplified region of the spectra. And from that amplified region of the spectra, in order for one to capture all the dynamic behavior, one should select those stiffnesses, and that would give -- that would capture the dynamics of the model. Now, some of them may be on the lower end of the spectra and some would be on the higher end of the spectra. So you -- if you do not know the actual test data, what the realistic value should be, you know, rocking frequency, for example, that's one of the reasons is how are you going to model the rocking adequately. What stiffness values one should use when you have a frequency of let's say two hertz, what is the acceleration at that point? What is stiffness one is going to use to model the rocking behavior in your system? And that was the explanation I'm trying to give is that one should use stiffnesses which are in the whole range, if you do not have the test data that validates any analysis.

Q. And, well, what you're saying, you

cannot use the contact stiffness from a static deflection for those purposes?

A. You should choose a range of contact stiffnesses and one -- every time you choose a contact stiffness, it would eventually have effect on the dead weight, which is the -- you choose a stiffness value, use that stiffness value, it will give you the dead load deflection.

Q. So --

A. So what you are trying to do is choose a stiffness which is going to basically show the rocking behavior of a particular object, and if one is not capturing that properly, then your dynamic response could be suspect.

Q. Well, let me ask you, just look at this figure that I've marked -- handed out and marked as PFS Exhibit 219. It shows a rigid cask, we're showing a rigid cask being dropped on a pad; okay?

A. Yes, sir.

Q. And it does a balance maybe one or two and comes to rest in a static position. Now, do you believe -- would you agree that a properly constructed model would be able to produce a good result for this problem, a good simulation of this problem using one model, and by that I mean, could you use this one model with one contact stiffness that would accurately simulate the initial dynamic impact of the cask, a subsequent balance of the cask and the final static position of the cask?

A. The answer is no. Let's say -- there are two reports that Holtec has produced. One is simply for dynamic analysis and the one for the cask drop analysis, a less dynamic program is used. So let's say if you take that model in a true nonlinear sense and put it on a pad and you analyze it, and you analyze it in a way where cask is jumping up and down, those stiffnesses are changing as a function of time. If you use those, that could probably give you a better solution. So you model the cask the way you have it in a three-dimensional finite element with all the elements within the cask model by appropriate element, all the masses distributed along the led, all masses distributed along the width of the cask, a radial direction of the cask. And if you were to do a true, true analysis, that would as the cask, let's say, applies more force, then you would have a deflection and the program will automatically -- would be able to do it. Now, again the question comes down to is how good has anybody validated those answers? The answer is no one has done it so far.

Q. But your answer is you cannot use the same model for this figure, this scenario I was showing you PFS Exhibit 219?

A. One can always use any model. It depends on the approximation.

Q. Well, could you get reasonable simulations using one model, in your opinion?

A. I have no idea.

Q. Could you do the simulation with your program and get reasonable results?

A. The program limitations are what you have just described, so it would not change the stiffness as it impacts. When you drop something, you have a nonlinear effect. The concrete surface could crack. It could crush. Has your stiffness changed as the cask drops at that point, the answer is yes. Is your model adequately predicting those in your evaluation, the answer is no problem, at least that I know of, or no problem has been solved in such a great detail where you have concrete crushing, where you have fuel draggling with thousands of degrees of freedom in the model.

Q. Two things: First of all, isn't that

what you did in this case three? You said you had a cask kind of bouncing up and down.

A. Well, case three, again --

Q. Isn't that what you were saying, basically this type of situation you just described now without getting into a lot of detail, isn't that what you described in case three?

A. It's limited again to the parameters and the program, like I say, capabilities. We have not modeled the basis springs and finite nonlinear element.

Q. And also isn't it true with respect to your model, you wouldn't be able to accurately predict the static deflection; correct?

A. The static deflection is predicted based on the stiffness value that one has chosen, and I have chosen a range of values to show this activity.

Q. And with respect to your stiffness of one times 10 to the six pounds inch, it would not accurately predict the static deflection; correct?

A. It shows a static deflection, but that's what it turns out to be. But it is also trying to account the rocking behavior of the cask.

Q. Well, all I'm saying is the static

deflection that you would have --

MR. SOPER: Can the witness finish? He's cutting off the witness in mid answer?

JUDGE FARRAR: Up to then, I think it was all right, but now I think you are.

MR. GAUKLER: And I apologize, Your Honor.

JUDGE FARRAR: Go ahead, Doctor.

DR. KAHN: Let me again explain. All I have done is use a range of stiffness values that would capture the dynamic -- that could affect the dynamic capability of this analysis. And that's all there is to it. It's a range of parameters, just like, say, coefficient of friction of .19, .2. Who could say what the actual coefficient of friction is going to be? So what shows a range, and that was a purpose.

Q. (By Mr. Gaukler) And my question was, initially, could you take one model with one stiffness value and accurately simulate this problem in PFS Exhibit 219?

A. There is no one model. Every analyst uses their own approximation, assumptions, and they would come up with a different solution. And what I came up with is what I presented.

Q. No, my question was, whether or not you could take this problem in PFS Exhibit 219, and in a model that one constructed for this problem, use one stiffness value to replicate or simulate the behavior seen in this model, the initial drop, the bounce and the final static condition, could you do that with one stiffness constant, vertical stiffness parameter?

A. I wouldn't do it that way. I mean if I had time and I had infinite computer memory, I'd rather do it three-dimentional cask with all the elements properly defined, all the, you know, slab adequately modeled, and we would do it that way, as opposed to going to another model and then somebody would ask another question and you would go to another model. And this was -- the purpose again of the study that I did was to show a range of parameters that would affect the dynamics of the casks, and that's all the purpose of the report is.

Q. I understand that, the purpose of your report. But my question is a little bit different. Is you take -- you considered a range of parameters. My question is, can you take one value of the parameter, i.e., one value of the contact stiffness and run this example or this model, this problem, and get a reasonable simulation of the motion and impacts shown on this page, which is the initial impact of the pad on the cask, subsequent bounce and then the subsequent static condition of the cask? Do you think you can pick a contact stiffness value parameter that would allow you to accurately simulate the motion and final static position of the cask as shown in PFS Exhibit 219? That's my specific question. Very specific.

A. I would not be able to predict whether any deflection that I get would be substantiated by any means. Yeah, it would be a theoretical solution. You can obtain lots of theoretical solutions, but it would be just a theoretical solution.

Q. But my question was, could you obtain a reasonable simulation of what would happen in reality with one contact stiffness parameter?

MR. SOPER: Well, he's answered the question, I think a couple of times.

MR. GAUKLER: I think he probably has, too, so...

JUDGE FARRAR: Objection overruled, if you want to continue to pursue it, Mr. Gaukler. I think Mr. Soper is correct, but --

MR. GAUKLER: I think he is, too.

JUDGE FARRAR: Okay.

Q. (By Mr. Gaukler) Before I leave this exhibit, I want to go back to one statement you made in the context of your model. Being able to predict bouncing, and I understood you to say, you really couldn't predict bouncing in your model? Did I misunderstand what you said?

A. Bouncing is -- it does take three motions into consideration, and as the cask moves up and down, it includes that into its analysis.

Q. I guess my question is, could your model do bouncing?

A. I'm not doing a bouncing analysis, I'm doing seismic three-dimensional analysis.

Q. Well, I thought you kind of said in one of your analyses, the casks essentially bounce and is your model capable of doing that?

A. The exhibit shows what I presented in those tables.

Q. I'd like to go on. The last time we talked, I showed you some ANSYS material on the choice of contact stiffness, that was specifically Exhibit SS. Do you recall that?

A. Yeah, I remember that.

MR. GAUKLER: Would you hand it out again, please.

JUDGE FARRAR: Mr. Gaukler, while he's handing that out, you said this has previously been marked?

MR. GAUKLER: Yes, it's been marked and introduced, PFS Exhibit SS.

JUDGE FARRAR: Thank you.

MR. GAUKLER: I would also like to hand out at this time, just so we have it available in case we need to refer to it, the copies of the hearing transcript the last time Dr. Khan testified here just in case we need to refer back to it.

JUDGE FARRAR: And these do not have to be marked since they're part of the transcript.

MR. GAUKLER: Right.

JUDGE FARRAR: Thank you.

MR. O'Neill: Is this the entire transcript or just portions of it?

MR. GAUKLER: This is a copy of the entire transcript of Dr. Khan's testimony, yes.

Q. (By Mr. Gaukler) I've handed out what's been previously marked as PFS Exhibit SS, and you remember discussing that last time you were here testifying; correct, Dr. Khan?

A. I was -- could you.

MR. GAUKLER: Could you repeat the question.

(The record was read as follows:

"Q. I've handed out what's been previously marked as PFS Exhibit SS, and you remember discussing that last time you were here testifying; correct, Dr. Khan?")

THE WITNESS: Yes, sir.

Q. (By Mr. Gaukler) And with respect to the second page of that exhibit, I asked you a question there about the minimum penetration given the best accuracies, if you remember correctly, and if you want to refresh your recollection, that was at transcript pages 7209 and 7210.

JUDGE FARRAR: Mr. Gaukler, before you ask the next question, seeing this print reminds me that I forgot to remind the witness at the outset today that having previously been sworn, he's still under oath, and Dr. Khan, have you been operating under that understanding?

DR. KHAN: All my life.

JUDGE FARRAR: Thank you, that's a good practice.

Q. (By Mr. Gaukler) And basically, I was asking the question if at that point, referring to the statement in the second page that minimum penetration gives best accuracy, that whether it was part of the ANSYS guidance that was part of this document, that the penetration would be deflection as a result from contact stiffness should be as small as possible. That was my question. And you answered at 7210, "It depends if you have a penetration problem. I don't think it's a penetration problem."

A. That is correct.

Q. And at the time, I understood your guidance, your answer as saying this guidance in SS was for a penetration problem. Is that what you meant to say, and we don't have a penetration problem here with respect to the cask?

A. Not to the same extent, that's correct.

Q. So you were saying that this guidance was inapplicable because it was not a penetration problem?

A. Penetration problems, as you know, it depends on the test. You got to show the test, and it depends how two bodies are interacting with each other. And this could be problem dependent, highly problem dependent. So yes, one could choose a value, but remember, the purpose of the selection of contact stiffness in a dynamic analysis is twofold. No. 1, is you are looking at the frequencies at which your system is going to respond. And that's if you want to capture the dynamic behavior of the cask, especially in the rocking. And how that is being captured is really the most important question. Now, if you have a test, it will automatically model everything in itself. In analysis, you can't really model so you start from a lower stiffness to a higher stiffness value and basically look at your response and see where you are in terms of your dynamic analysis. And that's the purpose. These penetration problems, like I say, they're problem dependent, they are object, two objects which are colliding with each other, and oftentimes, they are first calibrated and then these stiffness values are used.

Q. Now, I want to take a look, and I have the entire training manual here, if you look at the first couple of pages, isn't it true that this guidance is talking about basic concepts of contact stiffness? And I'd be glad to take and give you the entire training manual.

A. No, that's not necessary. The problem that you are solving is a different problem than what is being described here. And I basically said that a test date in a dynamic case where cask is jumping and show how ANSYS has calibrated those stiffnesses to predict a seismic response. And I have not seen any test data that shows the validity of this concept in a dynamic behavior.

Q. Now, my question is, isn't this guidance, general guidance not tied to any particular type of problem? It says contact stiffness basic concepts.

A. I mean we use contact stiffness and it depends on which problem you are looking, you choose those. This is not a penetration problem. Sliding is not a penetration problem.

Q. And my question to you, this guidance and contact --

MR. SOPER: Let me object to this continued reference to guidance. This is a training manual, not the manual for the program. And the reference to the guidance is a misnomer.

MR. GAUKLER: I would think a training manual would be more appropriate for guidance than the users manual, Your Honor.

JUDGE FARRAR: Well, why don't we just -- we can argue about that later, what it amounts to. Why don't we just call it the manual for now.

DR. KHAN: I also said that, you know, ANSYS has over 500 sample problem. Not a single problem they have presented that shows the validity of their concept.

Q. (By Mr. Gaukler) Now, my question is, does this say anyplace that this is limited to penetration problems?

A. It just says --

MR. SOPER: The document speaks for itself.

DR. KAHN: Yeah, it says the penalty of stiffness to help enforce the compatibility of contact interface, and that's just one of the ways of doing it.

Q. (By Mr. Gaukler) But it says basic concepts, contact stiffness basic concepts; correct?

A. Yeah, sure. This is what's written here.

MR. GAUKLER: I'd like to hand out some other pages from the manual. I'd like to have these marked as PFS Exhibit 220 and 221, and why don't we mark the larger one with 220 and the smaller one, which only has three pages, as 221.

JUDGE FARRAR: All right. We'll have the reporter mark those for identification.

(EXHIBITS-220 & 221 MARKED.)

JUDGE FARRAR: Mr. Gaukler, just to make sure we're clear, both of these documents have the same cover page, but the one with the larger number of pages, we've marked as 220 for identification?

MR. GAUKLER: Yes, as the second page and the one we marked as 220 says Advanced Contact and bullet presentations for ANSYS 5.6.

JUDGE FARRAR: Right. And the second page of 221 says determining a value and has three pictures on there?

MR. GAUKLER: Right, and it's Page 3-6 down in the lower end.

JUDGE FARRAR: Thank you.

Q. (By Mr. Gaukler) Now, the document that's been marked as PFS Exhibit 220 is introduction to the training manual and it identifies the different things that --

MR. SOPER: I object to the question. Mr. Gaukler is testifying as to what this document is, and those representations ought to come from a witness who knows the answer.

MR. GAUKLER: I would like to be able to finish the question first before he makes his objection.

JUDGE FARRAR: I took it, Mr. Soper, it's just a preliminary characterization. You're right, that it's only Mr. Gaukler's characterization and doesn't carry any weight in that regard, but I think it's a permissible way to introduce a question, so we'll overrule the objection. Go ahead, Mr. Gaukler.

Q. (By Mr. Gaukler) This is a course, a training course, as described at least in the introductory pages, for advanced contact and board pretension training course, so it's a training course for use in terms of contact stiffness and other matters that relate to it; correct? Is that how you interpret it?

A. It says advanced contact and board pretension.

JUDGE FARRAR: Mr. Gaukler, the cover sheet says it's a training manual. Is it important that it's part of a course or --

MR. GAUKLER: Not necessarily, no.

JUDGE FARRAR: Oh, I see. And inside page says welcome to the training course. Does the witness see that?

DR. KHAN: Yes, sir.

Q. (By Mr. Gaukler) And if you look at Page 14, one of the topics it identifies is contact stiffness; correct?

A. This is all for static cases. It has no resemblance to the dynamic analysis that's performed, it has nothing to do with the nonlinear dynamic analysis. It has to do with pretension of the force of two contacting surfaces.

Q. So it has nothing to do with the dynamic analysis?

A. It has nothing to do in the rocking of the cask. There is no ANSYS guidance.

Q. And how do you know it has nothing to do with the rocking of the cask?

A. Because all it is is training material that they want to promote basically the program, and that's all. This is nothing but a marketing brochure. All the theory is in the manual.

Q. You're saying that a training manual in terms of whether given advanced information is promotional and has nothing to do in terms of further training a person with respect to how the program can be used and its capabilities?

A. The program has a manual, and program is a theoretical manual. They can give you a seminar, basically, what the program does. So if your manuals are good enough and theory is explained enough, these could be used as a promotional --

Q. Well, have you gone to a --

MR. SOPER: Well, can the witness finish his testimony, please.

JUDGE FARRAR: Yes, go ahead.

DR. KAHN: In my olden days, I did have guys from ANSYS come and give talk on dynamic analysis and how to perform seismic analyses, how to perform impact analyses, yes. And we focused on the dynamic part of it, and we questioned them on its relativity. And the question that still remains the same is where is the test?

Q. (By Mr. Gaukler) Have you taken a training course in ANSYS in terms of where one of the topics is contact stiffness?

A. No, not contact stiffness.

Q. Have you taken any course in terms of -- from ANSYS in terms of use of the program?

A. Yes, I just said.

Q. Was that a course or was that somebody coming in and asking questions -- answering questions for you?

A. No, they used to come and give a seminar and then we invited them to come and specifically talk about seismic analysis of objects.

Q. And was that with respect to seismic qualification of acrylic which you were working with at the time?

A. Yes.

Q. Bumps, motors and the like?

A. That's correct. Dynamic analysis, yes.

Q. I'd like to have you --

JUDGE FARRAR: Mr. Gaukler, let me interrupt. We have a replacement court reporter here. If it wouldn't interrupt your train of thought, let's go off the record and let's take a ten-minute break while they switch.

(Recess Taken.)

JUDGE FARRAR: Folks, I'm sorry to be late getting back. As I understand my colleagues informed you, I'm a settlement judge in another case and have been trying to reach some people at a key point and was successful in reaching them. So I apologize for the delay in getting started.

Go ahead, Mr. Gaukler.

Q. (By Mr. Gaukler) Dr. Khan, are you familiar with the Hertzian Contact Theory?

A. Say it again, please.

Q. The Hertzian, H-e-r-t-z-i-a-n Contact Theory?

A. No, sir.

Q. So you don't know if it's a classical theory for contact mechanics?

A. No, not in relation to the dynamic analysis, no.

Q. Do you know how to calculate the contact stiffness between the HI-STORM and the pad?

A. I have seen Holtec report how it has been calculated using half space, and then the other time based on certain frequency, and those were the two ways you could use it. You could assume a value if you have test data and validate that way.

So there is no unique, one way of calculating. You could also do a very good finite element analysis, very detailed, and can calculate the displacements and can calculate the stiffness. But the question that still remains is that these are all variable with respect to time, and how you are going to change those with respect to time is really --

Q. Have you ever calculated the contact stiffness?

A. As I said, those are all in my report, the range of the stiffness that I used.

Q. I understand that you put in the range of stiffness that you used. Have you ever calculated using classical methods or finite element methods contact stiffness between two objects?

A. No.

Q. Do you know -- you made reference to static contact stiffness and dynamic contact stiffness. Do you know whether for elastic bodies whether dynamic contact stiffness would be greater than or lower than static contact stiffness?

A. I don't know.

Q. Are you aware that dropping of a cask or tipping over of a cask has been benchmarked?

A. I have seen that statement that dropping of a cask has been benchmarked in -- I think in one of the LS-DYNA reports, computer program called LS-DYNA I believe that Holtec has used that says that it has been benchmarked.

Q. Have you used that benchmark in any respect with respect to your model?

A. For a dynamic case that I know of, Holtec has not used. I just used Holtec's starting design parameters. The answer is no.

Q. You do not use that in any respect --

A. No.

Q. -- in modeling your case?

A. It would be interesting, though, to use it.

Q. I would like to go to question and answer 31 of your testimony.

A. Which exhibit?

Q. It's your own testimony, prefiled testimony, question and answer 31 of your prefiled testimony. It's the actual questions and answers of the prefiled testimony itself, not any of the exhibits.

A. If you have a copy. This one? Okay, I found it. Question number, sir?

Q. Question and answer 31. And in that question and answer you state your thesis that you should pick the contact stiffness to accord with the amplified region of the earthquake response spectra, correct?

A. Yes, sir.

Q. And you I take it set out a formula by which one should accomplish that task?

A. Yes, sir.

Q. And that formula is -- can you read that formula for me, please?

A. Frequency is equivalent to 1 over 2 pi under root K/M.

Q. The what?

A. K divided by M.

Q. The square root of that?

A. Yes.

Q. And in that formula F is the frequency of --

A. Of interest.

Q. The frequency of the cask?

A. No, frequency at which you want the system to be. Okay, so let's say you set your frequency 1 Hz, 2 Hz, 3 Hz, any frequency within the amplified range, so you set your frequency and then you know the mass and then you calculate the stiffness value.

Q. But are you talking about picking the -- so K would be the contact stiffness value we've been talking about, right?

A. Yes. It would be the stiffness corresponding to that structural frequency.

Q. And M would be the --

A. Total mass of the object.

Q. And here we're talking about the cask?

A. That is correct.

Q. So basically what you want to do is pick a contact stiffness such that you get a frequency F that's in the amplified range of the earthquake response spectra is what you're saying, correct?

A. That is correct.

Q. And then this frequency would be the frequency of the structural object here, the casks; is that correct?

A. That is correct.

Q. And that would be the vibration of --

A. Dynamics of --

Q. Dynamic movement of the cask, vibration or dynamic movement of the cask under earthquake conditions?

A. That's correct, sir.

Q. And I take it, then, that you used this formula to calculate what you considered to be an appropriate range for contact stiffness for unanchored casks which you refer to in question and

answer 32. Is that correct?
A. That is correct.
Q. And can you just kind of walk through one of those calculations for me and tell me how you did that? Say, for example, with 1x106 pounds per inch, how would you take --
A. I did not do any calculations. I said one could choose this formula to calculate a range of stiffness values to cover any dynamic amplifications that could occur. In the report that I presented, it just shows a value between 10 to the power 6 and whatever the last number was. But there is a way that one could look into the dynamics, and a range of stiffness values could be obtained by this formulation. I did not do this.
Q. But you say that 1x106 pounds per inch would correspond to a cask frequency that would fall in the range of the amplified --
A. Yeah, it would be one of the many frequencies that --
Q. That would fall in that range?
A. Sure.
Q. So can you show me how you used that formula, used 1x106 pounds per inch in that formula to come to that conclusion?

A. No, I did not use this formula. I just -- we started out with a smaller value, went all the way to the higher value.

Q. I understand what you did. I'm asking you to give me an example of using this formula.

A. Let's say --

Q. And why don't we take one of the variables that you said down here would result in the range of amplified --

A. Do you want me to do an actual calculation?

Q. Yeah. Let's take the stiffness of 1x106 pounds per inch.

(Pause while witness performs calculation.)

A. I did do a calculation with a calculator. Let's say what I have here is frequency is equivalent to 1 over 2 pi under root K divided by M. Let's say frequency is 2 Hz. 2 Hz times 2 pi is equivalent to under root K divided by weight divided by g. Then you describe both sides, so you get 4 pi squared is equivalent to K x 386.4 divided by, let's say the total cask weight is 360 kip, I used that, and therefore K is equivalent to this number. So whatever that number turns out to be, this would be one of the values.

Q. So assuming that you were interested in the frequency of 2 Hz, that's how you would calculate the K?

A. That's right.

Q. Now, you're saying -- and you -- in that process you used the mass equivalent to the weight divided by gravity?

A. That is correct.

Q. And so the weight was the 360,000 pounds?

A. That is correct.

Q. And gravity is 32 feet per second squared?

A. 386.4 inches per second.

Q. So for example, if I wanted to find out, suppose I wanted to work backwards and I wanted to find out the frequencies that you claim are relevant in question and answer 32. On that I just would take, say for the first one, 1x106 pounds per inch and put that in for K in that formula, correct?

A. Yeah. You could back calculate -- you can back calculate frequency or you can back calculate stiffness depending on if one number is given.

Q. So in other words, just by taking these two stiffness values, 1x106 and 10x106, and substituting them into the formula, I could get the frequency that you claim we should tune our structural system to?

A. Okay. Let's not -- all I'm saying is that one should use a range of frequencies, look at your response spectra and decide where the motion would be amplified, and you pick values corresponding to those in the absence of any test data. In the absence of. If I don't know any frequency of a structure and if I'm supposed to design a structure, I'm supposed to pick peak of the spectra times, another factor they call multiload factor, and then find the forces in the systems, displacements in the systems.

Q. So basically what I'm saying, though, is you would take these -- to see what frequencies you think we should look at specifically, you would take these numbers and substitute them in for K in that formula and that would tell you the frequencies?

A. It would be one of the ways one could approximate it. But it still is a rocking behavior, and in a rocking behavior you have one

A. Yes, I'm aware.

Q. So are you aware, therefore, that LS-DYNA was benchmarked per those cask drop tests?

A. Would you please --

Q. You understand, therefore -- I take your last answer to mean that you understand that LS-DYNA was benchmarked using these cask drop tests.

A. I have not seen the actual analytical results and I have not seen how exactly it was benchmarked, but I have read the statement that it has been, so I'm just taking it on the face value.

Q. You mentioned damping. Let's go into that topic, okay? New topic. You claim that the damping that Holtec used in its cask stability analysis was too high, correct?

A. Yes.

Q. And they used, Holtec used 5 percent critical damping in their -- using DYNAMO with respect to the modeling using DYNAMO, correct?

A. That's correct. And let me emphasize why I made that statement. If you are using a nonlinear sliding analysis and if your energy dissipation mechanism is sliding by friction, then by taking higher damping values you may be double counting it, okay? If a rigid body is sliding and if that's the assumption, then all the energy is being absorbed by these friction forces. And by taking certain amount of damping on top of it, you may be underestimating it or you may be double counting it. That's -- and that just -- I think the contact stiffness damping value is what really -- it might underestimate the dynamic response.

Q. Could you read back the last part of his answer?

A. It may underestimate the dynamic response.

Q. What may underestimate?

A. If you are using a contact stiffness damping high enough on top of sliding friction, and if you are taking both on a higher side, then your cask response may be underestimated.

Q. Isn't it true that -- first of all, do you know how -- how did you incorporate damping into your model?

A. It is a model damping.

Q. What?

A. It's a model damping.

Q. Assume that the cask just slides in your model. Is there any loss of energy or dissipation of energy due to damping in your model?

A. Yes.

Q. There is?

A. Yes.

Q. Do you know how Holtec modeled its --

A. Yeah. It specified the -- it's based on what I read in the report associated with those stiffness which are used in the model.

Q. So you had two stiffnesses in your model, you had a horizontal stiffness and a -- strike that.

Let's go back to some of the background on this, okay? First of all, you're aware that the damping that Holtec used in this model is not structural damping of the object itself? For example, the damping that may occur by the canister that may accidentally hit the inside the cask or the fuel baskets that may hit the cask -- may hit the canisters, correct?

A. All I see is a damping value. I don't know the basis of that damping value.

Q. Well, you've heard Dr. Singh and Dr. Soler testify here at the hearing several weeks ago, correct? You were here when they testified, correct?

A. Yes, sir.

Q. And do you recall that Dr. Singh testified that they did not include that type of structural damping in their model?

A. Mathematically damping is a damping. What it does is really, one can describe as long as a damping is used to damp out the motion, that's all that matters. It's just a number in your model. That's all there is to it.

Q. What's the physical damping that Holtec represented by the number that it used in this model? Do you know that?

A. You could describe it. It is -- if their program is working, the way it is using it is a constant value that gets applied to the stiffness associated with this structure.

Q. And get down to, usually you have a damping associated with this spring and the two go together, correct?

A. Yes.

Q. So you would have a spring in your model, then you would have a damper associated with that spring?

A. If you have a damping, justifiable

damping, yes.

Q. If you have damping, that's correct.

A. Sure.

Q. And in your model you had a spring between the base of the cask and the pad?

A. That's correct.

Q. And that's where you put in that spring -- that's where you put in your vertical contact stiffness was the stiffness of that spring, correct?

A. In my model the stiffness was for the entire structure, because the way I modeled it, there are beam elements all along the height of the cask and along the horizontal, in the horizontal plane, and then you've got the stiffness, contact stiffness at the base. So everything was associated with the damping that I used. So it was a structural damping. That includes contact element also.

Q. But with that contact element, the contact spring, you had a damper associated with that contact spring, correct?

A. When you specify damping, it automatically assumes it.

Q. With the spring?

A. That's right.

Q. And here you're talking about the spring between the cask and the pad, correct?

A. Yeah. I'm saying the entire structure, entire structural model, wherever you have a stiffness there is a damping associated with that stiffness. And it was from a whole structure not specific to the contact but including contact stiffness.

Q. But for the particular spring you had -- that damping value associated with a particular spring, you also had the contact stiffness associated with it, correct?

A. That's right.

Q. And that here in this spring we're talking about the vertical contact stiffness -- the vertical contact stiffness, correct?

A. Vertical as well as horizontal.

Q. So you associated damping with the horizontal spring as well?

A. Yeah. It was included in the model.

Q. So you had a damping of whatever it was, 0.1 percent to 5 percent associated both with respect to the vertical spring and the horizontal springs in your model?

A. Yeah, the structural -- that's right, everything.

Q. Well, let's suppose that hypothetically you did not include any damper with your horizontal spring; the only damping you had associated in your model was with respect to the vertical spring. Assume that hypothetically. Assuming that hypothetically, in just a purely sliding situation there would be no dissipation of energy with respect to damping, correct?

A. Could you restate your question?

Q. Hypothetically assume that you had no damping associated with the horizontal spring and you have sliding, pure sliding, no liftoff, nothing in a vertical direction -- pure sliding in the X and the Y horizontal plane. You would have no dissipation of energy with respect to damping; isn't that correct?

A. My structure still has a damping, so there would be some damping associated with those structural element. The only thing that you would be neglecting is the damping associated with the base contact stiffness. But the structure will still be damped.

Q. Well, you would not be including any

damping with respect to the horizontal movement, correct? You would be ignoring any structural damping with respect to the horizontal movement since you have no damper associated with the horizontal spring. Isn't that correct? Hypothetically. I'm talking hypothetically now. You have no damping associated with the horizontal spring; therefore, assuming that to be the case, there would be no dissipation of energy due to damping in a purely sliding situation. Isn't that correct?

A. Sure, that's correct.

Q. So assuming that Holtec did not include any damping in the -- with the horizontal spring, then -- strike that. So in that situation that we just talked about, there would be no damping associated with the horizontal spring, friction would be the primary source of energy dissipation, correct?

A. That's what's being used.

Q. And that would be the case, energy would be the primary source of -- friction would be the primary source of energy dissipation with respect to sliding, and assuming that you had no damping associated with your horizontal spring, correct?

A. Sure.

Q. Now, let's focus on the vertical spring. Now, if -- assume that you have some -- and you have some damping associated with the vertical spring, okay? Assume that we have damping with our vertical spring and assume that we have motion of the cask, tipping or rocking slightly where the cask tips up somewhat, comes back down on the pad, hits the pad, tips up again in a different angle someplace else slightly, comes back down on the pad. You would agree, would you not, that there would be some energy dissipation in those impacts between the cask and the pad, correct?

A. There would be some, yes.

Q. And that it would be appropriate to include some damping value for that impact, correct?

A. Yes.

Q. Now, this damping impact that you would have between the cask and the pad in that situation, you could think of it -- you could analogize it to dropping a ball, some type of ball on a hard surface, correct?

A. No.

Q. Well, when you drop a ball on a hard

surface it bounces up part of the way, correct?

A. No. The damping -- what you have is an earthquake motion. You have an object that's sitting and is moving up and down, okay? Let's say if the structure is flexible, then you have a structural damping associated with it. Okay? You have a combination where simply because of motion of an object in the air, its internal deformation, rattling internal stuff, you may see some damping associated with it. The vertical stiffness you are going to get, there would be some impact stiffness and some impact damping associated with it. I don't really know whether it's 1 percent, half a percent, 2 percent. Nobody knows.

Q. So you don't know what the impact damping would be of the cask hitting the pad?

A. Unless you experimentally determined it.

Q. Now, would you admit that, assuming that the cask and the pad were perfectly elastic, that would mean that no energy was dissipated? Say you take a ball and you drop it down from say a height of a foot, and the perfect elastic ball comes back up a foot. That would be a perfect elastic --

A. I would not use that analogy. There's a dead weight associated with that structure. So, you know, if there is no gravitational effect, we'll all be flying. The gravitational effect is going to bring everything down to the floor. So there is a gravitational effect that's working when something is dropping.

But when you look at the vibration dynamics in the vertical direction, it has barely associated with how, how much -- what kind of stiffness you have for the object in the vertical direction and how it is going to respond in the vertical direction under a dynamic situation.

Q. Now I'm getting a little bit confused. Let me make sure we're talking about the same thing.

A. Sure.

Q. When you talk about the vertical direction, are you -- let's assume that there's no damping and no loss of energy with respect to the internals of the cask, so we're basically talking about -- assume that the cask is a rigid body, okay, and all of the internals are rigid so there's no internal rattling during the earthquake so there's no loss of energy from the internals of the cask. Okay?

A. Yeah.

Q. And that the only thing you have is the impact of the cask back down on the pad, then it comes back up again and you have another impact back down on the cask on the pad. And now my question is, can you analogize that just to a ball dropping from a foot, say, and see how far it comes back up and that would give an idea of the damping that you have associated with that impact?

A. There would be some damping associated with it, but unless you do, again, an impact type of analysis and you match your dynamic model with the test data, you wouldn't really know exactly how much damping is associated with it. So those dampings are experimentally determined.

Q. Well, let's just take an example. Suppose you have perfectly elastic bodies. Let's just take a perfectly elastic ball, and I drop it down from a foot and I have a perfectly elastic surface. That means the ball bounces back up a foot again, correct?

A. Sure.

Q. That's a perfectly elastic body. Now, if I take a perfectly plastic body and drop it from a foot, it's not going to bounce back up at all, it's going to stay on the surface, right?

A. Yeah.

Q. And that the -- and in between you can have a wide range of properties between a perfectly elastic body and a perfectly plastic body, correct?

A. But remember, when the two objects are interacting you are internally deforming them, and therefore a lot of energy could be lost as a result of interaction between the two bodies. So if the other object displaces or deforms elastically or inelastically, you have lost some energy in those collisions. And therefore you don't really know how much -- how much is energy you are contributing to the damping or how much energy you are contributing to the stiffness associated with those objects.

Q. Let's assume that we have perfectly rigid bodies, okay, so we don't have this deformation. Okay? And if you have a perfectly elastic body, it does not use any energy upon impact. That's how come the ball would drop from a foot, would come down and back up to a foot again, correct?

A. Sure.

Q. And now my example of the perfectly plastic body -- so in my perfectly elastic situation where I drop a ball from a foot and it comes back up, there would be no dissipation of energy in that process, correct?

A. There would always be some dissipation, always be some dissipation of energy, because you have air. You're not doing this experiment in vacuum.

Q. I'm assuming the perfect elastic body, okay? There's no dissipation in terms of the impact, correct?

A. Okay.

Q. Is that correct?

A. Sure.

Q. Now, if I have a perfectly plastic body and I drop it from a foot, I'm going to dissipate all of the energy upon impact, correct?

A. Sure.

Q. Now, by picking a low damping value, you suggest in your report that you should use either a 1 percent damping value or maybe even .01 in one of your runs. What you're saying is that the cask/pad system in fact acts more in the elastic range as opposed to the plastic range. Is that what you're saying?

A. All I'm saying is if you are -- let's say, assume that you have a coefficient of friction of 1, 1. That means it's perfect. It is attached to the body surface.

Q. Do you mean to say coefficient of friction?

A. Coefficient of friction 1.

Q. How did that get into the discussion of damping?

A. I'm just saying, that means you are trying to divide your energy into two. One is through friction and one is through structural damping. And if you are using your structural friction damping as the most dominant part, then what is the -- what is the damping associated in the sliding? You have a structure that's sliding, you have a base of stiffness, and you are assuming a damping associated with those shear stiffness. I mean, that's what Holtec analysis has done. Holtec analysis has used the stiffnesses and corresponding damping.

Q. I said hypothetically we're assuming no damping in the horizontal spring. We're just talking now about damping in the vertical spring, and there's no damping in the horizontal spring. And we've agreed in that situation that with sliding, friction would be the primary dissipation of energy?

A. Yeah.

Q. Now, I'm focusing on the vertical spring.

A. Yes, there would be some damping, sure.

Q. And my point is that by taking a damping value with respect to the vertical spring, you are in effect saying that the cask/pad system with respect to the vertical spring is in, more in the elastic range than in the plastic range, and you would in effect be much more likely to bounce like my example with the perfectly elastic ball, correct?

A. Well, 1 Hz frequency, 1 Hz frequency is a very low frequency.

Q. You're answering my question or not?

A. Well, I think we may be looking at two different things. I'm looking at a dynamic situation. How are you making a model? You make certain assumptions, okay? We made certain assumptions on damping, we made certain assumptions on stiffness. And we have produced a range of stiffness and damping that could have effect on the dynamic behavior of the casks.

If you have a test data, all of these things would be really a moot point, in my mind. So coefficient of friction could be higher, it could be lower; damping could be higher, damping could be lower. All of these mathematical simulation is one's idea of describing how he perceived this problem to be. And you have seen that Dr. Luk, he has analyzed this same structure in an entirely different way as opposed to Holtec and really the same. So you'd be -- under the assumption of criteria, you will have a difference.

So what I'm saying is that the cask dynamics is a function of many, many parameters, including damping. I don't know whether the damping is 1 percent, 2 percent, 5 percent. In general for dynamic analysis, damping is -- NRC has, in various reg guides you choose damping values between 1 and 7 percent depending on the structures that you have. And for those cases, especially in the nonlinear cases where you do not know if you're damping, they have to be experimentally determined.

Q. And my question was to you, that by using a damping value, low damping value like 1 percent, .01 percent as you've done in some of the runs in your case with respect to the vertical spring, you are in essence assuming that the cask/pad interface is elastic and you'll get a bouncing effect similar to an elastic ball or close to an elastic ball. Isn't that correct?

A. 1 Hz frequency does not tell me it's elastic anything. It just says 1 Hz frequency.

Q. You use a damping value of 1 percent and .01, correct?

A. Yes.

Q. And that is a very low damping value, correct?

A. Yes.

Q. And results in very low dissipation of energy upon impact between the pad and the cask, correct?

A. That's right.

Q. And therefore that's very similar to, albeit it's not completely elastic, that's very similar to an elastic ball or almost perfectly elastic ball coming down and bouncing back up maybe not completely all the way up to the height it dropped from, but pretty close to the height it dropped from.

A. But you've got a combination of

horizontal and all sorts of motion. The analysis that I have done is a three-dimensional analysis. It includes all the motions. It has a horizontal motion, it has a vertical motion, it has a friction, it includes various effects and whatever the dynamics is in that instant of time.

Q. But I'm talking about the proper dissipation of energy with respect to the damper associated with the vertical spring. And isn't it true, just focusing on the dissipation of energy with respect to damping associated with the vertical spring where I just described to you is correct, you basically are assuming that you are in almost a perfectly elastic condition by using a very low damping value such as 1 percent or .01 percent?

A. Low damping has nothing to do with a perfectly elastic or perfectly plastic. It has nothing to do -- in the plastic case when you have two bodies impacting, it's an energy dissipation mechanism you are using.

MR. SOPER: Might I ask the Board if they could admonish some of the spectators. Dr. Singh is laughing and slapping his head and distracting me from hearing the witness, and I think it takes away from the decorum of this proceeding.

JUDGE FARRAR: I had not noticed that, Mr. Soper, but I assume that all the people here will be comporting themselves in a professional and nondistracting manner.

MR. SOPER: Thank you, your Honor.

MR. GAUKLER: I've lost my train of thought now. If you can go back and re-read the last two questions and answers.

(Requested portion of the record read.)

Q. (By Mr. Gaukler) Physically what that does that mean, Dr. Khan?

A. Physically what it means is an object resonating at a certain frequency has a certain damping value. It is moving up and down with the motion that is being applied. That's all there is to it.

When the damping increases, of course your motion is going to decrease. It will still be in the elastic. All the analysis that we are doing is elastic with respect to the stiffness that you're using. This is not a bilinear stiffness in the vertical direction.

Q. What I'm saying is, though, that by

using a very low damping value, you are essentially assuming that the -- that it's almost a perfectly elastic situation?

A. At zero percent damping you could say that. As the damping increases you are damping out the motion, and it could still be elastic but you would be dissipating energy for the high value.

Q. And as you worked yourself up from zero, you'll have, you'd be getting less elasticity as you went up from zero in terms of the damping value, correct?

A. Again, not elasticity. It is the damped motion.

Q. So you would have more damping of motion as you went up from --

A. That is correct, associated with that motion.

Q. You'd also have more dissipation of energy by the same token, correct?

A. That's correct.

Q. I take it from your statement that you don't know whether it would be 1 percent, 3 percent, 5 percent, some other percent of damping; you have not attempted to evaluate how much loss of energy you would have in the impact from the cask and the pad, correct?

A. That's correct.

Q. And is it also true that your prior work experience did not involve evaluating the loss of energy between a body and a concrete pad?

A. That's correct.

Q. And virtually all your work before concerned bodies that were anchored, correct?

A. Mostly, yes.

Q. And therefore you're not purporting to give an opinion as to what percent damping would or would not be appropriate in this case, correct?

A. That is very correct, yes.

MR. GAUKLER: I'm about to go on to a new topic. Do you want to take a break for lunch now or continue? I guess the next topic would take --

JUDGE FARRAR: How long would you -- we did get a late start today, so --

MR. GAUKLER: The next topic may not take that long -- a few minutes, half hour.

JUDGE FARRAR: If everyone can hold out, why don't we do that. In that case trying I'm to settle I can reach someone else after one o'clock, so I'd rather not stop now.

(Discussion off the record.)

Q. (By Mr. Gaukler) I'm going to be referring to question and answer 33 in your testimony and to pages approximately 15 and 16 in your report.

JUDGE FARRAR: And that report, Mr. Gaukler, is State 122?

MR. GAUKLER: I believe it is. I don't have the number. It's the report dated December 11, 2001, Altran.

Q. (By Mr. Gaukler) Now, in question and answer 33 of your testimony you state that it's possible that a cask could tip over in a 2000-year design-basis earthquake, correct?

A. That's correct.

Q. First of all, your model does not directly model cask tipover directly?

A. That's correct.

Q. So this is something you arrived at indirectly as opposed to directly?

A. That is correct.

Q. And if I understood what you said in your answer, question and answer 33 and what you state at pages 15 and 16 of your report, your conclusion that a cask might tip over in the

2,000-year design-basis earthquake is based solely on the velocities of the cask's movement that you calculate in your model, correct?

A. That's correct, sir.

Q. And basically you predicted in your model that the casks could move with velocities that would be greater than those for which you believe it might be possible for the cask to tip over, correct?

A. That's correct, sir.

Q. And for example, specifically on page 16, bottom of the page in the report, you specifically refer to steady run No. 1 in Table 3, correct?

A. That's correct, sir.

Q. And Table 3 is the one that appears on page 13, correct?

A. That is correct, sir.

Q. And as a matter of fact, the Table 1 is the one we've discussed -- I mean, the run -- steady run No. 1 in Table 3 is the one we've discussed several times before, which is the cask moving 40 feet, correct?

A. That's right, 360 inches.

Q. And that's in one direction. I think we took the -- we take some of the squares and then you probably get a roughly 35 to 40 feet lateral displacement, correct?

A. That's right.

Q. And so your conclusions about potential cask tipover is solely based upon the velocities that you developed in your runs for Table 3, correct?

A. That is correct.

Q. And you do not have any other data upon which you base your conclusions that the cask might tip over other than that, correct?

A. That is correct.

Q. With respect to that run 1 on Table 3, we've discussed this before. And I just wanted to clarify, that's the one that moves roughly 40 feet, 35 to 40 feet in a diagonal direction and it goes up, bounces up two feet in the air. Last time I believe at the hearings you indicated that you did not know whether these results would be accurate or would be something that would accurately predict reality, correct?

A. That's true.

Q. So just so the record is clear: you're not asking the Board to believe that in the event of a 2,000-year design-basis earthquake that your model, particularly this run, accurately predicts what in fact would happen with the casks?

A. I will rephrase it, sir. These are the range of damping values for which the runs were made. If one was to experimentally determine that the damping is indeed .01 percent, which is very low, then one would expect this kind of solution. But if one shows that the damping values are 1 percent, 3 percent, 5 percent, accordingly the solutions are going to change.

Q. And you said before you did have an idea -- you were saying what the damping value should be here, should be in this situation?

A. Yeah, I --

Q. Now, you referenced the fact that the --

JUDGE FARRAR: Did you finish that answer?

THE WITNESS: Yes, sir.

Q. (By Mr. Gaukler) -- that the solution -- so in other words, the point of your study was just to show that the solution was sensitive to the choice of input parameters?

A. Yes, sir. I have a sheet that I got from the time history analysis that PFS has provided, and I'd like to just show that to you, sir, to specify why this could be happening. Is it possible I could --

Q. I would say your counsel can do that on redirect. They'll have a chance to put that up at that point in time.

A. What this means is your time histories become very, very sensitive, or the PFS time history that we have is very sensitive at low damping value.

Q. Now, is it also possible that in addition to the solution being sensitive to the choice of input parameters that the program's ability -- that the solution could also be sensitive to -- the program's ability to reach a sensible solution may depend on whether it can handle the input parameters put into it?

A. The program is as good as any other program. I don't think -- unless the rotations are very, very large, then I would believe. But for rotations which are smaller, 3 degrees, 5 degrees, I think it should be adequate.

Q. So you don't think that's a reasonable possibility, in other words, is what you're telling me?

A. Well, I think you also look at the model. Your model becomes very sensitive at low damping; your model becomes very sensitive with the coefficient of friction; the model becomes very sensitive how you model this also. Just because this is a model number third doesn't mean results are not going to vary if you change it. It has been shown by others that the results could vary also if you take instead of eight maybe 32 springs or maybe 36 springs, or if you take a full rigid body you could have a different solution.

Q. I guess my question was just whether or not, in addition to being sensitive to the choice of input parameters, another potential source of sensitivity might be whether the program can handle the particular input parameters you use. Is that another possibility?

A. It didn't appear in this case.

Q. Did you check?

A. Yes, sir.

Q. How did you check?

A. Looked at the manual, talked to people. I did additional runs. I mean, and the manual tells you what you could use, and that's the basis.

Q. Did QA raise any issues at all in terms of the -- your QA raise any issues at all with respect to the use of the program in these certain senses?

A. The QA program came with a certification manual for which the program could be used.

Q. I think you probably misunderstood my question. I don't mean to interrupt your answer. My question was directed towards Altran's QA review. When your document underwent QA review, did any of the people reviewing your report raise a question on whether the program was capable of handling this type of model, SAP 2000?

A. The report has a checker. It has approval and we followed the guidelines, used the program the way it was described, and we did validation of the program through known solution.

Q. But my question was, did any -- was an issue raised by any of the QA reviewers in the review of whether SAP 2000 was an appropriate program to run this type of model, particularly the type of models you were running in Table 3?

A. No.

Q. I believe you state at some point in your testimony that the NRC -- excuse me -- Altran has a QA program approved by the NRC?

A. No. In our -- let me rephrase it. We have a QA program that conforms to Appendix B.

Q. I believe it's question and answer No. 20, if you could look at that. The last part of the question, question 20, the question is whether or not your analysis complied with the NRC quality assurance requirements, and you mentioned the fact that you have a QA program in accordance with 10 CFR Part 50 Appendix B, and at the very end you go on to say, "And was approved by the NRC."

A. I think -- let me correct this thing. This is -- the requirements are made by NRC, and we basically follow those guidelines and we conform to those. NRC does not come and, you know, approve a program. We have a team that comes and audits our program, and that has been audited by nuclear council.

Q. By who?

A. There's a group of utility and their quality engineers, they go company to company and audit their programs, and so it was also audited.

Q. So the statement that "and was approved by the NRC" is a misstatement?

A. Yeah. The quality assurance program is by NRC, but NRC does not approve your program or follow the program.

Q. And they did not specifically approve your program?

A. No.

Q. Now, in question and answers --

Off the record for a second.

(Discussion off the record.)

Q. (By Mr. Gaukler) Now, in question and answers 34 and 35 of your testimony you claim that Holtec needs to benchmark its cask stability analysis with actual shake table test data, correct?

A. This is question No. 34, sir?

Q. Yeah, question and answers 34 and 35 in your testimony.

A. That's correct, sir.

Q. Now, I take it that your claim that actual shake table testing is necessary here, at least one of the primary reasons why you think it's necessary here is because of the results of your analysis which you conclude show that the cask movements are highly sensitive to the choice of contact stiffness and damping?

A. This is not only my claim. I think there's an NRC Reg Guide 1.100 endorses IEEE 34475, and basically states that for nonlinear analysis where you don't really know what the solution is going to be, you perform tests and validate your analytical data. You do some kind of benchmarking of your -- so this is just following a requirement that for nonlinear analysis that could be very sensitive, you perform shake table tests.

Q. So what you're saying -- well, so you're saying two things, then. You're saying that, number one, your analysis those that the movements are highly sensitive; and number two, you claim that Reg Guide 100 in those circumstances require shake table testing. So there's two parts?

A. Validation of it, that's right.

Q. So there's two parts to why you do those shake table tests?

A. That's right.

Q. Shake table tests should be done here?

A. That's right.

Q. Let's focus on the first one first. Assume that the results of your analysis were wrong. Assume you were showing that the results of your analysis were wrong and that cask movements are not highly sensitive to the choice of contact stiffness and damping. Wouldn't that undercut your rationale for why you claim shake table testing is necessary here?

A. No. The analytical means is not an acceptable means of justifying somebody's lower number. Okay, just because I get a smaller number and you get a larger number does not stop you from proving whether the larger number is wrong or the smaller number is wrong.

Q. My question was, assuming that it were determined hypothetically, okay, determined that the choice of contact stiffness and damping was not -- strike that. The cask movements were not highly sensitive to the choice of contact stiffness and damping, that would undercut the primary basis why you believe shake table testing should be done here?

A. In the absence of any test data, one analysis would show a smaller number, one analysis show -- so I would disagree with your statement.

Q. Well, suppose your analysis is shown to be wrong for whatever reason. Suppose that contrary to what you say it was shown that you exceeded the bounds of SAP 2000 and that led to the program blowing up and giving you erroneous results. Under that hypothetical condition --

A. You still have to do a test.

Q. Wouldn't that remove, undercut your argument that you need to do shake table testing?

A. You still have to do shake table testing because you don't have any basis for any test data, any results even from a program that might seem to be giving you a correct solution.

Q. So I take it, then, by that statement you believe that shake table testing would be required basically in every case where you have a nonlinear performance?

A. You essentially have to validate a portion of your analysis, and then you extend those analyses to include all the cases for a design purpose. That's how we do all the testing.

Q. Is that the practice in the industry, as far as you know?

A. That's what at least I was used to.

Q. And that was the area of seismic equipment qualification, correct?

A. That is correct, sir.

Q. And that area you were dealing with -- one of the standards you were dealing with was IEEE standard 344-1987?

A. That is correct, sir.

Q. That was one of the primary standards you were working with, correct?

A. That was one of the primary standards.

Q. And also Reg Guide 1 --

A. 1.100.

Q. And let's focus on that.

JUDGE FARRAR: Mr. Gaukler, if this would be a good point before you launch into what sounds like a --

MR. GAUKLER: It's going to be probably about a 15- to 20-minute topic.

JUDGE FARRAR: Okay, it's five of one. Let's break until two o'clock.

(A recess was taken.)

JUDGE FARRAR: All right. We're back for the afternoon session.

Mr. Gaukler, just for planning purposes, how much time do you think you have left?

MR. GAUKLER: Less than an hour.

JUDGE FARRAR: Oh, good. Okay. Then let's get right on with it.

Q. (By Mr. Gaukler) Good afternoon, Dr. Khan?

A. Good afternoon, sir.

Q. Before we broke we were talking about shake table testing, and I'd like to go to the second part of your reliance for shake table testing, which you refer to IEEE Standard 344-1987 and, I believe, Reg Guide 1.100.

Now, IEEE Standard 344-1987, that's industry guidance for the seismic provocation of Class 1E equipment for nuclear power plants, correct?

A. Yes, sir.

Q. And Class 1E equipment is electrical equipment, correct?

A. It also includes mechanical and INC equipment. Reg Guide 1.100, Revision 2, I believe, extended the use of this methodology to all Class 1 equipment, including electrical, electromechanical --

MR. GAUKLER: Okay. I guess I'd like to pass out a -- I'm not going to pass out 344, but I'm going to pass out Standard 384 which has a definition of Class 1E equipment. And then I'm also going to pass out Regulatory Guide 1.100. I'd like to have them both marked as exhibits, and they'd be 222 and 223. And why don't we make the IEEE Standard 384-1992, which is an excerpt, as 222 and the Reg Guide 1.100 as 223.

JUDGE FARRAR: All right. The reporter will mark those for identification.

(APPLICANT'S EXHIBIT-222 AND EXHIBIT-223 WERE MARKED.)

(A discussion was held off the record.)

Q. (By Mr. Gaukler) I'd like to have you first look at PFS Exhibit 222, which is IEEE Standard 384-1992 which is a different IEEE Standard than you referred to in your testimony, but it does have a definition of Class 1E equipment. Do you see that on the second page of the document?

A. Yes, sir.

Q. And it's the third definition from the bottom of the page there, correct?

A. Yes.

Q. And does that correctly state your understanding of Class 1E electrical equipment?

A. That's correct.

Q. And so basically -- can you read that definition, please?

A. The safety classification of the electrical equipment and system that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or are otherwise essential in preventing a significant release of radioactivity to the environment.

Q. And the cask would not be Class 1E equipment, correct?

A. That is correct.

Q. Now, didn't you say you refer to Regulatory Guide 1.100 that is --

JUDGE FARRAR: Mr. Gaukler, let me interrupt just to make sure we have something clear here. First off, in my copy it looks like it's saying Class 2E. That may be just because it's got a highlighter over it. Do you have the original, unmarked?

MR. GAUKLER: I had the original, and I looked at it. And I can represent it was 1E when I looked at it when it was unmarked.

JUDGE FARRAR: Okay. We'll take that representation for now. Look at it again tonight and confirm that for us again tomorrow.

And, second, let me ask the witness, the fact that this definition is contained in Standard 384, your experience would indicate the same definition would be in the standard you were referring to?

THE WITNESS: That is correct, sir.

JUDGE FARRAR: Okay. Fine.

Go ahead, Mr. Gaukler.

Q. (By Mr. Gaukler) Now, you read Reg Guide 1.100 which endorses IEEE 344 for electrical and mechanical equipment. Now, would the cask be mechanical equipment as defined in Regulatory Guide 1.100?

A. The cask would be general equipment, mechanical equipment by function.

Q. By function. So you think it would be mechanical equipment by function?

A. Yeah. It could be also called structures. You know, basically they are performing a function to store --

Q. I'd like to have you turn to page 2 of PFS Exhibit 223 which is the Regulatory Guide 1.100.

A. Yes, sir.

Q. And if you look at the last full paragraph in the first column on that second page, it says, "This Regulatory Guide covers two categories of equipment: (1) safety-related electric (Class 1E) equipment, and safety-related mechanical equipment, and (2) non-safety-related equipment whose failure can prevent the satisfactory accomplishment of safety functions. Examples of mechanical impairment within the scope of this guide are valves, valve operators, pumps, compressors, chillers, air handlers, fans, blowers, fuel rod assemblies, and control rod drive mechanisms."

A. Yes.

Q. And isn't it true that all those examples of mechanical equipment are examples of the equipment, the particular mechanical equipment as having moveable parts or having some function other than just being a structure -- rather than communicating structural integrity?

A. In general, from my experience, this standard has been used as a guidelines for qualifying structures, passive as well as active. And you could define passive structures are those which may perform some safety function as changing the state from open to closed, closed to open, and also passive items. And this has been an industry practice for using IEEE 344 criteria for qualifying all type of equipment because it forms a very good basis of analysis and testing and -- so that has been an industry practice by most of the utilities.

Q. So let me parse your answer. I'm just trying to understand it. Are you saying, therefore, that casks are not mechanical equipment as is commonly denominated, but this guide is used, in any event?

A. Well, when you look at the definition of -- say, of shutdown equipment, cask is not used as, say, shutdown equipment, okay? Cask is used for storage. But from a seismic analysis, from qualification perspective, programs are the same, methodologies are the same. You still use steel. Allowables are the same. You use adequate at particular location.

So one would not say it's whether IEEE 344 works, but all the basis that forms -- that forms the basis of qualification of the component is all there. And so it's a good guidelines. Everybody uses it. We have used it. And -- for supertanks to -- high temps that contain fluid in it, for high temps that move. So it's been a very generally used guidance in the industry.

Q. So I guess my question is, then, the casks would not be mechanical equipment that would fall under the literal terms or requirements of Reg Guide 1.100, correct?

A. I can't really say what -- which category it would be. But it is a structure that needs to be designed, and you impose the design requirement. And you could choose IEEE 344-87, and, actually, there's also guidance 1536 that forms the basis of qualification. They're -- essentially somebody says do a static analysis, dynamic analysis, and these are the methodologies. Use these allowables. Show whether you got the test results. Show how you got demonstrated your qualification. And that's all.

Q. Well, let's go back and focus first on terms of IEEE 384. In terms of electrical equipment, you're thinking of electrical equipment like pumps, motors that would operate -- would need to operate under earthquake conditions, correct?

A. That's one of the classes, sure.

Q. And these -- would it be fair to say that these pumps and motors would have fairly close tolerances to have to be evaluated under earthquake conditions?

A. Sure, for functionality.

Q. And with respect to something like when you're doing a seismic qualification -- qualification test for a pump or a motor or some other piece of equipment that has to operate either electrically or mechanically, you're going beyond concern with structural integrity of the -- of the component, you're looking at the capability of the component to operate, correct?

A. That's also one of the requirements. Sometimes you look at the item sitting -- for example, let's say cabinet. You don't want it to fall, okay? So even though -- it doesn't really have an electromechanical function, but you want to maintain the structural integrity. You want it to be within the -- within the space that it was designed for.

Q. But even with respect to a cabinet, it would contain electrical connections and equipment, correct?

A. Sure, but --

Q. And the built-in --

MR. SOPER: Well, he needs to finish his answer.

Q. (By Mr. Gaukler) Go ahead.

A. But the functionality, when you look at the electrical wiring in the cabinet, for example, it just -- you have a current through it, and what you are looking at is is it going to stay in its place, whether the anchor bolts are going to be there, is it going to sheer off, is it going to hit the neighboring item and, along with it, some items which are more sensitive that require functionality. And in those cases we monitor the actual functionality during the testing. In some cases you don't need to.

Q. And so what you're telling me is that the focus of the IEEE Standard 384 is on operability, but there would be some items that you would need to look at structural integrity at?

A. As well.

Q. As well.

A. Yes.

Q. And -- and the other thing is that IEEE 344 basically would concern equipment that's mounted or -- mounted or bolted down, correct?

A. No, not necessarily.

Q. I'd like to hand out a copy of -- I'm not going to mark it, I'm just going to show you a copy of IEEE 344 and give that to counsel as well.

Take a look at page 16, and that's under --

JUDGE FARRAR: Mr. Gaukler, do we need this or can we follow without --

MR. GAUKLER: I'll try to make it clear.

JUDGE FARRAR: Okay.

Q. (By Mr. Gaukler) Section 16 -- excuse me, page 16 has a section called "Testing," and doesn't Section 1.1 of that section labeled "Mounting" say that the equipment to be tested shall be mounted on the vibration table in a manner that simulates the intended service mounting? The mounting method shall be the same as that recommended for active service and shall use the recommended bolt size, type, torque, configuration, weld pattern and type, et cetera?

A. Yeah. If it has -- if it has bolts, you should use the exact same bolt to justify. If you don't, you don't. Mounting, it could be simply freestanding.

Q. But you have never tested any freestanding stuff from the shake table yourself, correct?

A. No, sir.

Q. And are you aware of freestanding stuff having been -- freestanding equipment being tested freestanding on the shake table?

A. Not to my knowledge. If there was one, we wouldn't be having this discussion.

Q. I'm talking about electrical equipment, electrical or mechanical equipment that was being tested pursuant to IEEE 344 or Reg Guide 1.100.

A. Could you please repeat --

Q. Are you aware of equipment that's been tested to IEEE Standard 344 or Reg Guide 1.100 that has not been mounted in the sense of being anchored?

A. I do not know, sir.

Q. Now, you quote from -- in your testimony in Question and Answer 35, I believe it is, you state that the -- in the second full sentence of Section 6 of IEEE 344 that the analysis method is not recommended for complex equipment that cannot be modeled to adequately predict its response. Testing with -- analysis without testing may be acceptable only if structural integrity alone can ensure the intended -- can ensure the design intended function.

Do you see that in your testimony?

A. Yes, sir.

Q. Now, first of all, isn't it true that structural integrity of the MPC or the cask alone would protect and serve its intended function here in terms of preventing release of radioactivity?

A. If you can demonstrate the qualification of that particular equipment which is complex and complicated and predict accurately a response, then you would be able to say, yes, everything is within the design limit. I mean what you are trying to show is your design, and the methodology to use your design, if it is complex and complicated or controversial, then proving of those or acceptability of those data is in -- questionable. It doesn't mean that they are wrong. It doesn't mean that they are incorrect. But you need to justify by some means the results of your analysis where equipment is complicated or complex in structure.

Q. Well, the second sentence I read that you quote there, it says analysis without testing may be acceptable only if structural integrity alone can ensure design intended function.

And we're talking about -- presumably, since it refers back to the first sentence, we're talking about complex equipment that cannot be modeled to adequately predict its response.

And I'm just asking you here whether -- isn't it true that structural integrity alone of the cask and canister, however that was shown or demonstrated, would serve the design intended function of the cask and canister? Isn't that correct?

MR. SOPER: I object to the form of the question. I've lost what its asking.

MR. GAUKLER: If the witness doesn't understand, I'll reask it.

JUDGE FARRAR: Let me hear it, madame reporter.

(The question was read.)

MR. GAUKLER: Why don't I just reask the question. I think it might be simpler.

JUDGE FARRAR: Okay.

Q. (By Mr. Gaukler) First of all, do you consider the cask and canister system to be complex?

A. It depends how they are anchored or how they are -- if you anchor the casks, then they'll be simple. If they're unanchored, then their dynamic behavior will be complex.

MR. GAUKLER: Could you read that answer back again, please?

(The answer was read.)

THE WITNESS: Okay. For an anchored system, if you look at casks, let's say, similar to a tank -- and we use tank all the time, and you can anchor them. Inside the cask you have MPC, and there are small gaps. And you can analyze those gaps because they are small. And then the fuel inside, you can look at the integrity of the fuel. But when the entire cask starts sliding and motions become too large, then predicting a dynamic behavior is what's the -- what we are talking about.

I think cask itself is a rugged item, so nobody's saying that cask is not a good structure. I think it's a strong, rugged structure. The question is does it move 50 inches? Does it move 5 inches? Does it move 2 inches? How is -- the dynamics of the whole thing is put together, that's a question to demonstrate from a design perspective.

Q. And do you know, whether it moves 50 inches or 5 inches, to what extent that affects its design intended function of maintaining the radioactive material?

A. I don't know.

Q. And assuming that it -- the -- it maintained its designed -- maintained the confinement of the radioactive material, whether it moved 5 inches or 50 inches, it still would be performing its design intended function, correct?

A. No. You meet your design requirements. You show all your equations, all allowables are being met for both cask items, fuel and interaction, spacing between the casks. You set out a design. You said, I'm going to design it, and I'm going to design it for these parameters. And, as a designer, you are obligated to show that you are meeting those by code, not by making a judgmental assessment that everything is going to be okay.

And if we continue to use that kind of argument, you could practically design anything without actually doing any computer modeling or any analysis. I think 4 or 500 years ago people have designed buildings, very sturdy building, very strong building, and they're still standing. And you may not find any element analysis. You may not find any dynamic analysis. But they're good structures.

So nobody's saying that casks that Holtec has is not good. I think it is the means to prove the design that you wanted to prove. I think these are the questions. And I think that's where we are having difficulty. If we says it should not move significantly, have we proven beyond reasonable doubt? And I think there is a question as to if we have satisfied those. And in my judgment I think it has not been.

Q. But doesn't the quotation that you have right here from 344-87 in your testimony say that analysis without testing may be acceptable only if structural integrity alone can ensure the design intended function? So doesn't this quotation you have really talk about the design intended function in terms of the ultimate function of the component --

A. No, no, no. Design functions are -- you set out design requirements before you do anything. You say, I want to meet all the allowables per this code, per that code. You choose either ASME, AISC, and then you set out your analysis within those parameters and show that that meets the requirement. And then you go and, of course, meet the ultimate criteria, what-if type of question.

Q. But 344 deals when you have to do testing, correct?

A. What did you say?

Q. 344 deals -- at least as part of -- 344 in your testimony deals when you have to do testing, correct?

A. Both testing and analysis.

Q. When -- right. And --

A. The analysis method, it says how one should perform the analysis, what type of analysis methods are available. And if you go back, actually, this also tells you if you do not know the dynamics of it, you use the peak of the spectra. This tells you what accelerations one should use in designing it if one is not sure about it.

Q. Now, let's go back to -- I want to focus on testing. I want to focus on design intended function. Are you telling me that assuming that there's no release of radioactivity in an earthquake event by the MPC, multiple purpose canister, and cask, that's not sufficient to show that it has performed its design intended function?

A. I -- I can't answer this question, sir.

Q. You don't know?

A. I have -- I don't know.

Q. And is it also true that -- taking the converse, if it can be shown by analysis that the design will be met that you don't need testing?

A. Then it goes on to say, when you go back and look at the nonlinear analysis -- there's a section on nonlinear analysis, and I'll show you where it is.

In 6.4, sir, on page 15. You want me to read this section?

Q. I guess I'd like to have the question read first and make sure you're answering the question.

Will you reread the question I asked, please?

(The question was read as follows:

"Question: And is it also true that -- taking the converse, if it can be shown by analysis that the design will be met that you don't need testing?")

THE WITNESS: Not for a nonlinear analysis, according to this. If you go and look at this Section 6.4 for nonlinear analysis, I think it's -- the question is the demonstration of your solution and nonlinearities exist, how accurately one is predicting. And if there is a question, then analysis alone cannot be justified.

Q. (By Mr. Gaukler) But you -- according -- from the introduction in your testimony to

Section 6, it says the analysis method is not recommended for complex equipment that cannot be modeled to adequately predict its response.

A. Right. And when you go -- go and read in details all these sections -- and I'm just going to read you a quote. If a system exhibits significant nonlinearity, site behavior must be recognized and accounted for for any subsequent analysis so as to accurately predict the system response. If the nonlinearity cannot be adequately modeled, testing is required.

Q. If it cannot be adequately modeled?

A. That's right.

Q. So if you can adequately analyze something and model it, then you don't need to do testing, correct?

A. It is -- it is a possibility.

Q. It's more than just a possibility. It says that directly, doesn't it?

MR. SOPER: Well, I object. The document speaks for itself.

MR. GAUKLER: He cited to the document. I'm trying to understand what he means by it.

JUDGE FARRAR: Objection's overruled.

You may answer.

THE WITNESS: Yeah, I think -- well, when analysis become complex, complicated, where there are a lot of questions, testing is a means to qualify or justify your design basis. And that's what we have been doing here, and that's what we will continue to do, I think.

Q. (By Mr. Gaukler) Now, the introduction that we have, that you cite yourself in the testimony, says the analysis method is not recommended for complex equipment that cannot be modeled to adequately predict its response, correct?

A. That's correct.

Q. And so if you can model something to adequately predict its response, testing is not required.

A. You can model anything -- I mean within the limits of the program, you can model anything. But how -- who is to say that one is adequately predicting it? And I think that's the question.

And if -- the very -- and I go back. The reason we don't have questions about linear analysis, because there are a lot of test data available, so one can go and compare these test data with linear analysis. For nonlinear analysis, the information or the knowledge that we have today is limited. And as Dr. Luk in his testimony also alluded to, that he tried to do shake table tests because he thought that would be a good thing, he can compare the data. And so those questions are still in a lot of people's mind, are we doing these analyses accurately? And we don't know.

Q. In terms of shake table tests, do you know how one ought to adequately conduct the shake table test when you have to control the linear inputs?

A. Could you --

Q. For a shake table test, wouldn't you have to know your inputs in terms of benchmarking for future uses?

A. I -- let's say -- let us suppose that we have, from Dr. Luk's work, motions which have been identified on the top of the pad and we take those motions and have a simulated smaller scale model and we test it. So those data have been obtained or at least are given in Dr. Luk's report.

Q. Do you know, for example, how one would benchmark, say, friction in any shake table test of a freestanding object on a concrete pad?

A. Well, if -- if one -- again, this is the million dollar question. We have a predicted response of a lot of these things. I think in the last few months I have seen a lot of nonlinear analysis results. So let's say if one wants to validate their model, there are two ways they could do it. One is they go now and say I'm going to take a prototype and I'm going to do a test. And let's say if I take this prototype and if I assume friction coefficient of this and a height and D ratio of this and a weight of this magnitude, my analysis predict I'm going to get Y displacement. You do a test of the same model, and you see how close or how far apart you were in your analysis.

Now, you then fine tune your model. You fine tune your model. You say that -- and, again, you have to do dynamic analysis to show that the movement is going to be, for all the dynamic parameters you have used for this input motion, this much and that would form a reasonable basis for your model for predicting it.

And it might turn out to be your range or bound may reduce significantly once you got the test data available. And that could be actually validated at that time.

Q. Do you know how you would model

friction, though, or how you would model contact stiffness in a shake table test?

A. You don't -- you just put your object on a surface that would represent the PFS site.

Q. Well, how do you know -- in terms of benchmarking it in terms of wanting to know how to compare it to your analysis, how would you be able to benchmark what those inputs were so you could go back and benchmark it against your analysis? Do you know how you would control those input variables that are to provide a benchmarking which would be the objective of such testing, with respect to the freestanding cask? I'm asking if you know.

A. The objective of the testing is to give you an idea as to how much cask is going to move and how are they going to behave if you apply ground motions or motions that you put in. Now, you've got to have a cask or a scale model made up of steel or similar surface that the cask is made up of, and then you take the base, which is going to be concrete, and then shake it and see what happens.

Q. Do you know how you would model the pad or the cement-treated soil under the pad at PFS?

A. You -- like I said, if you believe that the time histories obtained from soil structure interaction analysis are adequate -- and I will qualify. Let's say if we all agree, we take that, and then everything is built in in those time histories. And then you basically test the freestanding cask with those input motion.

Q. Now, you reference in your testimony on Question and Answer 36 benchmarking of the -- with respect to the Holtec analysis, and the question is has -- have the HI-STORM stability results for PFS been benchmarked with another computer code?

Do you see that question and answer?

A. Which, please, sir?

Q. Page -- Question and Answer 36.

A. Okay.

Q. And you refer to a -- some depositions of Dr. Singh and Dr. Soler in November 2001. That's State Exhibit 121.

A. Yes, sir.

Q. Now, you also attended Dr. Singh's and Dr. Soler's deposition in March 2002, correct?

A. Yes, sir.

Q. And you didn't attend the one back in November 1991 (sic), did you?

A. The -- the only one I attended was the -- a few months ago, I think.

Q. The March 2002?

A. Yes.

MR. GAUKLER: Okay. Now I'd like to have this marked as PFS Exhibit 224.

JUDGE FARRAR: All right. The reporter will so mark it.

(APPLICANT'S EXHIBIT-224 WAS MARKED.)

Q. (By Mr. Gaukler) Now, you recall at the March 2002 deposition of Dr. Singh and Dr. Soler they talked about the benchmarking that they had done with the computer code DYNAMO?

A. That's right.

Q. And benchmarking -- the purpose of benchmarking a computer code is to increase your confidence in its capability to predict adequate or correct responses, correct?

A. Sure.

Q. And that's so -- you know, so -- and you recall at that deposition Dr. Singh and Dr. Soler described the process they went through in terms of benchmarking the DYNAMO code?

A. Could you please -- process of --

Q. What the -- the process of how they went about to benchmark the DYNAMO code.

MR. SOPER: Is the question does he recall what they said?

Q. (By Mr. Gaukler) Do you recall what they --

A. All I recall, there was a discussion, but I don't recall exactly what was said in that deposition. But there was some -- something said about DYNAMO.

Q. Will you take a look at what I've handed out? Page 31 through 34, if you could briefly review that.

JUDGE FARRAR: While he's doing that, Mr. Gaukler, this is from Exhibit 222 of the Singh/Soler deposition?

MR. GAUKLER: March 2002 Singh/Soler deposition.

JUDGE FARRAR: Mr. Gaukler, in this deposition who's doing the questioning?

MR. GAUKLER: The State, Ms. Nakahara, and Dr. Khan was in attendance as well.

Q. Have you had a chance to review it?

A. Yes, sir.

Q. Has that refreshed your recollection generally?

A. Yes, sir.

Q. Dr. Singh and Dr. Soler were talking in the deposition of the benchmarking they had done with their DYNAMO code against various classical problems, correct?

A. Yes, sir.

Q. 12 to 14 or 16, some number like that, correct?

A. Yes, sir.

Q. And these were classical problems of different sorts in order to ensure that DYNAMO would adequately predict the -- the type of motion or -- duplicate the solution of the classical problem?

A. That's correct.

Q. And they also referred to the fact that they had prepared a lengthy validation report for the NRC in that respect?

A. That's correct.

Q. And that was a publicly available document with the NRC, correct?

A. Yeah.

Q. Have you gone out to try to review that validation report? Have you reviewed it?

A. No, sir.

Q. You have not sought to obtain it?

So you don't have an opinion whether or not the validation effort that Holtec made in that respect is adequate?

A. I just take it on the face value. It was done for re-racking purpose, for high density racks. It was not done for cask stability analysis as the -- if you look at the question, Dr. Soler, have you asked ANSYS for any nonlinear analysis in general?

Yes.

Have you used it for any cask stability analysis?

The answer is no.

When was the last time -- so the validation for this program was done for high density rack.

Q. Now, isn't -- isn't it true, if you read through this, that the validation -- the classical solutions that they ran for DYNAMO were not -- were not necessarily applicable to wet storage or dry storage, they were just generally whether or not DYNAMO could adequately duplicate and predict the classical solution?

A. The code has not -- I don't know if the code has changed, but 12 to 14 problems that were mentioned, I believe they are compared properly. I believe they have been validated correctly. So I just state it on the face value.

Q. Okay. And so you haven't gone back to review that report?

A. And, you know, I believe that would be correct, because if they said that they did it, that means they did it.

Q. And you haven't gone back to review the validation report to determine whether or not the validation that they did is -- extends beyond wet storage to other types of storage, correct?

A. In the deposition what was said was that when was the validation done, and I think it was in regards to wet storage re-racking.

Q. But were the solutions that they validated DYNAMO against limited to wet storage applications?

A. That's what was said. That was my understanding --

Q. That was your understanding of that?

A. That's correct.

Q. I'd like to have you look at the bottom of page 36 and 37. That's -- in addition to talking about the validation in the validation report, they also refer to the fact that they had run DYNAMO against a comparison with ANSYS, correct?

A. That's correct, sir.

Q. And so they're benchmarking the DYNAMO code against the ANSYS code, correct?

A. That's correct.

Q. Now, isn't it true that when Dr. Soler's responding on the bottom of page 36 and the top of page 37 in terms of that benchmarking with respect to ANSYS, he specifically says that that benchmarking did not specifically deal with racks, per se? Go ahead and take a look --

MR. SOPER: I object to the recharacterization of his testimony. It says what it says.

THE WITNESS: There was no question --

JUDGE FARRAR: Wait, wait. There's an objection pending.

Mr. Gaukler?

MR. GAUKLER: He was there. I'm asking him whether or not he understands what Dr. Soler said. He has made some representations of what he recalls and understands what Dr. Soler and

Dr. Singh said with respect to this validation, and I'm pointing this out to him and saying isn't it true that that's not correct? Does that refresh your recollection?

MR. SOPER: Actually, that's a different question somewhat.

JUDGE FARRAR: Why don't we start over and ask that question.

Q. (By Mr. Gaukler) If you look at page 36 and 37 where Dr. Soler's talking about the benchmarking that they had done between DYNAMO and ANSYS, does that refresh your recollection that he wasn't just talking about spent fuel? I mean it wasn't tied specifically to wet storage.

A. Is it in regards to your Question No. 36, has -- the HI-STORM cask stability reserves for PFS has been benchmarked with another computer code?

Q. I'm just asking a general question.

JUDGE FARRAR: Wait. I thought -- let's go off the record and straighten this out.

(A discussion was held off the record.)

JUDGE FARRAR: Let's go back on. I think now we're all on the same page.

MR. GAUKLER: Let me rephrase the

question since, hopefully, we're all on the same page now.

Q. With respect to what you were saying concerning the benchmarking of DYNAMO against ANSYS, if you look at the bottom of page 36 to the top of 37, that paragraph, doesn't that refresh your recollection that the benchmarking that they did between the two codes did not specifically deal with the racks, per se?

MR. SOPER: And I object to the form of the question. Doesn't it refresh his recollection of what? I'm not sure what the question is.

JUDGE FARRAR: Let's try this again. When you gave an answer a few minutes ago, you didn't know you were being asked about the deposition. Is that what happened there?

THE WITNESS: I believe the questions are being answered for the deposition and my presentation at the deposition. And I think the question is was DYNAMO validated. The answer is yes. Was it validated against ANSYS? The answer is yes. Was cask stability analysis validated with ANSYS? The answer is no.

I think this is what my -- in my Question and Answer 36, this is what I'm saying, is that when we were -- when we were asking do you have analysis by ANSYS, and the answer was no. There was no question about validation. Validation part has been done as a part of re-racking and with other cases with ANSYS. So answer is DYNAMO is -- if there's a confusion, DYNAMO is validated against no problems and against ANSYS based on what Dr. Soler and Dr. Singh say.

Q. (By Mr. Gaukler) And my question to you is in that process of validation was that process limited to wet storage applications?

A. I --

MR. SOPER: I object to foundation. You're asking him about somebody else's validation.

MR. GAUKLER: To the extent he knows. To the extent he --

THE WITNESS: I can't really say. The only thing is -- as far as cask stability analysis is, validation was there any of their code used for this validation, and I believe at that time the answer was no. Was the same model that DYNAMO used was run on ANSYS? The answer is no.

MR. GAUKLER: Excuse me. I need to have the last kind of answer read back to me to make sure I understand it before I either ask or don't ask any more questions on this.

(The answer was read.)

MR. SOPER: Your Honor, while there's a little pause here, let me object to this whole line of questioning if it's going to continue. This is the deposition of other witnesses. And the questions to this witness is what did they say, what did they mean, and it's just improper. There's no foundation for him to say anything but what the document itself says.

MR. GAUKLER: Two things, if I could respond, Your Honor. First of all, he has a question and answer in his own testimony, and it's -- and it referred to one deposition of Dr. Soler and Dr. Singh. So I think it's fair for me to go to another deposition of Dr. Soler and Dr. Singh, one in which he was, in fact, there and listened to and judging the -- for asking the correctness of the answer he gave in his testimony.

I really think I have one more question on this, and I think there's -- we've beaten this -- you know, there's been enough -- let me just ask one more question. Then I think that will take care of it, as far as I'm concerned.

JUDGE FARRAR: If you ask more than one,

Mr. Soper, I'll take up your objection.

MR. SOPER: Fair enough, Your Honor.

Q. (By Mr. Gaukler) I'm just asking what you know. Do you know as a fact whether the benchmarking that was done on DYNAMO was limited only to the spent fuel racks?

A. I can't say for sure.

MR. GAUKLER: Let me ask to have a second to see if there are any more questions.

JUDGE FARRAR: Okay.

(A discussion was held off the record.)

MR. GAUKLER: Can we just take a break? I think I'm done, but I may just have two or three questions.

JUDGE FARRAR: Certainly. You mean just in place?

MR. GAUKLER: Yeah. Why don't we just take an in-place break.

JUDGE FARRAR: Okay.

(A recess was taken.)

JUDGE FARRAR: Mr. Gaukler?

MR. GAUKLER: No further questions.

JUDGE FARRAR: Mr. Soper, then your objection is moot.

MR. SOPER: I believe so, Your Honor.

Thank you.

MR. O'NEILL: Your Honor, I'd appreciate a few more minutes. I was going to say my staff members have abandoned me here so --

JUDGE FARRAR: When I said we were going to take a break in place, some people took advantage of it. But since I don't have a bailiff that I can order to arrest people --

MR. O'NEILL: I'd just like to confer with them briefly for a few minutes.

JUDGE FARRAR: Should we take a break ?

MS. MARCO: Yes.

JUDGE FARRAR: Okay. It's a little early but -- it's 12 after. Let's come back at 25 after.

JUDGE FARRAR: I think we're ready to go, Mr. Gaukler.

MR. GAUKLER: Just a housekeeping matter. I'd like to move for the admission of three of the documents I had marked this morning -- or this afternoon, PFS Exhibit 222, which was the excerpt with the definition of Class 1E equipment from IEEE Standard 384-1992, PFS Exhibit 223, which was Regulatory Guide 1.100, and PFS Exhibit 224, which were the excerpts from the March 6, 2002

Singh/Soler deposition.

And for the court's -- for the Board's reference, I was able to -- I do have the original of 222, and before you Xerox, you can see that is 1E.

JUDGE FARRAR: All right. Thank you.

On 222, is there any objection to that one? 222, Mr. Soper, is the --

MR. SOPER: No objection to 222.

JUDGE FARRAR: -- the definition which the witness --

MR. O'NEILL: No objection, Your Honor.

JUDGE FARRAR: 222 will be admitted.

(APPLICANT'S EXHIBIT-222 WAS ADMITTED.)

JUDGE FARRAR: 223, the staff reg guide?

MR. SOPER: No objection.

MR. O'NEILL: No objection, Your Honor.

JUDGE FARRAR: That's good. So 223 will be admitted.

(APPLICANT'S EXHIBIT-223 WAS ADMITTED.)

JUDGE FARRAR: And 224, the excerpts from the deposition?

MR. SOPER: No objection.

MR. O'NEILL: No objection.

JUDGE FARRAR: All right. Then that

document also will be admitted.

(APPLICANT'S EXHIBIT 224 WAS ADMITTED.)

JUDGE FARRAR: Mr. Gaukler, that's it in terms of housekeeping? You're not going to offer the other ones?

MR. GAUKLER: No, I'm not.

JUDGE FARRAR: Okay. Mr. O'Neill?

JUDGE LAM: Before the Staff counsel questions, I'd like to ask Dr. Khan a couple of quick questions.

Dr. Khan, one of the essential claims in your prefiled testimony, Dr. Khan, it's on page 13, your answer to Question 33, that it is possible for the cask to potentially tip over. Dr. Khan, do you have an opinion as to how likely that is?

THE WITNESS: I have a gut feeling if earthquake level is as high as PFS, then there is a potential that it could tip over. I can't say with certainty. The levels of earthquake has a -- if you look at the data that Dr. Luk has produced and the motions which are being seen on the top of the pad, then those would be very high level motion for which there is a great potential for cask tip-over.

JUDGE LAM: Well, Dr. Khan, one reason I ask the question is because I see the word "potential" and then "possible." To me anything is possible.

THE WITNESS: Yes, sir. Anything is possible, but there is a potential of a tip-over with the increasing level of earthquake. And -- and the way I see that the casks are jumping, at least from the analysis that we have done in sensitivity -- and one thing that I'm not sure if anybody has predicted accurately is the cask rocking, and that's where the potential for tipping would come, is how accurately one would model because, you know, what you have is -- the rocking is a very difficult behavior to mathematically model, and that's -- that's one of my concern, that that could be possible, potential -- there's a potential for this tip-over for that level of earthquake.

JUDGE LAM: And -- Dr. Khan, and now the essential element in your prefiled testimony relate to your recommendation about shake table testing. If -- if this Licensing Board were to impose that requirement, how should it be done?

THE WITNESS: Judge Lam, I think it has to be done in a -- in a win/win situation where all parties would agree, in my judgment, to the input motion that has to be applied, okay, for any shake table testing. So doing a test where motion is still being questioned or there is a -- you know, any concern, then the test will be questionable after we have done it. So the motion that we are going to use to shake a test has to be agreed upon, all parties.

Then what we also have to do is to say that, okay, we are going to use this size and this shape of a prototype cask. And, again, we can agree the size that would be determined mostly by the limitation of a table that may be available in this country, unless we all want to go to Japan, you know. But there is a limitation up to which a testing can be done, and so size could be scaled down within those limits. And agree up front that whatever happens to the results, we're all going to accept it.

And unless those things are -- are done, I wouldn't recommend testing it because then the question will come, well, you didn't do testing this way, you didn't do testing that way. We should say this is the methodology, get as much information from the testing as possible, okay, and say that whatever tested data we are going to get, here is a method that we are going to use as a benchmark and, if we have to extend this to 8 cask or 4 casks, we all agree. So ground motion or motion at the top of the pad that we need to apply has to be designed by everybody, okay?

And, in my judgment, I guess you look at the range of values that one has to use to justify an analysis, and sometimes that range becomes unrealistic, okay? But in the absence of any data, you basically use those ranges and say there is a potential for this and there is a potential for this. So you have a range of values. And the test will eliminate a lot of those unnecessary conservatism that analysis has introduced. So that would be effective.

And that's why I think NRC has been recommending and we have been doing testing to eliminate unnecessary conservatism. Especially when we are talking about high seismic environment, if we have to go and use, you know, various small damping, it becomes very difficult. So if you do a test, damping is a part of the test. Whatever it was, it was all there. And so testing itself eliminates unnecessary conservatism, and it gives solutions that we can see and we can believe in.

JUDGE LAM: Thank you, Dr. Khan.

JUDGE FARRAR: How long, Dr. Khan, would it take a group of eminent, cordial scientists on each side to work out the protocol for the testing, and then how long would it -- if that were agreed upon, how long would the testing and analysis take?

THE WITNESS: My gut feeling is two to three months should be a sufficient time to agree on the input motion, agree on the model, agree, set a place. And then what may be difficult part is, let's say, manufacturing of whatever component we want to do. And that may be time consuming, but somebody can manufacture the standard blocks or the standard rigid bodies to define the shape for testing.

So my gut feeling is maybe a reasonable size test could be done in three months if all party, you know --

JUDGE FARRAR: So is that in three months -- suppose we said start today?

THE WITNESS: Three months we should be able to finish it.

JUDGE FARRAR: Including the negotiation, the construction and the test?

THE WITNESS: Okay. Let's say we could

write a specification for testing. We can think about the scale modeling, and we start talking about those and then find a person who could manufacture those things and then allow this time for all parties to agree to the motion that we are going to apply to the table. And I think that may be a -- a difficult part because a lot of analysis is hertz and I don't know what that would turn out to be.

But if that can be agreed upon, that we'll use this as a basis and -- then I think everything will be fine. So motion itself is the challenging part that I see.

JUDGE FARRAR: And so the whole -- but you're saying within three months or so you could do all that and have the test done?

THE WITNESS: Yes, sir.

JUDGE FARRAR: I remind you this morning you said you followed a practice of telling the truth all the time, and we have -- I won't name anybody, but there are a number of lawyers in this room who said the seismic hearing would take two weeks. So I ask you to reconsider your answer. And are you going to stick with the three months?

THE WITNESS: Well, purely -- as a

purely technical guide, and if I'm given this task with people who are willing to work with me to come to a solution, I think it can be done.

JUDGE FARRAR: Okay. Thank you.

Mr. O'Neill?

CROSS-EXAMINATION

BY MR. O'NEILL:

Q. Good afternoon, Dr. Khan. Martin O'Neill, counsel for the NRC Staff. I just wanted to ask you a few additional and then follow-up questions.

You just mentioned a moment ago rigid bodies or rigid blocks, and I know Mr. Gaukler a few weeks ago had questioned you about your prior work with rigid blocks. It was my understanding that these were actual objects; is that correct?

A. That is correct.

Q. But not actual structures, systems or components associated with a nuclear facility, correct?

A. That's correct.

Q. What was the approximate size or dimensions of these particular blocks that you worked with, just roughly speaking?

A. A hundred pounds, 200 pounds. These are loose objects, you know, flying -- flying around. You want to tie them down, so you wanted to make sure that they don't move significantly. So that's the limit.

Q. So I presume they were intended to kind of approximate or mimic in size objects that you routinely dealt with for purposes of seismic qualification, equipment qualification --

A. That is correct.

Q. You were first approached by the State to do this work in October 2001?

A. Approximately.

Q. Approximately?

A. Yes.

Q. And your report was included in the State's response to PFS's motion for summary disposition of Part B of Utah Contention L on December 7, 2001, correct?

A. That is correct, sir.

Q. So, roughly speaking, you've had about two months to perform your analysis and complete the report?

A. That is correct, sir.

Q. Okay. In response to Question 15 on

page 6 of your prefiled testimony, you indicate that you were hired to evaluate Holtec's seismic cask stability results by independently modeling, quote, portions of the sliding and tip-over phenomenon of the HI-STORM 100 Cask under seismic motion for a 2,000-year earthquake at the PFS site, close quote.

What did you mean by portions of the phenomenon? Could you be more specific?

A. Let's say Holtec has analysis -- drop analysis. I did not do any checking of that part, or evaluating. So the only part where I did any work was to do a seismic analysis, sliding and rocking analysis. That -- and that report is all that I did for the State. So Holtec report --

Q. Okay. You -- I'm sorry. You do say portions of a sliding and tip-over phenomenon.

A. Okay.

Q. So was your analysis of that phenomenon even more circumscribed, limited?

A. Very limited, very, very limited.

Q. Very limited?

A. Yes.

Q. Your model of the cask is a finite element model, correct?

A. That is correct, sir.

Q. If you can recall, what is the number of elements in your model in degrees of freedom?

A. I believe I describe, I think, 72 elements. Let me double-check it for you, sir.

Yeah, it has 72 finite elements.

Q. 72?

And degrees of freedom?

A. Each node -- if you look -- let's say there are 6 degrees of freedom at each node, and 1, 2, 3, 4, 5, 6 -- and there are 8 of them so -- 1, 2, 3, 4, 5, 6 -- there are 6 nodes per element -- let's see. 48 times 6, I believe.

Q. Okay.

A. There are 48 nodes. Nodes time number of degrees of freedom.

Q. Okay. So it's correct that in your model you modeled only that -- the cask itself, correct? I mean you did not model the concrete storage pad --

A. No, sir.

Q. -- the cement-treated soil or the soil cement or the soil foundation, correct?

A. That is correct.

Q. Take it one at a time if you -- okay.

So in that sense you wouldn't have considered dynamic coupling of these various structural components?

A. No, sir.

Q. Or the soil -- resulting soil structure interaction effects?

A. No, sir.

Q. Earlier today you seemed to suggest that maybe under different circumstances you might have sought to model some of these things. I think you said you would have had all elements properly defined.

A. You know, one thing, if you ever have a -- have an earthquake and you shake everything all together, that will be the best solution. But what we have been doing, we have been doing what you call subcomponent testing where building is analyzed, you get the floor motion and you take component, you analyze or test it. So this is how we -- I did. Where motion was given, we used that and just applied at the base of the cask and got the response.

Q. You applied a freefield motion at the base of the cask?

A. That's right.

Q. So your calculation in no way was intended to be a design calculation?

A. It -- it was never intended to be a design calculation.

Q. Okay. With respect to contact stiffness and damping, those two things that have been discussed at great length, you didn't actually attempt to correlate these parameters, the actual properties of the specific structures and soils at the proposed site, correct?

A. No, sir.

Q. And you can't say with 100 percent certainty that the numerical values used in your model are correct, true?

A. That is correct. They provide a range of values, and they fall within -- depends on how one uses it. It could fall on the lower side or it could fall on the higher side.

Q. I wanted to talk a little bit about the QA program --

A. Yes, sir.

Q. -- for -- you know, that -- that you reviewed the Altran report under. So my understanding is that the individuals who -- I think you called them the verifiers -- who reviewed the report focused largely on the numbers themselves, like, to give computational accuracy, per se?

A. Computational accuracy and also how it was modeled. They did check, you know, whether the number of elements were there. They checked the masses. They checked the input parameters that are described. They checked those values, that they have been input correctly.

Q. But they wouldn't have made any determination as to whether one might consider these values realistic. I mean they didn't make any determinations as to the real world plausibility of these values.

A. The analysis -- again, this was a parametric study, and when you do a parametric study, you are considering from one extreme to another extreme. And so, in that sense, they were making sure that for one extreme you have this answer, for the other extreme you have that answer. And so if the truth lies somewhere in between, then that determination would be made.

Now, if we had tested data available, then that would have been a valued comparison. We did not have that.

Q. During the course of your March 5, 2002 deposition, you made a statement to the effect that these individuals -- to the extent that these individuals might have looked at the logic of your analysis, it wasn't a detailed, sophisticated analysis. They looked at the equation and checked the numbers to see if it made sense.

I'm referring to page 59 of your March 5, 2002 deposition transcript. It's one of -- one of the pages included in that handout. I'll give you a moment to find that, page 59.

A. Okay. Yeah, I got page 59, sir.

Q. Do you see the statement I'm referring to? It says, yeah, logic, yes, that it wasn't a detailed, sophisticated analysis. They looked at the equation and checked the numbers to see if it made sense, yes.

A. Yeah, this was, I believe, a second -- there are two checkers. One checker checked the stability calculation which was performed, so he looked at whether the angle, 39 degree or so, was correctly calculated. Was the input he used correctly calculated? Was the calculation for the kinetic energy and potential energy correct? So they -- they checked those values, one guy.

The other guy checked the mathematical modeling. This modeling is really -- you do it on computer, and so sometime it is very difficult to check it because of what you're inputting. So a guy goes to the computer, sits down, looks at the input parameters and checks it.

Q. So you were responsible, though, for choosing the range of values used that was --

A. Yeah, that's right. We discussed it, and we -- we did it.

Q. You indicated or, you know, agreed that you don't have an NRC approved QA program.

A. Yeah.

Q. But that you attempt to conform, I guess, to the spirit of those requirements, correct?

A. That is correct. We do --

Q. But -- I'm sorry.

A. And I -- we have a QA program that conforms to the requirement of 10 CFR, Part 50.

Q. But you don't actually have to submit a QA program, you know, plan, to the NRC for formal review, or you're not subjected to NRC audits. Would that be correct?

A. That is very correct, sir.

Q. You mentioned NUPIC. Could you explain that acronym again or clarify? I didn't quite understand that. What is that?

A. NUPIC, Nuclear Utility -- I -- I can't really correctly describe. But these are folks selected from various nuclear utilities, QA folks, and they go and audit vendors and basically qualify them for utility as a whole, as a group, so we don't have to really get audited by 12 different utilities and the group just comes and does it for everybody. So that -- that's -- that's what they have been doing.

Q. So do they specifically audit your company or do they audit the vendors of the ANSYS program?

A. They audit -- actually, my -- my knowledge is that they audit vendors, they audit contractors, they audit subcontractors. Wherever they feel it is necessary for them to go to check the quality implementation program, they go and do it.

Q. Has Altran Corporation specifically been audited by NUPIC?

A. That is correct. We -- we have been audited, actually, the last two years -- every two years they come and audit, and we have been audited, I believe, last year.

Q. In Answers 10 and 21 of your prefiled testimony, you indicate that you used beam elements in your analysis of cask stability. What exactly is a beam element?

A. A beam element is a -- is an old finite element that has 6 degrees of freedom, 3 rotation and 3 translation at each end. So the total number for a 3-D beam element would be 12.

Q. I'm going to return to the issue of damping. You would agree that there would be some structural damping associated with the interaction of the cask shell with the MPC, the fuel basket and the fuel assembly, in other words, the cask internals, in the event that it was subjected to some type of ground motion?

A. Yes, sir.

Q. But with respect to this type of damping, I think Holtec assumed there would be no such damping, there would be 0 damping, correct?

A. I -- I don't really know from the report where the damping description was given except for contact stiffness damping was, so as far as -- if you model a cask as a rigid body and all you have is 6 spring and you're applying damping, then the motion of the entire cask is being dominated by those springs and associated damping. If you were to model the cask as beam elements and then you have damping, then you will have additional dampings with those elements.

Q. But assuming you did ignore this particular damping effects, I mean that would be conservative, correct?

A. Yes, sir.

Q. You would agree that, as a general principle, material damping in structures can cause absorption of earthquake wave energy which is either -- internal deformation, correct?

A. Yes, sir.

Q. And that radiation damping could cause dissipation of the earthquake wave energy?

A. That's correct, sir.

Q. In Answer 32 on page 13 of your testimony, you suggest that a range of possible contact stiffnesses should be evaluated. Just because a given contact stiffness value might be theoretically possible, that doesn't necessarily mean it's -- that it would be representative of the real behavior of the cask at the site, correct?

A. Yeah, that could be true. When you consider the range of parameters, they are very extreme from one low end to high end.

Q. So somewhere in that range, presumably, lies the --

A. That's right.

Q. -- the applicable value?

A. And, actually, this is also true for friction. If do you a true friction, you probably won't see .2 and .8. You will see some -- truth lies somewhere in between.

Q. Dr. Khan, several points. You know, you emphasize choosing a contact stiffness value that corresponds to the cask frequency in the amplified spectral range so that it's effectively -- when you do that, you're effectively choosing a cask frequency that matches the applied ground motions, correct?

A. When -- when I am saying cask frequency, I'm talking about rotation of the cask, okay? And that rotational stiffness, rotational springs that will cause this cask to move will have certain damping, and it will have certain frequency associated. That model -- that behavior was to be chosen, say, from a certain frequency range. And you choose it from 1.5, hertz, 2 hertz, 3 hertz. You put in a range of values if you don't know the frequency.

Q. But -- but the goal or your goal was to maximize the resonance effects on the cask in that case?

A. I -- in all honesty, I did not really try to pick -- and maybe this afternoon, when I get a chance, I'll show you. I never tried to maximize. I just chose a value that would fall in that amplified region of the spectra and give a response.

Q. Well, Dr. Singh and Soler did a number of beyond design basis scoping analyses in which they used -- performed using VisualNastran, correct?

A. Yes, sir.

Q. And they attempted to tune the stiffness and damping to maximize resonance effects. Isn't that a comparable approach?

A. Yes, it is a comparable approach. That's right. But let's say they chose 5 hertz, and I'll show you it may not be 5 hertz. It could be a little bit higher, a little bit lower where you may get even much higher dynamic response.

Q. Considering amplification of earthquake wave energy of these resonance effects, I mean that would be conservative?

A. Yes, sir.

Q. I have a question, and this is a preface by saying, you know, it's hypothetical. Assuming that you had a cask that was only subjected to a vertical motion, okay, you know, what acceleration would be necessary to lift the cask off the pad, in this case, for the PFS site?

A. 1 g, greater than 1 g.

Q. 1 g.

A. Correct.

Q. What is the design basis ground motion for -- the vertical component of the design basis ground motion or acceleration at the PFS site? Are you aware of that value?

A. For 2,000-year, I believe, the ZPA at a hundred hertz is about .7, okay?

Q. .695, yes.

A. But from the time history, at about 34 hertz, it's greater than 1 g.

Q. But, I mean, assuming hypothetically there's no amplification of the design basis ground motion, the cask wouldn't lift-off the pad in that case, would it?

A. Yeah. If -- if the vertical acceleration is less than 1 g, it will just move up and down with the ground.

Q. I want to turn now just briefly to your tip-over analysis or potential for cask tip-over. Is it correct that in that component or that portion of your analysis that you considered all energy associated with the seismic event as causing the cask to uplift?

A. Yes, sir.

Q. Did you consider that any of this energy might be absorbed if the cask is sliding? Did you completely ignore possible absorption of cask energy as a result of cask sliding in this part --

A. If you look at any tip-over analysis, in tip-over analysis what you are saying is what is the maximum velocity one can apply to get an instantaneous kinetic energy that would be high enough to tip it over? So the answer is yes, you could. But if your instantaneous cask velocity for some reason happened to be higher than what this calculation shows, you might tip over. There is a potential, but you can't say for sure.

And, again, here is the reality in

mathematical modeling. Is it really going to be a coefficient of friction of 8 that's going to tip over? What if coefficient is .5? What if it's .3? You would not have it. But in the range of analysis that you are choosing, that's what you are doing, and I think that's what has been done.

Q. But in the results of your various runs shown in Table 3 in the report, I mean, you in some cases show sliding. I mean --

A. Sure.

Q. -- there would have to be some energy absorbed by that sliding, I think.

A. Yes, some energy -- a lot of energy could be absorbed by sliding. But in one case, if you see sliding and you got somehow -- somehow, at that instant of time, the coefficient of friction effective .8 and you have an instantaneous velocity of whatever number we are predicting here, there is a potential for that. But that's just a mathematical model. That's just a mathematical representation. If you have a velocity that can exceed this, it is -- it is a possibility.

Q. Well, with respect to shake table testing, you would agree that that particular process or approach is not devoid of limitations and complexities as well, right -- I mean correct? In particular, if you were to attempt to perform such a test with a scale model, you would have to extrapolate those results to the full scale cask, correct?

A. Yes, I believe that would be true. Now, let me explain. When you look at all these analyses that have been performed by Holtec and even by us or other people, what you are saying is I have a cask which is this high, that it has this much diameter, the center of gravity is here, this is my moment of inertia, and you do analysis.

So as far as mathematical modeling is concerned, it does not really know that the cask is really a huge monster. For mathematical modeling a hundred-pound analysis is going to require same amount of time as 10,000-pound or 100,000-pound analysis. So if you have to solve same number of equation for a given input, mathematical modeling is essentially the same. So if you have a scaled down model, your analytical effort is just about the same as you have in a cask which is a full scale model.

So what you -- what you are doing is you've got to ratio the cask parameter down to a manageable level where you say that I'm going to use this input motion. Motion is not changing. It is the cask geometry you are trying to shrink it down.

Q. Well, we're dealing with an 180-ton cask, so it would have to be scaled down considerably --

A. Sure --

Q. -- correct?

A. -- sure, significantly.

Q. Could you give an estimate as to how much you'd have to scale it down?

A. Well, I think you go back and look at the table limit, and that will limit the -- let's say if you go and look at table maybe at -- used at San Diego, University of California San Diego, they have table -- some other places, they have table. Look at their capability, and then that defines -- that limits the maximum weight for a given g that you could apply, see? So it would be some scaling back and forth to assess the geometry.

Q. So in the United States, in terms of current shake table capabilities, it might be a few thousand pounds, correct?

A. Yeah, it could -- it could be few

thousand. But -- but I haven't really seen the actual specification for using San Diego table. That could be somewhat bigger table.

Q. So with respect to this type of analysis, I mean, in numerical structural analyses, are you saying that such programs -- I mean such programs are always -- always are and must be validated with actual test data?

A. Actually, this case, this may be the only class of problems where the least amount of information is available, to the best of my knowledge. Had there been more testing available, I don't think we would be doing such a thing.

Q. And -- but you haven't done any type of testing to validate your own modeling efforts, correct?

A. I wish I did.

MR. O'NEILL: I have no further questions. Thank you.

THE WITNESS: Thank you, sir.

JUDGE FARRAR: Does the State have any redirect?

MR. SOPER: We have a little, Your Honor.

JUDGE FARRAR: Okay.

MR. SOPER: We're handing out, Your Honor, a page from State's Exhibit 120 just for reference. We're not marking it or asking to have it marked. It shows pages 41 through 44 of the depositions of Dr. Singh and Soler, March 6, 2002. And my question will relate back not to today's testimony but when we last convened for this witness on May 7th.

REDIRECT EXAMINATION

BY MR. SOPER:

Q. Dr. Khan, do you have the handout that was just distributed before you, sir?

A. Yes, sir.

Q. When you testified on May 7th during your cross-examination, Judge Farrar asked you a question. If I might read from that day's transcript, the judge asked you this: On page 43 of the Soler deposition in the middle of that big paragraph he is talking about not blindly applying code so that your program blows up on you. What program or what code is he talking about there, as you understand it?

And you answered, In this paragraph -- in this paragraph he is talking about

VisualNastran.

Now, have you since had time to review page 43 and, specifically, the portion where Judge Farrar pointed out -- the full sentence goes like this -- it's line 15 -- So if you attempt to take a code that is written for small deflections and blindly just apply it and get a result that would indicate large deflections, either your program will blow up on you or it will just give you ridiculously large results that have no physical meaning, or it will simply give you wrong results that you may think there's a physical meaning to it.

Now, with respect to that, sir, let me ask you again Judge Farrar's question. What program or what code is he talking about there, as you understand it?

A. Sir, is this Dr. Singh's and Dr. Soler's --

Q. Yes, it is.

A. Okay.

Q. Do you see that portion there on page 43?

A. Yes.

Q. And it's about in the middle there.

That starts, So if you attempt to take a code.

JUDGE FARRAR: Mr. Soper, where was -- in the May 7th transcript, where was my question?

MR. SOPER: I'm reading from page 7196, Your Honor.

Q. Now, Dr. Khan, in response to Judge Farrar's question on May 7th, you indicated that you thought they were talking -- that that sentence referred to VisualNastran, and have you since reconsidered that and looked at the reference to the small deflection code and --

A. Yeah, it --

Q. -- and so forth?

A. Yeah, it could be DYNAMO.

MR. SOPER: Thank you.

This is just sort of a housekeeping affair, Your Honor.

JUDGE FARRAR: I didn't hear what you just said.

THE WITNESS: DYNAMO, sir.

JUDGE FARRAR: So on page -- the answer to my question on 7196, you meant to say he was talking about DYNAMO?

THE WITNESS: The small deflection program.

MR. SOPER: Do you have any question on that, Your Honor?

JUDGE FARRAR: Well, yeah, I guess I have a question about the conclusion I was drawing from his incorrect answer, so do we need him to -- does that just mean that the conclusion I then went on -- or my next question, then, was -- is now irrelevant?

MR. SOPER: It seems self-explanatory with that change, Your Honor.

I'm passing out now what I'd like to have marked as State Exhibit 195.

(STATE'S EXHIBIT-195 WAS MARKED.)

Q. (By Mr. Soper) Dr. Khan, you've testified that in modeling this problem the system should be sensitive to damping and stiff -- stiffness values --

JUDGE FARRAR: Mr. Soper, wait a minute. Before we get into this, obviously back on May 7th I thought I was on to something. And I think you've just asked a simple question that shows I wasn't on to something, but I'm not sure, on such short notice, I follow all the logic. Do we need --

MR. SOPER: Well --

JUDGE FARRAR: Or you can either tell me what you think you've shown, or the witness can tell me? But I want to make sure I'm now clear on where we were then or I thought we were then and where you think we are now.

MR. SOPER: The statement you referred to about blindly using a code that may give wrong results, when you thought that meant a reference to VisualNastran, you said, well, that would support why they didn't use VisualNastran, but that wouldn't support why they didn't use DYNAMO. So now having said that that sentence refers to DYNAMO, it would support now why they didn't use DYNAMO.

JUDGE FARRAR: Okay. Thank you.

And this exhibit has been marked as what?

MR. SOPER: State 195.

I'll start my questioning again, I guess, Your Honor.

Q. Dr. Khan, it's been your testimony, has it not, that the modeling of a cask on a pad should be sensitive to damping and stiffness values?

A. That's correct, sir.

Q. And have you done any work to

demonstrate what you mean by that statement?

A. Yeah. I guess what I did was I took the PFS time histories for 2000-year return period and I plotted generated response spectrum for 1-percent damping, 3-percent damping, 5-percent damping and 40-percent damping. Now, this is for the actual time histories that were provided to us by PFS.

Q. Let me ask you, are you referring now to State 195 exhibit?

A. That is correct, sir.

Q. And can you tell me what that first page of Exhibit 195 shows?

A. It shows response spectra for vertical direction for 2000-year return period time history.

Q. And can you tell me how you prepared that?

A. The time history that was given is applied to a single degree of freedom system that varies frequency from 0 all the way -- or very small number all the way to 34 hertz. And this is the spectra that this time history would generate or has been generated by Geomatrix.

Q. It appears to me that the vertical acceleration for 1-percent damping at approximately 3 hertz is only about -- or less than half of the response in the vertical direction at approximately 6 hertz. Is that --

A. That's correct.

Q. So the vertical response on No. 1 is very sensitive to the frequency of the system; is that right?

A. That is correct.

Q. Can -- what did you conclude about this -- from this particular study?

A. The conclusion was that if you look at 40-percent damping for -- for the time history that we have, there is practically no amplification. That means your system is acting as a rigid system. For 5-percent damping, you see amplification which is consistent with what one would see.

Then you have at 3-percent damping -- at 1-percent damping -- let's say if you -- if your structure is -- has a vertical frequency of about 6 1/2 hertz, you will see a spectra or acceleration on that body of about 4.1, 4.2 g. If you change the frequency, actually increase the frequency and you increase the frequency to 8 hertz, your acceleration goes down to 3 g. If you make the frequency 8 1/2 hertz, it jumps back up to 4.1 hertz. You reduce it to 9 hertz, it goes back down to less than 3 -- around 3.3 g's. And it continues on.

So what this shows is if you have a smaller or lower damping system and you change your stiffness -- and even, let's say, if you go all the way to 30 hertz, the acceleration in the vertical direction is much higher than 1 g, and so you will see jumping effect of the casks. And when you see the ZPA which is given of .7 or -- I'm not exactly sure. Let's see. The vertical acceleration of .695 at a hundred hertz is less than 1 g.

So the time histories that we have in the vertical direction are sensitive, depending on the stiffness that you choose, the damping value that you choose, and all these peaks and valleys will change your dynamic response for one instance to another instant.

Q. Do you know whether or not in any of its evaluations Holtec used a 40-percent damping figure?

A. I believe 40 percent was used for the study for beyond design basis case.

Q. The following page of State 195 which bears the heading "2000 Return Period RESPONSE SPECTRA -Vertical," can you tell me what is represented on that page, page 2 of -- the pages aren't numbered but --

A. I lost it.

Oh, okay. I have -- basically I have three response spectra, one in the vertical direction, one in the east to west and one in the north-south direction.

Q. But I'm wondering if you have -- are you looking at what was just handed out, Dr. Khan? Because they're in a certain order and we're all referring to that --

A. Yeah, east to west.

MR. GAUKLER: I'm confused in terms of what he's referring to, if he could --

MR. SOPER: Me too.

Q. Dr. Khan, would you -- so that we can be consistently referring to the same page, the handout that you were just handed, let's use the sheets in the order that they were stapled together and --

A. Unfortunately, I unstapled it.

Q. Oh, okay. I see what we're doing. Here comes another copy.

JUDGE FARRAR: The one you were first talking about was the vertical?

THE WITNESS: Okay. The first, yeah, is the vertical spectra.

JUDGE FARRAR: And now you want to talk about which one?

MR. SOPER: The second page.

THE WITNESS: The second page is the digitized values for those vertical spectras. The third page is north-south response spectra, response spectra north-south for 200 (sic) years return period --

Q. (By Mr. Soper) Can you describe what that shows for us, please, and why that's significant?

A. Again, if you look at the response spectra, at 40-percent damping there is no amplification. For this time history, if you are analyzing a structure, it will basically behave like a rigid structure.

For 1-percent damping there is a significant variation. If -- again, in the horizontal direction if rocking frequency happened to be at about 4 hertz, you will see a pretty high peak of about 4 g. And if you go down and change the rocking frequency or even, in this case, soils frequency to about 5 hertz, your response is going to be about 2 1/2, 2.7 g's. If you go and look at 6 hertz, so if you fine tune your soil to 6 hertz, your response should go up to 3.6 g's, approximately. You go to 7 hertz, it goes down again. 7 1/2 hertz, it goes back up again.

So for 1-percent damping your system should become very sensitive in the amplified region, and if you choose contact stiffness -- actually increasing the frequency does not necessarily mean you'll get a lower response.

Q. Thank you.

And then the page following the response spectra north-south is -- can you describe that for us, please?

A. Digitized values for north-south spectra, and the last -- fifth page, hows the response spectra for east-west direction.

Now, this is even more interesting. If you look at the 1-percent curve, if you choose a structure that happens to have a frequency of about 8 1/2 hertz, the response at 1-percent damping, 3-percent damping and 5-percent damping are very, very close to each other. If you look at -- if your soil happens to be in that direction or a structure happened to be about 6 1/2 hertz, you are seeing an acceleration of about 4 g's. If you choose your structural frequency at 11 hertz, your response becomes much higher than what you would see at about 7 1/2 hertz.

So as you could see, the ground motion itself is giving you response that's going to be significantly varying, depending on what one chooses.

Q. And the last page, sir, of this exhibit?

A. Is the digitized values for the -- for the east-to-west response spectra.

Q. And what does this study say with respect to your conclusion that --

A. At least from these curves, it shows that 40-percent damping would be fairly high to get any dynamic amplification.

Q. What does it say with respect to your testimony that a range of stiffness values at various frequencies and a range of damping values ought to be used to -- to study this model?

A. This clearly indicates a variation in response that would be observed if one chooses contact stiffnesses which would be varying or stiffnesses that would be varying and also the damping that one chooses. I'm -- I have not plotted 2 percent, 1 1/2 percent. You know, you could plot many damping. But the behavior at low frequencies is going to be like this. And if you go less than 1 percent, it would be more erratic.

Q. It also appears, if you tuned your system to 33 hertz, you would miss most of the g acceleration.

A. That is correct.

Q. And that's for all directions.

A. That is correct, sir.

MR. SOPER: I would offer State Exhibit 195.

JUDGE FARRAR: Before I ask for any objections, Dr. Khan, how did you generate these curves? You took the time histories --

THE WITNESS: I took the time history and applied to a single degree of freedom system whose frequency ranges from very small all the way to 33 hertz. So that's the response spectra for the PFS time history.

JUDGE FARRAR: Now, when you did that, did you use a model you developed to do that or is that just a routine calculation that everyone in the room would generate the same curve?

THE WITNESS: Everyone -- everybody

should be able to generate the same curve. 5-percent curve was already generated by PFS for this -- for their time history. And those values I compared with, and they're fairly close.

JUDGE FARRAR: Okay.

THE WITNESS: And then all I did was change the damping to 40 percent to see whether this input motion amplifies at any frequencies, and at 40-percent damping, no amplification. Then I said, What happens to 1-percent damping? And then your response just becomes very sensitive.

JUDGE FARRAR: Okay. Thank you.

Any objection to the admission of this document?

MR. GAUKLER: I've just seen this document for the first time, Your Honor, so I need to talk to my experts, et cetera.

JUDGE FARRAR: Okay. Why don't you -- Mr. O'Neill, what's the Staff's position, or do you want to do the same thing?

MR. O'NEILL: Yeah. I was going to say I adopt a similar position. I'd like to confer with my experts here.

JUDGE FARRAR: And while you're conferring with your experts, I have something I want to confer with my experts on, so we'll all do this at once.

(A recess was taken.)

THE COURT: We're back on the record. Mr. Gaukler?

MR. GAUKLER: Yes, your Honor. We would object to the introduction of this exhibit. We believe that it's irrelevant and potentially misleading. My understanding is it's a representation of a linear spring mass system. The apply a time history to has shown no relation to the casks that we would have at PFS, the system we would have at PFS, and as such it's A, not relevant, and B, by allowing it in it could be misleading, that people could interpret it as being applicable to the casks at PFS.

Like generating multiplication tables is one way to look at it, your Honor. You just take a spring and a mass system and you will apply different frequencies for the spring, different frequency, and you generate these curves for time histories applied to it.

JUDGE FARRAR: By people who could be misled by it, do you mean us or the jury?

MR. GAUKLER: Well, I'm sure that your

Honors have very good technical advice on the Board. I'm concerned further down the line where it gets further up, okay?

JUDGE FARRAR: We won't tell the commissioners you said that.

MR. GAUKLER: I'm thinking about beyond the commissioners.

JUDGE FARRAR: You mean the Court of Appeals?

MR. GAUKLER: Court of Appeals I'm thinking of, your Honor.

JUDGE FARRAR: Mr. O'Neill?

MR. O'NEILL: Yeah, I would object on essentially the same grounds, your Honor. These particular figures appear to represent response spectra for freefield ground motions, for the ground motions and not ground motions that were applied at the base of the cask. In that sense we consider them to be misleading and not relevant to the action or site characteristics or phenomena that we will be observing at the site.

JUDGE FARRAR: Mr. Soper?

MR. SOPER: Your Honor, all the objections that have been raised are cross-examination matters, and they can examine

Dr. Khan about the particulars. But they show exactly what the witness says they show, the sensitivity of damping and frequency response to this sort of modeling, which is the whole point. It's highly relevant here.

(The Board confers off the record.)

JUDGE FARRAR: The Board thinks these are relevant for the purposes, limited purposes offered. Demonstration that they don't show other things are matters that you gentlemen can establish on further examination with this witness. So we'll overrule the objections, but we think on the condition that in case some of those other people, Mr. Gaukler, to whom you referred get this document without -- you know, and see it independent of the transcript, that maybe this could have a better label on it that says freefield or says something that's more descriptive of or more narrowly descriptive of what it is.

So Mr. Witness, you can -- Mr. Soper, you can confer with your witness or I can just ask him what he, having heard this discussion, what he thinks would be a better label, or you can suggest one.

MR. SOPER: I might suggest this. The

objection that this represents a freefield ground motion I think is not well taken because I think that's exactly what the ground motion applied by Holtec was. In fact, the 5 percent damping curves shown here are the same numbers that Holtec came up with. So I'm not sure labeling this freefield ground motion somehow sets it apart. It in fact is consistent with what's been done. I think -- I don't want to put words in the witness's mouth, but we would be happy to title this in any way that's helpful to the Board. But with that notion in mind.

MR. O'NEILL: Your Honor, it's my understanding, too, that there's a difference between applying -- and obviously I don't want to testify, and that's not my intent. There's a difference between applying freefield ground motions at the base of the cask itself and at the base of the soil column.

MR. SOPER: Well, I think no matter what we label it, it will all become clear, precisely clear on the questions and the responses. So I'm not sure that we can label it to everyone's satisfaction, but I think we can develop cross-examination that will --

MR. GAUKLER: I think a label should be applied to the exhibit. I'm just going to throw one out. I don't know if it's even correct exactly. My colleague here -- response of theoretical single degree of freedom system to input ground motion. I'm just giving that as an example that I believe at least is partially if not totally descriptive of what this shows.

THE WITNESS: There is a description already given in Geomatrix report that says "comparison of time history and design response spectra." One could say that design response spectra at 1, 3, 5, and 40 percent damping for 2,000-year return period.

JUDGE FARRAR: Okay, tell you what we'll do to save some time. Why don't we -- we'll defer action on the motion to admit. When we get to it we'll do the cross-examination and then we will admit it with a title that you all will agree upon at the end of that cross-examination. So it's going to be admitted, we'll do the cross, and then we'll come up with a title for itj.

(STATES'S EXHIBIT-195 WAS ADMITTED.)

MR. SOPER: Very well. Thank you, your Honor.

JUDGE FARRAR: Given the break in the action --

(the Board confers off the record.)

JUDGE FARRAR: Before you go on, let me ask the witness something that I'm trying to get a visual image of. This may or may not be an intelligent question.

I understood gravity when I studied it about things falling down. I'm having a little trouble with things falling up. If on a pad, any old pad, you had some pebbles and you had a boulder the size of that speaker and you had a cask and they all got hit with a sustained 2 g pulse, vertical, what would the pebbles do and what would the boulder do and what would the cask do? Would they all jump up the same distance?

THE WITNESS: They might or they might not.

JUDGE FARRAR: Thank you. Okay, go ahead.

THE WITNESS: It depends on what the condition is, how the CG of these things are sitting with respect to the vertical, with, you know, contact conditions.

JUDGE FARRAR: Make them all the same

shape, like little tiny --

THE WITNESS: Then they should jump about the same.

JUDGE FARRAR: Little tiny cylinder-like pebbles and a boulder that looks like a cylinder and the cask.

THE WITNESS: Yeah. If you hit it with identical vertical acceleration, they should see the same thing. But where they could differ if they are frequency dependent somehow, then it breaks that off.

JUDGE FARRAR: Go ahead, Mr. Soper.

MR. SOPER: Thank you, your Honor.

Q. (By Mr. Soper) Dr. Khan, with respect to State Exhibit 195, I believe you testified a minute ago that the 5 percent damping curve was very close to representing what PFS or what Holtec has submitted with respect to their 5 percent damping for the 2,000-year return period. Is that correct?

A. It was given by Geomatrix.

Q. Excuse me, Geomatrix.

A. That is correct.

Q. Dr. Khan, can you explain to us the significance of freefield ground motion with respect to this study?

MR. GAUKLER: "This study" being Exhibit 195?

MR. SOPER: Exhibit 195.

A. This is directly coming from the freefield input motion based on what we have seen in Dr. Luk's report. There would be -- it's scaled up accordingly, depending on the damping values used on the top of the pad. So they have a direct effect on what the pad is going to see when these motions are applied and what damping is selected. And so if you select certain damping values, let's say for beyond design basis 1 percent damping was used, then the spectra corresponding to 1 percent damping would be further amplified based on the results that we have seen from Dr. Luk's report, and then that would become effective.

Q. You also testified, Dr. Khan, that in addition to the system being sensitive to damping value and stiffness values, that the modeling of the system was also important. By that I don't mean what computer code is used, but the way that the system is contemplated or modeled. Can you explain any difference in modeling that you used and Holtec used and/or Dr. Luk used?

A. I would just attempt. I'm not 100 percent sure the actual model have been described, but based on the calculations which are in some of the appendices that I saw, cask was modeled as a rigid member with masses and mass moment of inertia applied at its center of gravity. It wasn't very clear from the report whether there was other masses along its height, but that was what I understood from the report.

The modeling that I did was, I've got beam elements that aid vertical position of zero, 45 degrees, 90 degrees added on the radius, and each beam element has a mass lumped at these nodes. And they are rigidly connected to members so there is a better mass distribution. I did not calculate mass moment of inertia. The program automatically uses beam elements to calculate the mass matrix for these elements.

And so if one goes and changes the model, there could be some more changes in the results. So I'm not really sure, if one wants to go and model this as a shell element with everything modeled the way the cask truly is, you might have some different result.

Q. You were asked earlier today whether or not a coefficient of friction of .8 would necessarily cause a tipping of a cask. Can you explain your reasoning as to why or why not that high coefficient of friction may or may not be significant in the cause of tipping?

A. High coefficient of friction would try to lift the cask up as opposed to lower coefficient of friction which will tend to slide the cask. So at a high coefficient of friction if your instantaneous velocity becomes significant that it can overcome the potential energy, then because of the kinetic energy there's a potential that it could tip over. So as the coefficient of friction gets higher and higher, then the potential for tipping increases.

Now, what one has also observed is if your vertical motion gets high or exciting the cask due to rocking motion, then you could have a solution that you can never -- you may not be able to predict whether .7 could be more sensitive or .8 could be more sensitive or .6 could be more sensitive. It depends on the dynamics. If the vertical motion amplifies the dynamics of the cask where it starts lifting up and then, you know, you could see significant velocities that could take over.

Q. For example, if the vertical motion were to cause the cask to lift up off the pad and the pad slides with respect to the cask, at that instant in time the coefficient of friction would be not meaningful or not important. Is that right?

A. That's correct. All those instances when the cask is above the floor, then coefficient of friction is not acting.

Q. You were asked on cross-examination if you at any time did anything to test the limitations in the SAP 2000 reference document, I believe it was a training document, and you answered that you did not. However, you had testified previously you hadn't found any limitations. Can you explain your testimony of that?

A. Yeah. Limitations programs is a dynamic analysis, and I think Mr. Gaukler has shown what elements it can use. It's a small deflection program. It's not a program that will be able to handle large rotations because of change -- it will not accurately predict the large rotational effects, but it can predict the sliding displacement for what amounts there would be.

Q. Anything about -- excuse me. Were you finished?

A. So limit of sliding displacement is not imposed on this program.

Q. So there's nothing about the SAP 2000 program that would in any way invalidate your results?

A. Sliding displacement, no, sir.

Q. Dr. Khan, can you tell me how you calculated the response spectra for the 5 percent damping that's shown in Exhibit 195?

A. Response spectra is calculated by applying the PFS time history at the base of the single degree of freedom system which has a frequency given on the X axis, the horizontal axis. So let's say, pick, for example, 5 Hz. Okay? So a single degree of freedom system which has a 5 Hz frequency, you apply the base motion and you get the maximum acceleration of the mass that is vibrating, and that acceleration is given in the Y axis. That's in g's, so you just vary the frequency and you get those results.

Q. Did you use the time history from Geomatrix?

A. That is correct, sir.

Q. Did you change that in any way?

A. Nothing. It's identical input that I got from the State of Utah.

Q. Is this the same time history used in the Holtec 2,000-year analysis?

A. I believe so.

Q. Do you know whether or not Holtec assumed the storage pad was rigid in its analysis?

A. I don't know, sir.

MR. SOPER: That's all I have. Thank you, your Honor.

JUDGE FARRAR: Mr. Gaukler, you have some recross, I assume?

MR. GAUKLER: Yes, I do. Can we take about a five-minute break, if that's possible?

JUDGE FARRAR: Mr. O'Neill, you'll have some?

MR. O'NEILL: Yes.

JUDGE FARRAR: Both of you will go into the areas with Mr. Soper's examination okay. Let's take a -- do you just want to consult?

Let's take a -- it's two minutes after. Let's come back at ten after.

(A recess was taken.)

JUDGE FARRAR: All right, go ahead,

Mr. Gaukler.

RECROSS-EXAMINATION

BY MR. GAUKLER:

Q. Dr. Khan, referring to State Exhibit 195, first of all, I just want to clarify that the formula that you used in generating these curves that appear in Exhibit 195, is that the same formula you were talking about earlier today that appears in question and answer 31 of your testimony, M equals 1 over 2 pi times square root of K divided by M?

A. There was no formula used. The program automatically generates the response spectra. You apply a time history. You apply time history and it automatically generates the spectra at a specified frequency.

Q. But say the frequency that you have at, say, 10 Hz would be equal to 1 divided by 2 pi times square root of K, which is the stiffness of your spring, divided by M, which is the mass of your system. Is that correct?

A. Yeah, that's right.

Q. So in other words, I could go over here and say the frequency at 10 Hz was equal to 1 divided by 2 pi times the stiffness divided by the mass of the system, and then basically ran that for four different damping values, correct?

A. Yes, sir.

Q. So you ran the -- for each frequency you generated four solutions at each point?

A. That is correct, sir.

Q. What program did you use to run this?

A. SAP 2000.

Q. SAP 2000. And it's what you would call a single degree of freedom system?

A. That is correct, sir.

Q. And what does it consist of?

A. It's one mass and one -- let's say if you call it a beam member, it has a stiffness, it has a mass. And it is very similar to what Geomatrix has done, or identical to what Geomatrix has done in their report when a spectra was generated. So it is a standard method to generate spectra from a given time history.

Q. So you have a single mass and it has a spring value, a spring with it, and it only can move in one direction, either the X direction, the Y direction, or the Z direction?

A. That is correct, sir.

Q. And you generated, you did separate runs for each one of those three directions?
A. That is correct, sir.
Q. That's what is seen in Exhibit 195?
A. That is correct, sir.
Q. Now, what was the mass that you used in doing your run?
A. I did not use any mass. Program automatically selects the frequencies corresponding to these. So there is no mass that you have to select, there is no stiffness that you have to select. It's all built into the program.
Q. So you don't know what the stiffness of the mass is at any particular point?
A. No, sir.
Q. But you do know that the frequency is equal to 1 divided by 2 pi times K divided by the square root of M?
A. I believe the program does it. This is a very --
JUDGE FARRAR: Implicit in there was like the mass varies?
THE WITNESS: If you look at the frequency of a single degree of freedom system, you could vary mass and stiffness to have a frequency

value. So either you can increase the mass or decrease or vice versa.

JUDGE FARRAR: I understand that. But I guess I'm having trouble visualizing -- this graph is not just the result of this formula.

THE WITNESS: That is correct, sir. There are -- hundreds of time history analyses have been performed to get the response for each of those frequencies.

Q. (By Mr. Gaukler) Now, you're not representing that these graphs in any way represent the accelerations that would be seen by the cask or the pad at PFS, correct?

A. They would be affected by this, because this is coming from the ground motion that we are applying.

Q. But the values are not what you necessarily would see with respect to the cask and pads at PFS, correct?

A. Yeah, it would be significantly different, because if you go back and look at Dr. Luk's report, this is spectra for various damping values that I plotted would be applicable to the freefield location, at the freefield location. And from there what happens, the model filters it, amplifies it and makes its own determination. So this would be changed or being affected by soil damping and other effects.

Q. And also by SSI effects, correct?

A. That's what I said.

Q. And also in terms of, for example, whether or not these graphs would have any relevance to, say, what the casks, how the casks would respond would depend upon whether the natural frequency of the casks coincided with some of these -- with the frequency on these graphs, correct?

A. It will have significant effect. This is the basic of the design.

Q. I'm saying in terms of whether you're saying -- in terms of resonance that we were talking about before, whether or not in terms of stiffness and resonance it would depend upon the natural frequency of the cask to -- or the cask and pad.

A. That is correct. Cask and pad response or frequencies would be whatever the frequency is. But what is being input is going to excite the response. The input is only used as an excitation force, and it reacts to the physics of the cask and the pad system. And so, for example, let's say if you happen to have a frequency of the system at 5 Hz, okay, that's one of the cases that Dr. Soler presented, then you would see that it would be affected by the accelerations that are shown in these curves at 5 Hz.

Q. Now, the accelerations here are only illustrative of your single mass system, correct?

A. Excuse me, sir?

Q. Your accelerations here are only illustrative of your single mass one degree freedom system, correct?

A. This is the representation of a response spectra for the time history that PFS has provided.

Q. And the applicability of these curves depend upon your K and your M, correct?

A. No. It is not my K and it is not my M. It is the frequency at which each single degree of freedom system will vibrate if this input motion is applied.

Q. But that single degree of freedom system has a particular K and a particular M that corresponds to that frequency, correct?

A. That's how it is generally obtained.

Q. And so therefore you're taking a K and M that represents that frequency for the formula that we just discussed about earlier, correct?

A. Let me clarify again. If you give this time history to Geomatrix, okay, which has provided us this time history, say, go and plot this response spectra at 1, 3, 5, and 7 percent damping. They should get very, very close to what I've got here. And any program, dynamic program can generate this response spectra.

Q. And in terms of response spectra, in terms of time histories, you're making a point that, say with a 1 percent damping you go from a value of, say, at 5 Hz you go from 2.5, and if it goes to 7 Hz, you go up to above 4. You're making the point that you have spikes in that damping --

A. That's right.

Q. -- in that curve, correct?

A. That is correct, sir.

Q. Now, isn't that really true that in any type of time history you have spikes in terms of your -- the accelerations at the different frequencies? In other words, a raw time history is not a smooth curve that shows no spikes in it, correct?

A. Yeah. And that's again the reason why when you vary the frequency you would then collect the effect of all peaks and valleys that may happen because of the peaks and valleys that you observe with this spectra. This is what's being applied as an input. I have not generated anything new. This is a part of the ground motion that's given to us. And your system will behave to that input motion if you choose 1 percent damping, 2 percent, 3 percent, whatever you will choose.

Q. And this does not say, your curves here do not say what the particular or what the appropriate damping should be, correct?

A. That is correct, sir.

Q. And by the same token, none of these curves here represent what a particular contact stiffness and associated frequency would be, correct? With respect to the pads and the cask, correct?

A. It definitely shows one thing, that 40 percent damping you will not excite a structural response for this time history. Means your structure is behaving practically rigid all the way from low frequency all the way to high frequency.

Q. Isn't that really true for most single oscillator systems, as you increase damping you're going to dampen out the spikes a bit? Isn't that true, generally speaking, for this type of system?

A. It has nothing to do -- this is a single -- this is a response spectra. That's the fundamentals of the design.

Q. Yes. But I'm saying in terms of you saying that it shows no response, isn't it true that as you increase your damping for a single oscillator system that you're going to dampen out the various spikes you would otherwise see at a lower damping, correct?

A. If you choose -- if you choose a very high damping, then you would see no amplification. That means you are basically acting as a rigid system. Everything is tied and there is amplification. But if you choose a damping which is showing some amplification, that basically shows that system is responding and there is some -- you apply an input, you get a response, the response is higher than input, and so you have an amplification.

Q. And whatever particular -- what damping you should use would depend upon the particular system, correct?

A. That is correct, sir.

Q. And this says nothing in terms of what particular damping you should use?

A. That is correct, sir.

Q. And it also says nothing in terms of what particular contact stiffness --

A. That is correct, sir.

JUDGE FARRAR: Mr. Gaukler, before you change subjects --

MR. GAUKLER: Getting ready to do that.

JUDGE FARRAR: Maybe we shouldn't have had a two-week break, because I seem to have forgotten some of the things I learned.

This formula, the 1 over 2 pi formula, it I understand plays some role in generating this.

THE WITNESS: That's right.

JUDGE FARRAR: What mass do you use in that formula?

THE WITNESS: I did not select any mass. The programs, these programs automatically select a frequency, okay, that gives them the X axis value and apply a ground motion and gets the response. So you could choose, depending on the program that you are using. It's really immaterial. No matter which program you use, no matter who does it, your solution is identical.

JUDGE FARRAR: Now, explain to me in simple terms again the relationship between, if any, between contact stiffness, coefficient of friction, stiffness of spring and damping.

THE WITNESS: If you apply --

JUDGE FARRAR: Start with coefficient of friction, because I know what that is.

THE WITNESS: Coefficient of friction?

JUDGE FARRAR: Right. I know what that is. Now, how is contact stiffness related to that?

THE WITNESS: Contact stiffness is assumed between two surfaces which are in contact with each other. And stiffness becomes effective to model the motion, rocking motion and compression stiffness when an object is interacting with each other. So it's like impacting each other, you have stiffness between two objects.

JUDGE FARRAR: But some of that would have a bearing instantaneously on what the coefficient of friction would be?

THE WITNESS: Yeah. Coefficient of friction is going to be when two surfaces are rubbing against each other. And the stiffness is going to have two items are hitting against each other, are applying force against each other.

JUDGE FARRAR: Okay. Now, how about stiffness of spring?

THE WITNESS: The stiffness is, if you take a spring and you apply a unit load and you deflect, you measure the deflection. So this is nothing but force per unit deflection.

JUDGE FARRAR: Okay. So in this context, how, if at all, is that related to the -- help me here.

THE WITNESS: Yeah. What is -- how this is related with the contact stiffness structure. See, the structural behavior is excited by what you apply as an input motion, okay? If you apply static load it will deflect statically. If apply a dynamic load, it will act dynamically. So if your ground motion has important frequencies that are capable of exciting the structural frequencies, then you may have a resonance at that point.

So let us suppose that I see a peak at 5 Hz, for example. And if your structure happened to be at 5 Hz, then my response is going to be very high. And that's how they relate.

JUDGE FARRAR: Thank you.

Q. (By Mr. Gaukler) Dr. Khan, I have one other area I want to follow up on briefly. Counsel for the State handed you a page from I think State Exhibit 120, which was part of the deposition of the Singh/Soler March 2000 deposition. Do you have a complete copy of that exhibit by any chance, sir?

A. You said March 6th, sir?

Q. State Exhibit 120, which should be attached to your testimony. Do you have that?

A. 120, yes, sir.

Q. And that's the exhibit that you were asked about with respect to page 43 by counsel for the State. Now, if you recall back on May 7th when we first were discussing this, we were discussing it in the context of question and answer 26 of your testimony. Do you remember the discussion that we were having in the context of your question and answer No. 26?

A. I have to go back and look. I'm trying to find it here. Okay.

Q. If you look at the last paragraph of your answer on answer 26, and you say about the third sentence from the bottom of that answer that "Holtec did not conduct its analysis at Diablo Canyon with DYNAMO because it was concerned with the accuracy of DYNAMO." Do you see that in the last paragraph of your answer 26?

A. This is answer No. 36, right?

Q. 26.

A. 26. This is on page 10?

Q. I believe it's page 11, top of page 11. I believe -- excuse me. It's on the bottom of answer 26. Go up one, two, three -- it's the fourth sentence up. "Although anchored casks will experience limited rotation at Diablo Canyon, Holtec did not conduct its analysis at Diablo Canyon with DYNAMO because it was concerned with the accuracy of DYNAMO." Do you see that sentence?

A. Yes, sir.

Q. Now, does what -- is there anything on page 43 of State Exhibit 120 which counsel for the State pointed to earlier today that says that Holtec did not use DYNAMO at Diablo Canyon even though it would experience more rotation because it was concerned with the accuracy of DYNAMO?

A. The DYNAMO was stated that it was for small rotations. And if you would expect larger rotations, then it would not be accurate, it would not -- it probably would not give accurate solution.

Q. Right. And you're saying here, "Although the anchored casks will experience limited rotation at Diablo Canyon, Holtec did not conduct its analysis at Diablo Canyon with DYNAMO because it was concerned with the accuracy of DYNAMO." That's what you say in your answer 26.

A. Holtec in their testimony said several things. They did studies with DYNAMO with unanchored casks. That's what was said in the testimony. Then they did anchored casks. Anchored casks final design was done with NASTRAN, visual NASTRAN.

Q. And my question to you was very specific. On page 43 of the Singh/Soler deposition which was pointed to you out by counsel for the State today, is there anything in that page of that deposition that says why Holtec did or did not use DYNAMO at Diablo Canyon?

MR. SOPER: On that page only particularly? Is that the question?

MR. GAUKLER: You pointed to that page and said that was the enlightening page, so I'm just asking him a question.

MR. SOPER: Well, that mischaracterizes the question to him with regard to that page.

JUDGE FARRAR: I think he pointedit to it as the enlightening page not for the subject you're talking about but for pointing out where my question went astray. As I think we said before, at page 7196 of the transcript I thought I was on to something because I misread and so did the witness at that time page 43. So under Mr. Soper's question the witness straightened that out, so he and I were looking at the wrong thing on May 7th.

Now, you've got a different question. And so Mr. Soper's objection is -- if you're following up on his question, which is what the purpose of this examination is, we have a -- you're asking a broad question and limiting it to the specific paragraph which we talked about for a different purpose.

MR. GAUKLER: If I could just briefly state what I believe was happening, okay. On May 7th we were discussing the various -- State Exhibit 120 specifically with respect to whether the witness had any support for his position for his statement that Holtec had chosen DYNAMO at -- used at Diablo Canyon for the reason stated in the sentence I just read from his testimony. It was in that context that your Honor asked the question that counsel for the State clarified, and I thought that counsel for the State was therefore saying, this gave the reason why Holtec -- gave the reason why the witness believed Holtec chose DYNAMO. In fact, if you look just at the sentence above it, he cites the page -- he sites page 43 there just above that sentence.

JUDGE FARRAR: Well, why don't we simplify this and get right to the point. And whether it's within the scope of recross or not, just ask him about Diablo Canyon. Forget the question I asked on 7196, forget the correction about it today. Just ask him about Diablo Canyon.

MR. GAUKLER: Okay.

JUDGE FARRAR: He makes a statement in question 26 that Holtec didn't use DYNAMO.

MR. GAUKLER: Right.

JUDGE FARRAR: We want to know where he got that from.

MR. GAUKLER: That's my question.

JUDGE FARRAR: Let's leave out what I said and what he said and what Mr. Soper said.

Have you got the question? What's your basis for saying they didn't use DYNAMO?

Q. (By Mr. Gaukler) For the reasons stated in your testimony.

A. The testimony was because of large

rotation as described on page 43. Holtec used, at least based on what we believe, Holtec said that they tried to -- they used DYNAMO for an unanchored system. They did several studies at Diablo. In the final analysis they chose NASTRAN. Okay, why NASTRAN was used even though the casks were anchored, we don't know. Why DYNAMO could not have been used, we don't know. The only thing we could figure out was there was a limited rotational issue associated with DYNAMO.

Q. So therefore, in your testimony when you say, "Although the anchored casks were experiencing limited rotation at Diablo Canyon, Holtec did not conduct its analysis at Diablo Canyon with DYNAMO because it was concerned with the accuracy of DYNAMO," you're saying you really don't know why Holtec did not use DYNAMO at Diablo Canyon. Is that correct?

A. That's correct. And the only place where we got the accuracy answer is in this 43 where it's modeled with large rotations.

MR. GAUKLER: No further questions, your Honor.

JUDGE FARRAR: Staff?

MR. O'NEILL: Your Honor, could I have a

few minutes just to collect my thoughts?

JUDGE FARRAR: Okay. We're going to finish this gentleman tonight? Soon?

MR. O'NEILL: Yes.

JUDGE FARRAR: Okay, go ahead.

RECROSS-EXAMINATION

BY MR. O'NEILL:

Q. You ready, Dr. Khan?

A. Yes, sir.

Q. Dr. Khan, does a response spectra identify the characteristics of the input time history? Yes or no?

A. Yes, sir, it represents the characteristics of the time history.

Q. Does the response spectra not in fact identify a response of a series of damped single degree of freedom structures whose frequencies cover the range of concern to the input time history?

A. Yes, sir.

Q. How is that consistent with your first response?

A. Basically you look at the frequencies of concern from 1 to 33 Hz, for example, and each frequency could be excited by an earthquake motion and a time history is given, and from each -- from that time history on each frequency you obtain acceleration for a single degree of freedom system that forms the spectra, that becomes the spectra. And at various damping values you plot those. So for PFS, for example, 5 percent spectra is given for range of frequencies all the way up to 100 Hz.

Q. For a given response spectra you could have multiple time histories, correct?

A. That is correct, sir.

Q. With respect to the figures contained in State Exhibit 195, your Y axis is labeled as acceleration. Wouldn't response acceleration be a more appropriate label for that vertical axis?

A. If you look at the response spectra plots that generally are plotted on Y axis, all you define is acceleration, and on X axis you define frequency or period, and then the title is usually response spectra.

Q. But isn't what this graph is showing, this particular figure is in response acceleration?

A. That is correct, sir. You could call it any term that will make you feel better, but in general it represents the acceleration of a single degree of freedom system, maximum acceleration of the single degree of freedom system.

Do you have a spectra given in Reg Guide 1.60? Do you have Reg Guide 1.60? Let's just look at the --

Q. We don't have a copy with us.

A. But if you look at -- basically it defines acceleration. Now, if the definition is different you could use that, but we use acceleration and frequency or period.

Q. Dr. Khan, you make frequent references to "system," the word "system" in your testimony. What does your definition of system include?

A. System could be a cask by itself; a system could be a pad and a cask; a system could be soil, pad, and a cask. It could be as huge as you would like it to be. So depending on what you are analyzing, you could define that system. System would be more than --

Q. What specific system did you use in State Exhibit 195?

A. In Exhibit -- I simply used program that generates response spectra from a time history. No, I did not use any cask, I did not use any pad. The only thing I used was the input time history of PFS.

Q. So you're not looking at a system that would include a cask, a pad, soil cement, a soil foundation?

A. Yeah. It's immaterial. This is the ground motion. This is earthquake. I used the earthquake which is given in terms of acceleration and time and converted that into frequency and acceleration.

Q. So the earthquake you used was a freefield seismic ground motion, or a ground motion associated with it?

A. Whatever PFS has given me in the digitized form for normal, for parallel and vertical.

Q. You would agree that -- excuse me. I lost my train of thought here.

Well, if you were to take into account the underlying soil foundation, that would filter the freefield response, would it not? There would be some frequency filtering effects?

A. There would be some, and I think that has been shown by Dr. Luk's report to some extent.

Q. Should you account for the radiation damping associated with the soil?

A. Yes, sir. Dr. Luk's report included all the effect of soil damping and it calculates the response at the top of the pad or at the bottom of the pad, and therefore when you apply these time histories that effect is already taken into consideration.

Q. Do you have an opinion as to what the magnitude of this radiation damping should be?

A. No, sir.

Q. And we're talking about the casks, but with the input motion of the pads, wouldn't that also be filtered by the soil?

A. Yes. I keep on going back to the results which Dr. Luk has presented. It has all been done. Let's say we agree to his results. You will see the spectra, amplify the spectra. And motion seems to have been amplified significantly, and therefore whatever soil damping effect, radiation damping effect, filtering effect that he has modeled so far is all there.

Q. What about the damping for reinforced concrete structure in Reg Guide 126.1? What is that based on?

A. My understanding is a lot of information in the Reg Guide is based on test data.

Q. What are the typical values that are indicated in Reg Guide 126.1?

A. If you are doing a stress analysis of the pad, then that damping could be as high as 7 percent for a large earthquake. For a smaller level earthquake it could be less. It could be 5 percent, maybe 3 percent. For equipment in general it could vary anywhere from 1 percent to 4 percent depending on site, depending on the technical requirements.

Q. Your particular model for the cask used beam elements. I believe we discussed that earlier. Correct?

A. Yes, sir.

Q. Did you calculate yourself what the natural frequency would be?

A. The program is, there's so many elements and so many masses, it automatically calculates it internally. So I was not able to do it by hand because it's a one degree of freedom system, but one can obtain it.

Q. But did you make any attempt to figure out what it was?

MR. SOPER: Let me object to the question at this point. Excuse me. I've been trying to be patient here, your Honor, but as you noted, the examination was supposed to be limited to my redirect, and these are all subjects that were not included in my redirect.

MR. O'NEILL: One of your specific questions dealt with how he was characterizing his model, I mean, the frequency in his model. I think he had raised some questions, too, about frequency at 30 Hz, for instance.

JUDGE FARRAR: When the State introduced this exhibit they introduced it for a limited purpose, and I expected the cross would deal with just locking in that limited purpose to avoid any confusion. So if you can make sure that you focus your questions that way, we'll get to the end sooner. Mr. Gaukler?

MR. GAUKLER: I was going to say, there was some separate testimony, though, in terms of modeling in terms of beam element. I don't know whether Mr. O'Neill is going towards that or Exhibit 195. And there was some separate redirect with respect to beam elements in Dr. Khan's model.

MR. O'NEILL: I know he did specifically discuss beam elements in his model.

JUDGE FARRAR: Right.

MR. O'NEILL: And I think it's in the advantages of that particular approach.

JUDGE FARRAR: We'll overrule the objection for now.

THE WITNESS: There would be many frequencies because of multi degree of freedom system. Program automatically calculates it depending on the stiffness that you use at the base and the mass that you have. And it could range anywhere from very low frequencies, 1 Hz, all the way to 100, 200 Hz. So depending on how many nodes you would be able to excite. Yes, you can calculate by fixing it at the bottom and you can get all sorts of frequencies.

Q. (By Mr. O'Neill) But is that a function of you having looked at a range of parameters and contact stiffness values? You didn't attempt to ascertain what you might consider a realistic frequency, realistic natural frequency of a system at PFS?

A. I wish I knew what the realistic frequency would be, and that's why a range was chosen. Had I known a specific frequency, then I would have picked values that would have matched those. And that's the reason a range is given.

And frequency will change as the stiffness is changing.

MR. O'NEILL: No further questions. Thank you.

JUDGE FARRAR: Mr. Soper?

MR. SOPER: Your Honor, we do have one more. As it turns out, it's Ms. Nakahara's area. Could she ask one question?

JUDGE FARRAR: Yes, certainly.

MS. NAKAHARA: For the record, I'm Connie Nakahara. I'd like to have this marked as State's Exhibit 196, which are a cover page from the development of time histories for 2,000-year return period design spectra, and the second page is dated March 21, 2001, Rev. 0, and Table 1 which consists of page 12, 13, and 14.

JUDGE FARRAR: All right. We'll have -- the reporter will mark that.

(STATE'S EXHIBIT-196 MARKED.)

FURTHER REDIRECT EXAMINATION

BY MS. NAKAHARA:

Q. Dr. Khan, is it correct you testified that the response spectra you calculated for 5 percent damping in State's Exhibit 195 was very similar or identical to the response spectra developed for -- developed by Geomatrix for the 2,000-year return period?

A. Yes.

Q. What's been marked as State's Exhibit 196, are you familiar with this document?

A. Yes.

Q. And I'd like to just quickly ask you to compare some values for your 5 percent response spectra and those obtained by Geomatrix. If you'll compare the -- for frequency of 5, the 5 percent response spectra in the vertical direction, what was the value you obtained?

A. 1.47 g's.

Q. If you'll compare that to the value that Geomatrix obtained, which should be on page 13, for 5 percent damping in the vertical direction.

A. Is 1.47945. My values are two digits, so -- and they have 5 digits.

Q. And is it your understanding that default normal time history is in the north-south direction?

A. That's my guess at this time, I believe so.

Q. Under that assumption will you identify the 5 percent damping acceleration for 5 Hz that you obtained in the north-south direction?

A. That -- my value is 2.13 g's.

Q. And if you'll compare that to the value that Geomatrix obtained.

A. 2.14129.

Q. And if you'll identify for the 5 percent damping acceleration that you obtained for 5 hz in the east-west direction.

A. I'm having a hard time locating. My value is 2.18. I'm trying to see which column that should be. One, two, three, four, five --

Q. You anticipated the next question. If you'll compare that to the Geomatrix value for the fault parallel.

A. I'm not sure, or at least I'm not seeing the 5 -- let's see. Okay, at 5 Hz would be -- I believe is 2.188, and my value is 2.18 g's.

JUDGE FARRAR: This compares to to the five digits 18846?

THE WITNESS: That is correct, sir.

Q. (By Ms. Nakahara) If you'll go through this exercise for 10 Hz just to compare. If you'll identify your 5 percent damping value for acceleration at 10 Hz in the vertical direction.

A. In the vertical direction at 10 Hz, Ms. Nakahara?
Q. Yes.
A. At 10 Hz is 2 g.
Q. Compare that to the value obtained by Geomatrix in the vertical direction.
A. 2.00011.
Q. If you'll identify the acceleration you obtained for 5 Hz damping at 10 Hz in the north-south direction.
A. My value is 1.57 g's.
Q. And if you'll identify the value obtained by Geomatrix.
A. Is 1.58448.
Q. And finally, identify the value in the east-west direction for 5 percent acceleration value in the east-west direction for 5 percent damping at 10 Hz.
A. At 10 Hz my value is 1.60 g's.
Q. And compare that to the value obtained by Geomatrix.
A. And Geomatrix value is 1.60646.
Q. And Dr. Khan, is it correct you testified earlier that when you compared the response spectra for 5 percent damping that you

obtained in State's Exhibit 195, was that obtained by Geomatrix that was very similar but not identical?

A. That is correct.

MS. NAKAHARA: And your Honor, I move to admit State's Exhibit 196.

JUDGE FARRAR: Any objection?

MR. GAUKLER: No objection, your Honor.

MR. O'NEILL: No objection, your Honor.

JUDGE FARRAR: Then it will be admitted.

(STATE'S EXHIBIT 196 WAS ADMITTED.)

MS. NAKAHARA: That's all we have. Thank you.

JUDGE FARRAR: That was the one question Mr. Soper told me you had.

Does that generate any need for further cross? All right, good. Dr. Khan, then you're excused, I guess for now. Thank you for your testimony.

MR. O'NEILL: Your Honor, I think one thing we agreed upon was that we'd have to determine the appropriate agreed-upon title for this.

JUDGE FARRAR: Yeah, you'll do that, not in our presence.

MR. O'NEILL: Just reminding you.

MR. SOPER: I was going to suggest, your Honor, that we use the same terminology that Geomatrix used on this Exhibit 196, design response spectra 5 percent damping and call it the fault normal, fault parallel and vertical.

MR. GAUKLER: We'll talk about it, your Honor.

MR. SOPER: Since it's the same numbers, almost, to the --

JUDGE FARRAR: Well, you all figure that out, and keep it simple.

All right, according to the e-mails you gave us, tomorrow we're going to have PFS's rebuttal to the Khan/Ostadan testimony in the form of Dr. Singh and Dr. Soler?

MR. GAUKLER: Yes. And I'm going to talk with the State, and they'll be ready to offer their rebuttal that they have with respect to Dr. Ostadan and Dr. Bartlett's testimony.

MS. CHANCELLOR: We need to talk about that, your Honor.

JUDGE FARRAR: We hadn't finished that. We in fact, Ostadan and Bartlett, we were --

MS. CHANCELLOR: Scheduled for Friday.

MR. GAUKLER: This Friday.

JUDGE FARRAR: Bartlett and Ostadan, hadn't we finished them?

MR. GAUKLER: No. We were halfway.

JUDGE FARRAR: Oh, we had more questions. We hadn't done redirect.

MR. O'NEILL: I don't think Mr. Turk finished his cross of Dr. Ostadan.

MS. CHANCELLOR: It should be noted in the e-mail where we are at with each witness.

JUDGE FARRAR: I see. We had interjected some Board questions but he had not finished. And you all don't want to have rebuttal till --

MS. CHANCELLOR: We'd like to get the direct case on first before we have rebuttal, but I'm willing to talk to Mr. Gaukler, but it doesn't seem logical to have rebuttal before you can finish direct.

MR. GAUKLER: Well, we know we have certain rebuttal already based upon their direct and what they've said. We're prepared to put that on with Dr. Singh and Dr. Soler. It would be efficient to do so.

JUDGE FARRAR: To get them out of here?

MR. GAUKLER: At least Dr. Singh, yes. Dr. Soler is going to stay around.

MS. CHANCELLOR: We haven't even started redirect.

MR. TRAVIESO-DIAZ: We have rebuttal to Section B testimony by six PFS witnesses if you include Dr. Soler and Dr. Singh, and we have one day to do rebuttal. I think if we try to do all that rebuttal in one day, regardless of whatever measures we may take to expedite it, I don't think we're going to get done. I don't think we're going to be able to put rebuttal testimony by six witnesses and examination with respect to it in a single day. I don't see how that feasibly be done. Given, though, I'm volunteering to prefile some of it to expedite the process, but still --

JUDGE FARRAR: Who are the six witnesses?

MR. TRAVIESO-DIAZ: Dr. Soler, Dr. Singh, Mr. Trudeau, Mr. Ebbeson, Dr. Singh and Mr. Youngs. So our concern is that --

JUDGE FARRAR: Wait a minute.

MS. CHANCELLOR: I count six.

MR. TRAVIESO-DIAZ: Yeah, six.

MS. CHANCELLOR: I thought you said

seven. Sorry.

MR. TRAVIESO-DIAZ: No, six.

If I may --

JUDGE FARRAR: And they're all going to say something different from what they said on direct?

MR. TRAVIESO-DIAZ: Yes. The problem is that the testimony of Dr. Bartlett and Dr. Ostadan, the one that they gave and the response they gave to my questions touched upon each of those witnesses' testimony. Some of the rebuttal is going to be very brief, but still you have potential of six people. So we're trying to anticipate and expedite some of the that rebuttal in areas that we know before Saturday. Otherwise I think all these people will have to go back to Washington, which I don't think anybody wants. That's what we're trying to avoid.

MS. CHANCELLOR: Could I ask a question about how long Mr. Gaukler or Mr. Travieso-Diaz thinks that it will take for Dr. Singh and Dr. Soler without rebuttal tomorrow, without rebuttal on D? Ostadan and Bartlett, I mean.

MR. GAUKLER: Rebuttal without Dr. Ostadan and Dr. Bartlett, just rebutting

Dr. Khan?

MS. CHANCELLOR: Correct.

MR. GAUKLER: I had figured in my mind a half day of total, roughly, without breaking it out. But the great majority of it is with respect to Dr. Khan.

MR. TRAVIESO-DIAZ: It may very well be, but there will be no time tomorrow to get to Dr. Bartlett and Dr. Ostadan. But if time permits, I think it will be desirable to get that portion of rebuttal that we can get done tomorrow, to the extent that we know already what the rebuttal will be.

MS. CHANCELLOR: The alternative is to start Dr. Arabasz. Oh, and we have rebuttal with Dr. Khan.

MR. GAUKLER: How much rebuttal do you have with him, approximately? Do you know?

DR. KHAN: I thought I was leaving.

JUDGE FARRAR: Surrebuttal?

MS. NAKAHARA: Dr. Soler and Dr. Singh.

JUDGE FARRAR: You mean after they do rebuttal you'd have surrebuttal?

MS. NAKAHARA: And rebuttal on Dr. Soler and Dr. Singh's direct.

MS. CHANCELLOR: Dr. Singh --

JUDGE FARRAR: Wait a minute. Wait. I thought they went -- they go first. I thought the purpose of your testimony is responding to their case.

MS. CHANCELLOR: But we -- we could respond to Dr. Singh and Soler's direct case with the rebuttal witness, Dr. Khan, and we could also --

JUDGE FARRAR: You all filed at the same time.

MS. CHANCELLOR: Right.

JUDGE FARRAR: So that's the disadvantage of that is that your testimony which in the ordinary course is rebutting their case isn't; you're trying to anticipate, you're saying you get another chance now?

MS. CHANCELLOR: I think we could finish all of cask stability tomorrow.

JUDGE FARRAR: Wait a minute. Are you saying that every set of witnesses you get two chances to respond, your prefiled chance and another chance?

MR. TRAVIESO-DIAZ: At least tomorrow.

JUDGE FARRAR: I heard that.

MR. TRAVIESO-DIAZ: I would say, however, that the scope of each successive rebuttal should be narrower and narrower.

JUDGE FARRAR: I just had not focused on the simultaneous prefiling problem, that what's your rebuttal case is not --

MS. CHANCELLOR: Rebuttal and surrebuttal are different.

JUDGE FARRAR: Okay. Well, then we've just got to go.

MS. CHANCELLOR: Dr. Khan is only available tomorrow, so we would like to get through with our rebuttal and surrebuttal, whatever we're calling it, with Dr. Khan tomorrow.

JUDGE FARRAR: Let's do this for your planning. It's going to be hard enough for us to follow. We'll take Dr. Singh and Dr. Soler tomorrow, but only on the rebuttal to Khan, not on the rebuttal to the testimony we haven't yet heard. That's adding too much complication.

All right, so we'll do them, and then you want to put Dr. Khan back on in response to their earlier testimony?

MS. CHANCELLOR: We could probably do in response to their earlier as well as any surrebuttal and just wrap everything up with Dr. Khan so that we can get cask stability.

JUDGE FARRAR: Okay, great. All right, then we'll --

MS. CHANCELLOR: And then do I need to advise Dr. Arabasz to come tomorrow in case he's needed at the end of the day?

JUDGE FARRAR: Where is he located?

MS. CHANCELLOR: At the university, but I think he needs to bring a suit.

JUDGE FARRAR: When is Mr. Turk due in?

MR. O'NEILL: One-thirty or two o'clock. My understanding is he said he was going to try to catch an earlier flight if possible.

JUDGE FARRAR: Okay, get Dr. Arabasz here. If he's dragged down the hill unnecessarily, that's little or nothing.

MR. GAUKLER: I should say that he should probably bring a suit, but we can advise him how the day's going at noon.

MS. CHANCELLOR: Okay, I'll do that.

MR. GAUKLER: We'll know better tomorrow morning exactly how much rebuttal we have with Dr. Khan. Just giving a very rough estimate right now this evening.

JUDGE FARRAR: All right, then fine. Then we'll see you all at 9 o'clock tomorrow morning.

(The proceeding was concluded for the day.)

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.