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**NUCLEAR REGULATORY COMMISSION**

Title: Private Fuel Storage, LLC

Docket Number: 72-22-ISFSI; ASLBP No. 97-732-02-ISFSI

Location: Salt Lake City, Utah

Date: Monday, June 3, 2002

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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

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## E X H I B I T S

No. MRKD/ADMTD

## APPLICANT'S EXHIBITS

219 Diagram	9360/
220 Pages from Manual	9377/
221 Three Pages from Manual	9377/
222 IEEE Standard 384-1992	9428/9463
223 Reg. Guide 1.100	9428/9463
224 Excerpts from Singh/Soler March 6, 2002 deposition	9451/9464

## STATE'S EXHIBITS

195 Response spectra for vertical direction for 2000-year return period time history	9493/9508
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1 June 3, 2002

10:00 a.m.

2  
3 P R O C E E D I N G S

4  
5 JUDGE FARRAR: Morning, everyone. We're  
6 back in Salt Lake City for a full week of seismic  
7 hearings today through Saturday. Good to see all  
8 of you back.

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

16 MR. O'NEILL: Okay.

17 JUDGE FARRAR: Second -- off the record.

18 (A discussion was held off the record.)

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

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

23 JUDGE FARRAR: All right.

24 MS. CHANCELLOR: We offered  
25 Mr. Solomon's testimony into evidence, but we can't

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1 find any reference to Exhibit 91, which is  
2 Mr. Solomon's curriculum vitae, and I would request  
3 that that be entered into the record. It was given  
4 to the reporter to have marked, and if the reporter  
5 doesn't have a copy, I can provide another copy.

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

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

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

19 MS. CHANCELLOR: Thank you, Your Honor.

20 JUDGE FARRAR: Ms. Gaukler.

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

25 JUDGE FARRAR: We had gotten several

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

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

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

18  
19 CROSS EXAMINATION (Continued)

20 BY MR. GAUKLER:

21 Q. Good morning, Dr. Khan.

22 A. Good morning.

23 Q. Welcome back.

24 A. Thank you.

25 Q. The last time we were talking about the

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1 use of SAP2000, and I'd like to follow up with some  
2 questions on use of SAP2000 and its capabilities.

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

6 A. That's correct.

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

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

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

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

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

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

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1       though?

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

5           Q.       And that also would include large  
6       deformations?

7           A.       No.

8           Q.       No. It would include large  
9       displacements?

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

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

18          A.       Thank you.

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

23          A.       That's correct.

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

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1 see that?

2 A. Yes, sir.

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

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

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

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

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

25 Q. And do you know at what point the

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

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

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

16 A. No, I don't.

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

20 A. Yes.

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

24 A. Okay.

25 Q. And do you recognize that as the first

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1 page of the chapter of the SAP2000 users manual  
2 concerning Nllink elements?

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

5 A. This is page 243?

6 Q. Yes.

7 A. Yes, that's right.

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

12 Did I read that correctly, the first  
13 sentence?

14 A. Yes.

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

17 A. How do you define local nonlinearities?

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

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

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1 nonlinearities.

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

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

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

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

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

18 A. That's how it is done.

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

23 A. The program automatically calculates  
24 that figure.

25 Q. And that still is a local nonlinearity,

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1       that local structural nonlinearity in your mind,  
2       that 40-feet displacement?

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

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

11          A.       Yes, sir.

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

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

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

20          A.       It's a relative displacement.

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

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1 A. Yes, sir.

2 Q. And the one I see is viscoelastic  
3 damping; correct?

4 A. Yes, sir.

5 Q. And gap and hook tension only?

6 A. That is correct.

7 Q. I take it the gap compression is only  
8 when you are looking at a gap and seeing whether it  
9 closes?

10 A. That's correct.

11 Q. And a hook, you're looking to see  
12 whether -- hook tension, you're looking to see  
13 whether something pulls apart?

14 A. Yes.

15 Q. Locally, it's a local point?

16 A. Yes.

17 Q. And what you're interested there is to  
18 do two things, pull apart or to stay together;  
19 correct?

20 A. That is correct.

21 Q. And with the gap compression, you're  
22 interested in something relatively close with the  
23 gap in where they actually hit at some point in  
24 time; correct?

25 A. No. All it does, it's between -- it's

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

4 Q. And then the other one is uniaxial  
5 plasticity.

6 A. Okay.

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

9 A. Yes, sir.

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

12 A. That's correct.

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

15 A. That's correct.

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

18 A. That is a theory on which all these  
19 nonlinear programs are based, and no program that I  
20 know of will give you an example where an input  
21 motion was applied and displacement of 50 inches,  
22 60 inches or 30 inches were obtained and compared  
23 with the test data. And that has been my question  
24 all along.

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

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

7 A. Yes, you could have.

8 Q. You could have?

9 A. Yes.

10 Q. That's your testimony?

11 A. Yes, sir.

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

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

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1 problem.

2 Q. And so the displacement could be 400  
3 feet?

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

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

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

25 Q. And what if you introduce a situation

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1 where in addition to just sliding, you have  
2 lift-off two feet? Now, that's a geometric  
3 nonlinearity; correct?

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

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

9 A. Yes.

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

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

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

25 A. For translational displacement, which

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1 means -- translational displacement, means it moves  
2 sideways, it moves up. That is not a change in the  
3 center of gravity of the object. Therefore, that  
4 is only -- that's not a kinematic nonlinearity.  
5 Kinematic where you have a motion of the rigid  
6 bodies. That is not related to the nonlinearity  
7 you're talking about where you may have large  
8 rotations.

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

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

23 Q. So I take it the answer to my question,  
24 just going up two, three feet and going out five,  
25 10 feet, you would not consider that to be a

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1 geometric nonlinearity?

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

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

6 A. No. The program does not consider that.

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

9 (A discussion was held off the record.)

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

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

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

22 Q. And now, with a friction coefficient of  
23 0.8, wouldn't you expect a cask to tip over before  
24 it would move 40 feet? Just as a physical matter.

25 A. There are a few things. I've got some

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1 time history that PFS provided. I've got those  
2 time histories. And I wanted to show that how  
3 sensitive your vertical motion could be, and if the  
4 cask lifts up due to these motions, then you  
5 basically have no effect of coefficient of friction  
6 at that inset of time, and its ground is just  
7 moving with respect to the casks. So when you got  
8 three motions acting simultaneously at that time,  
9 anything is possible. And I think one thing that  
10 we should recognize is nobody can predict the  
11 nonlinear behavior exactly.

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

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

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

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

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

7           A.       No.

8           Q.       You don't think so?

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

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

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

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

22          A.       Yes, sure.

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

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1 A. It depends on the vertical motion.

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

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

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

19 A. No.

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

23 JUDGE FARRAR: Yes.

24 (A discussion was held off the record.)

25 (EXHIBIT-219 MARKED.)

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

8 MR. GAUKLER: That's correct.

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

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

20 A. Could you please repeat it.

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

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1 dynamic problem?

2 A. No. What I said is -- let me repeat.

3 One should look at the designed spectra, okay.

4 Looking at the designed spectra, you look at the

5 amplified region of the spectra. And from that

6 amplified region of the spectra, in order for one

7 to capture all the dynamic behavior, one should

8 select those stiffnesses, and that would give --

9 that would capture the dynamics of the model. Now,

10 some of them may be on the lower end of the spectra

11 and some would be on the higher end of the spectra.

12 So you -- if you do not know the actual test data,

13 what the realistic value should be, you know,

14 rocking frequency, for example, that's one of the

15 reasons is how are you going to model the rocking

16 adequately. What stiffness values one should use

17 when you have a frequency of let's say two hertz,

18 what is the acceleration at that point? What is

19 stiffness one is going to use to model the rocking

20 behavior in your system? And that was the

21 explanation I'm trying to give is that one should

22 use stiffnesses which are in the whole range, if

23 you do not have the test data that validates any

24 analysis.

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

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

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

9 Q. So --

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

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

19 A. Yes, sir.

20 Q. And it does a balance maybe one or two  
21 and comes to rest in a static position. Now, do  
22 you believe -- would you agree that a properly  
23 constructed model would be able to produce a good  
24 result for this problem, a good simulation of this  
25 problem using one model, and by that I mean, could

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1       you use this one model with one contact stiffness  
2       that would accurately simulate the initial dynamic  
3       impact of the cask, a subsequent balance of the  
4       cask and the final static position of the cask?

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

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1       those answers? The answer is no one has done it so  
2       far.

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

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

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

10          A.       I have no idea.

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

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

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

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

3            A.        Well, case three, again --

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

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

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

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

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

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

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

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1 deflection that you would have --

2 MR. SOPER: Can the witness finish?

3 He's cutting off the witness in mid answer?

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

6 MR. GAUKLER: And I apologize, Your  
7 Honor.

8 JUDGE FARRAR: Go ahead, Doctor.

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

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

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

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

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

20          Q.       I understand that, the purpose of your  
21      report. But my question is a little bit different.  
22      Is you take -- you considered a range of  
23      parameters. My question is, can you take one value  
24      of the parameter, i.e., one value of the contact  
25      stiffness and run this example or this model, this

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1 problem, and get a reasonable simulation of the  
2 motion and impacts shown on this page, which is the  
3 initial impact of the pad on the cask, subsequent  
4 bounce and then the subsequent static condition of  
5 the cask? Do you think you can pick a contact  
6 stiffness value parameter that would allow you to  
7 accurately simulate the motion and final static  
8 position of the cask as shown in PFS Exhibit 219?  
9 That's my specific question. Very specific.

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

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

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

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

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

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1 MR. GAUKLER: I think he is, too.

2 JUDGE FARRAR: Okay.

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

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

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

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

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

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

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

25 A. Yeah, I remember that.

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

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

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

8 JUDGE FARRAR: Thank you.

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

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

16 MR. GAUKLER: Right.

17 JUDGE FARRAR: Thank you.

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

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

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

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1 A. I was -- could you.

2 MR. GAUKLER: Could you repeat the  
3 question.

4 (The record was read as follows:

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

9 THE WITNESS: Yes, sir.

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

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

22 DR. KHAN: All my life.

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

25 Q. (By Mr. Gaukler) And basically, I was

1 asking the question if at that point, referring to  
2 the statement in the second page that minimum  
3 penetration gives best accuracy, that whether it  
4 was part of the ANSYS guidance that was part of  
5 this document, that the penetration would be  
6 deflection as a result from contact stiffness  
7 should be as small as possible. That was my  
8 question. And you answered at 7210, "It depends if  
9 you have a penetration problem. I don't think it's  
10 a penetration problem."

11 A. That is correct.

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

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

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

21 A. Penetration problems, as you know, it  
22 depends on the test. You got to show the test, and  
23 it depends how two bodies are interacting with each  
24 other. And this could be problem dependent, highly  
25 problem dependent. So yes, one could choose a

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1 value, but remember, the purpose of the selection  
2 of contact stiffness in a dynamic analysis is  
3 twofold. No. 1, is you are looking at the  
4 frequencies at which your system is going to  
5 respond. And that's if you want to capture the  
6 dynamic behavior of the cask, especially in the  
7 rocking. And how that is being captured is really  
8 the most important question. Now, if you have a  
9 test, it will automatically model everything in  
10 itself. In analysis, you can't really model so you  
11 start from a lower stiffness to a higher stiffness  
12 value and basically look at your response and see  
13 where you are in terms of your dynamic analysis.  
14 And that's the purpose. These penetration  
15 problems, like I say, they're problem dependent,  
16 they are object, two objects which are colliding  
17 with each other, and oftentimes, they are first  
18 calibrated and then these stiffness values are  
19 used.

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

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

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

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

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

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

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

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

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

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

12 A. It just says --

13 MR. SOPER: The document speaks for  
14 itself.

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

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

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

24 MR. GAUKLER: I'd like to hand out some  
25 other pages from the manual. I'd like to have

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1 these marked as PFS Exhibit 220 and 221, and why  
2 don't we mark the larger one with 220 and the  
3 smaller one, which only has three pages, as 221.

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

6 (EXHIBITS-220 & 221 MARKED.)

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

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

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

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

19 JUDGE FARRAR: Thank you.

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

24 MR. SOPER: I object to the question.  
25 Mr. Gaukler is testifying as to what this document

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1 is, and those representations ought to come from a  
2 witness who knows the answer.

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

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

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

20 A. It says advanced contact and board  
21 pretension.

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

25 MR. GAUKLER: Not necessarily, no.

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

4 DR. KHAN: Yes, sir.

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

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

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

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

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

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

23 Q. You're saying that a training manual in  
24 terms of whether given advanced information is  
25 promotional and has nothing to do in terms of

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1 further training a person with respect to how the  
2 program can be used and its capabilities?

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

8 Q. Well, have you gone to a --

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

11 JUDGE FARRAR: Yes, go ahead.

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

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

22 A. No, not contact stiffness.

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

25 A. Yes, I just said.

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

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

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

10 A. Yes.

11 Q. Bumps, motors and the like?

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

13 Q. I'd like to have you --

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

19 (Recess Taken.)

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

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1 Go ahead, Mr. Gaukler.

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

4 A. Say it again, please.

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

7 A. No, sir.

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

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

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

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

20 So there is no unique, one way of  
21 calculating. You could also do a very good finite  
22 element analysis, very detailed, and can calculate  
23 the displacements and can calculate the stiffness.  
24 But the question that still remains is that these  
25 are all variable with respect to time, and how you

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1 are going to change those with respect to time is  
2 really --

3 Q. Have you ever calculated the contact  
4 stiffness?

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

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

12 A. No.

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

18 A. I don't know.

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

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

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

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

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

7 A. No.

8 Q. -- in modeling your case?

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

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

13 A. Which exhibit?

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

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

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

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1 A. Yes, sir.

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

4 A. Yes, sir.

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

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

9 Q. The what?

10 A. K divided by M.

11 Q. The square root of that?

12 A. Yes.

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

15 A. Of interest.

16 Q. The frequency of the cask?

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

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

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

3           Q.       And M would be the --

4           A.       Total mass of the object.

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

6           A.       That is correct.

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

11          A.       That is correct.

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

15          A.       That is correct.

16          Q.       And that would be the vibration of --

17          A.       Dynamics of --

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

21          A.       That's correct, sir.

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

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1 answer 32. Is that correct?

2 A. That is correct.

3 Q. And can you just kind of walk through  
4 one of those calculations for me and tell me how  
5 you did that? Say, for example, with 1x106 pounds  
6 per inch, how would you take --

7 A. I did not do any calculations. I said  
8 one could choose this formula to calculate a range  
9 of stiffness values to cover any dynamic  
10 amplifications that could occur. In the report  
11 that I presented, it just shows a value between 10  
12 to the power 6 and whatever the last number was.  
13 But there is a way that one could look into the  
14 dynamics, and a range of stiffness values could be  
15 obtained by this formulation. I did not do this.

16 Q. But you say that 1x106 pounds per inch  
17 would correspond to a cask frequency that would  
18 fall in the range of the amplified --

19 A. Yeah, it would be one of the many  
20 frequencies that --

21 Q. That would fall in that range?

22 A. Sure.

23 Q. So can you show me how you used that  
24 formula, used 1x106 pounds per inch in that formula  
25 to come to that conclusion?

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

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

6           A.       Let's say --

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

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

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

14               (Pause while witness performs calculation.)

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

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

4 A. That's right.

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

8 A. That is correct.

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

11 A. That is correct.

12 Q. And gravity is 32 feet per second  
13 squared?

14 A. 386.4 inches per second.

15 Q. So for example, if I wanted to find out,  
16 suppose I wanted to work backwards and I wanted to  
17 find out the frequencies that you claim are  
18 relevant in question and answer 32. On that I just  
19 would take, say for the first one,  $1 \times 10^6$  pounds per  
20 inch and put that in for K in that formula,  
21 correct?

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

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1 Q. So in other words, just by taking these  
2 two stiffness values,  $1 \times 10^6$  and  $10 \times 10^6$ , and  
3 substituting them into the formula, I could get the  
4 frequency that you claim we should tune our  
5 structural system to?

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

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

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

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1 A. Yes, I'm aware.

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

4 A. Would you please --

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

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

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

17 A. Yes.

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

21 A. That's correct. And let me emphasize  
22 why I made that statement. If you are using a  
23 nonlinear sliding analysis and if your energy  
24 dissipation mechanism is sliding by friction, then  
25 by taking higher damping values you may be double

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1 counting it, okay? If a rigid body is sliding and  
2 if that's the assumption, then all the energy is  
3 being absorbed by these friction forces. And by  
4 taking certain amount of damping on top of it, you  
5 may be underestimating it or you may be double  
6 counting it. That's -- and that just -- I think  
7 the contact stiffness damping value is what  
8 really -- it might underestimate the dynamic  
9 response.

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

12 A. It may underestimate the dynamic  
13 response.

14 Q. What may underestimate?

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

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

22 A. It is a model damping.

23 Q. What?

24 A. It's a model damping.

25 Q. Assume that the cask just slides in your

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1 model. Is there any loss of energy or dissipation  
2 of energy due to damping in your model?

3 A. Yes.

4 Q. There is?

5 A. Yes.

6 Q. Do you know how Holtec modeled its --

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

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

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

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

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

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1 correct?

2 A. Yes, sir.

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

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

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

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

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

21 A. Yes.

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

25 A. If you have a damping, justifiable

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1       damping, yes.

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

3           A.       Sure.

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

6           A.       That's correct.

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

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

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

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

25          Q.       With the spring?

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1 A. That's right.

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

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

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

14 A. That's right.

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

18 A. Vertical as well as horizontal.

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

21 A. Yeah. It was included in the model.

22 Q. So you had a damping of whatever it was,  
23 0.1 percent to 5 percent associated both with  
24 respect to the vertical spring and the horizontal  
25 springs in your model?

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

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

11          A.       Could you restate your question?

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

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

25          Q.       Well, you would not be including any

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

12 A. Sure, that's correct.

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

20 A. That's what's being used.

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

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1 A. Sure.

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

14 A. There would be some, yes.

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

18 A. Yes.

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

24 A. No.

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

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1 surface it bounces up part of the way, correct?

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

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

17 A. Unless you experimentally determined it.

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

24 A. I would not use that analogy. There's a  
25 dead weight associated with that structure. So,

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1 you know, if there is no gravitational effect,  
2 we'll all be flying. The gravitational effect is  
3 going to bring everything down to the floor. So  
4 there is a gravitational effect that's working when  
5 something is dropping.

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

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

15 A. Sure.

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

25 A. Yeah.

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

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

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

21          A.       Sure.

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

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1           A.       Yeah.

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

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

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

23          A.       Sure.

24          Q.       And now my example of the perfectly  
25 plastic body -- so in my perfectly elastic

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1 situation where I drop a ball from a foot and it  
2 comes back up, there would be no dissipation of  
3 energy in that process, correct?

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

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

11 A. Okay.

12 Q. Is that correct?

13 A. Sure.

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

17 A. Sure.

18 Q. Now, by picking a low damping value, you  
19 suggest in your report that you should use either a  
20 1 percent damping value or maybe even .01 in one of  
21 your runs. What you're saying is that the cask/pad  
22 system in fact acts more in the elastic range as  
23 opposed to the plastic range. Is that what you're  
24 saying?

25 A. All I'm saying is if you are -- let's

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1 say, assume that you have a coefficient of friction  
2 of 1, 1. That means it's perfect. It is attached  
3 to the body surface.

4 Q. Do you mean to say coefficient of  
5 friction?

6 A. Coefficient of friction 1.

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

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

21 Q. I said hypothetically we're assuming no  
22 damping in the horizontal spring. We're just  
23 talking now about damping in the vertical spring,  
24 and there's no damping in the horizontal spring.  
25 And we've agreed in that situation that with

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1 sliding, friction would be the primary dissipation  
2 of energy?

3 A. Yeah.

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

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

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

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

17 Q. You're answering my question or not?

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

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

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

23           Q.       And my question was to you, that by  
24 using a damping value, low damping value like 1  
25 percent, .01 percent as you've done in some of the

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1 runs in your case with respect to the vertical  
2 spring, you are in essence assuming that the  
3 cask/pad interface is elastic and you'll get a  
4 bouncing effect similar to an elastic ball or close  
5 to an elastic ball. Isn't that correct?

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

8 Q. You use a damping value of 1 percent and  
9 .01, correct?

10 A. Yes.

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

13 A. Yes.

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

17 A. That's right.

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

25 A. But you've got a combination of

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

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

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

22 MR. SOPER: Might I ask the Board if  
23 they could admonish some of the spectators.  
24 Dr. Singh is laughing and slapping his head and  
25 distracting me from hearing the witness, and I

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1 think it takes away from the decorum of this  
2 proceeding.

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

7 MR. SOPER: Thank you, your Honor.

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

11 (Requested portion of the record read.)

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

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

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

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

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

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

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

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

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

16 A. That is correct, associated with that  
17 motion.

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

20 A. That's correct.

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

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1 and the pad, correct?

2 A. That's correct.

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

6 A. That's correct.

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

9 A. Mostly, yes.

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

13 A. That is very correct, yes.

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

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

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

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

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1 (Discussion off the record.)

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

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

8 MR. GAUKLER: I believe it is. I don't  
9 have the number. It's the report dated December  
10 11, 2001, Altran.

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

15 A. That's correct.

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

18 A. That's correct.

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

21 A. That is correct.

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

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1 2,000-year design-basis earthquake is based solely  
2 on the velocities of the cask's movement that you  
3 calculate in your model, correct?

4 A. That's correct, sir.

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

10 A. That's correct, sir.

11 Q. And for example, specifically on page  
12 16, bottom of the page in the report, you  
13 specifically refer to steady run No. 1 in Table 3,  
14 correct?

15 A. That's correct, sir.

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

18 A. That is correct, sir.

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

24 A. That's right, 360 inches.

25 Q. And that's in one direction. I think we

1 took the -- we take some of the squares and then  
2 you probably get a roughly 35 to 40 feet lateral  
3 displacement, correct?

4 A. That's right.

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

9 A. That is correct.

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

13 A. That is correct.

14 Q. With respect to that run 1 on Table 3,  
15 we've discussed this before. And I just wanted to  
16 clarify, that's the one that moves roughly 40 feet,  
17 35 to 40 feet in a diagonal direction and it goes  
18 up, bounces up two feet in the air. Last time I  
19 believe at the hearings you indicated that you did  
20 not know whether these results would be accurate or  
21 would be something that would accurately predict  
22 reality, correct?

23 A. That's true.

24 Q. So just so the record is clear: you're  
25 not asking the Board to believe that in the event

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1 of a 2,000-year design-basis earthquake that your  
2 model, particularly this run, accurately predicts  
3 what in fact would happen with the casks?

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

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

15 A. Yeah, I --

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

17 JUDGE FARRAR: Did you finish that  
18 answer?

19 THE WITNESS: Yes, sir.

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

24 A. Yes, sir. I have a sheet that I got  
25 from the time history analysis that PFS has

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1 provided, and I'd like to just show that to you,  
2 sir, to specify why this could be happening. Is it  
3 possible I could --

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

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

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

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

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

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

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

18           A.       It didn't appear in this case.

19           Q.       Did you check?

20           A.       Yes, sir.

21           Q.       How did you check?

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

25           Q.       Did QA raise any issues at all in terms

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1 of the -- your QA raise any issues at all with  
2 respect to the use of the program in these certain  
3 senses?

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

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

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

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

22 A. No.

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

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

3           Q.       I believe it's question and answer No.  
4 20, if you could look at that. The last part of  
5 the question, question 20, the question is whether  
6 or not your analysis complied with the NRC quality  
7 assurance requirements, and you mentioned the fact  
8 that you have a QA program in accordance with 10  
9 CFR Part 50 Appendix B, and at the very end you go  
10 on to say, "And was approved by the NRC."

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

18          Q.       By who?

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

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

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

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1 follow the program.

2 Q. And they did not specifically approve  
3 your program?

4 A. No.

5 Q. Now, in question and answers --  
6 Off the record for a second.

7 (Discussion off the record.)

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

13 A. This is question No. 34, sir?

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

16 A. That's correct, sir.

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

24 A. This is not only my claim. I think  
25 there's an NRC Reg Guide 1.100 endorses IEEE 34475,

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1 and basically states that for nonlinear analysis  
2 where you don't really know what the solution is  
3 going to be, you perform tests and validate your  
4 analytical data. You do some kind of benchmarking  
5 of your -- so this is just following a requirement  
6 that for nonlinear analysis that could be very  
7 sensitive, you perform shake table tests.

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

14 A. Validation of it, that's right.

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

17 A. That's right.

18 Q. Shake table tests should be done here?

19 A. That's right.

20 Q. Let's focus on the first one first.

21 Assume that the results of your analysis were  
22 wrong. Assume you were showing that the results of  
23 your analysis were wrong and that cask movements  
24 are not highly sensitive to the choice of contact  
25 stiffness and damping. Wouldn't that undercut your

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1       rationale for why you claim shake table testing is  
2       necessary here?

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

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

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

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

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1 A. You still have to do a test.

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

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

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

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

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

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

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

21 A. That is correct, sir.

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

25 A. That is correct, sir.

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

3 A. That was one of the primary standards.

4 Q. And also Reg Guide 1 --

5 A. 1.100.

6 Q. And let's focus on that.

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

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

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

14 (A recess was taken.)

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

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

19 MR. GAUKLER: Less than an hour.

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

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

24 A. Good afternoon, sir.

25 Q. Before we broke we were talking about

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1 shake table testing, and I'd like to go to the  
2 second part of your reliance for shake table  
3 testing, which you refer to IEEE Standard 344-1987  
4 and, I believe, Reg Guide 1.100.

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

9 A. Yes, sir.

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

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

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

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

3 (APPLICANT'S EXHIBIT-222

4 AND EXHIBIT-223 WERE MARKED.)

5 (A discussion was held off the record.)

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

13 A. Yes, sir.

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

16 A. Yes.

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

19 A. That's correct.

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

22 A. The safety classification of the  
23 electrical equipment and system that are essential  
24 to emergency reactor shutdown, containment  
25 isolation, reactor core cooling, and containment

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1 and reactor heat removal, or are otherwise  
2 essential in preventing a significant release of  
3 radioactivity to the environment.

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

6 A. That is correct.

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

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

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

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

21 And, second, let me ask the witness, the  
22 fact that this definition is contained in Standard  
23 384, your experience would indicate the same  
24 definition would be in the standard you were  
25 referring to?

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1 THE WITNESS: That is correct, sir.

2 JUDGE FARRAR: Okay. Fine.

3 Go ahead, Mr. Gaukler.

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

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

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

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

16 Q. I'd like to have you turn to page 2 of  
17 PFS Exhibit 223 which is the Regulatory Guide  
18 1.100.

19 A. Yes, sir.

20 Q. And if you look at the last full  
21 paragraph in the first column on that second page,  
22 it says, "This Regulatory Guide covers two  
23 categories of equipment: (1) safety-related  
24 electric (Class 1E) equipment, and safety-related  
25 mechanical equipment, and (2) non-safety-related

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1 equipment whose failure can prevent the  
2 satisfactory accomplishment of safety functions.  
3 Examples of mechanical impairment within the scope  
4 of this guide are valves, valve operators, pumps,  
5 compressors, chillers, air handlers, fans, blowers,  
6 fuel rod assemblies, and control rod drive  
7 mechanisms."

8 A. Yes.

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

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

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

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

14                 So one would not say it's whether IEEE  
15          344 works, but all the basis that forms -- that  
16          forms the basis of qualification of the component  
17          is all there. And so it's a good guidelines.  
18          Everybody uses it. We have used it. And -- for  
19          supertanks to -- high temps that contain fluid in  
20          it, for high temps that move. So it's been a very  
21          generally used guidance in the industry.

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

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

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

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

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

22           A.       Sure, for functionality.

23           Q.       And with respect to something like when  
24      you're doing a seismic qualification --  
25      qualification test for a pump or a motor or some

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1 other piece of equipment that has to operate either  
2 electrically or mechanically, you're going beyond  
3 concern with structural integrity of the -- of the  
4 component, you're looking at the capability of the  
5 component to operate, correct?

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

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

17 A. Sure, but --

18 Q. And the built-in --

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

21 Q. (By Mr. Gaukler) Go ahead.

22 A. But the functionality, when you look at  
23 the electrical wiring in the cabinet, for example,  
24 it just -- you have a current through it, and what  
25 you are looking at is is it going to stay in its

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1 place, whether the anchor bolts are going to be  
2 there, is it going to sheer off, is it going to hit  
3 the neighboring item and, along with it, some items  
4 which are more sensitive that require  
5 functionality. And in those cases we monitor the  
6 actual functionality during the testing. In some  
7 cases you don't need to.

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

12 A. As well.

13 Q. As well.

14 A. Yes.

15 Q. And -- and the other thing is that IEEE  
16 344 basically would concern equipment that's  
17 mounted or -- mounted or bolted down, correct?

18 A. No, not necessarily.

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

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

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

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

2 JUDGE FARRAR: Okay.

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

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

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

20 A. No, sir.

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

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

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

4 A. Could you please repeat --

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

9 A. I do not know, sir.

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

20 Do you see that in your testimony?

21 A. Yes, sir.

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

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

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

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

23                   And I'm just asking you here whether --  
24 isn't it true that structural integrity alone of  
25 the cask and canister, however that was shown or

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1 demonstrated, would serve the design intended  
2 function of the cask and canister? Isn't that  
3 correct?

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

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

8 JUDGE FARRAR: Let me hear it, madame  
9 reporter.

10 (The question was read.)

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

13 JUDGE FARRAR: Okay.

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

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

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

23 (The answer was read.)

24 THE WITNESS: Okay. For an anchored  
25 system, if you look at casks, let's say, similar to

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1 a tank -- and we use tank all the time, and you can  
2 anchor them. Inside the cask you have MPC, and  
3 there are small gaps. And you can analyze those  
4 gaps because they are small. And then the fuel  
5 inside, you can look at the integrity of the fuel.  
6 But when the entire cask starts sliding and motions  
7 become too large, then predicting a dynamic  
8 behavior is what's the -- what we are talking  
9 about.

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

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

22 A. I don't know.

23 Q. And assuming that it -- the -- it  
24 maintained its designed -- maintained the  
25 confinement of the radioactive material, whether it

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1 moved 5 inches or 50 inches, it still would be  
2 performing its design intended function, correct?

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

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

22 So nobody's saying that casks that  
23 Holtec has is not good. I think it is the means to  
24 prove the design that you wanted to prove. I think  
25 these are the questions. And I think that's where

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1 we are having difficulty. If we says it should not  
2 move significantly, have we proven beyond  
3 reasonable doubt? And I think there is a question  
4 as to if we have satisfied those. And in my  
5 judgment I think it has not been.

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

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

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

24 A. What did you say?

25 Q. 344 deals -- at least as part of -- 344

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1 in your testimony deals when you have to do  
2 testing, correct?

3 A. Both testing and analysis.

4 Q. When -- right. And --

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

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

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

21 Q. You don't know?

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

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

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

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

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

10                   Will you reread the question I asked,  
11 please?

12                   (The question was read as follows:

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

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

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

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

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

12 Q. If it cannot be adequately modeled?

13 A. That's right.

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

17 A. It is -- it is a possibility.

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

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

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

24 JUDGE FARRAR: Objection's overruled.

25 You may answer.

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

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

13 A. That's correct.

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

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

21 And if -- the very -- and I go back.  
22 The reason we don't have questions about linear  
23 analysis, because there are a lot of test data  
24 available, so one can go and compare these test  
25 data with linear analysis. For nonlinear analysis,

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1 the information or the knowledge that we have today  
2 is limited. And as Dr. Luk in his testimony also  
3 alluded to, that he tried to do shake table tests  
4 because he thought that would be a good thing, he  
5 can compare the data. And so those questions are  
6 still in a lot of people's mind, are we doing these  
7 analyses accurately? And we don't know.

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

12 A. Could you --

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

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

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

25 A. Well, if -- if one -- again, this is the

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

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

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

25 Q. Do you know how you would model

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

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

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

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

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

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

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

13                   Do you see that question and answer?

14          A.       Which, please, sir?

15          Q.       Page -- Question and Answer 36.

16          A.       Okay.

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

20          A.       Yes, sir.

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

23          A.       Yes, sir.

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

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

3           Q.       The March 2002?

4           A.       Yes.

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

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

9                   (APPLICANT'S EXHIBIT-224 WAS MARKED.)

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

14          A.       That's right.

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

19          A.       Sure.

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

24          A.       Could you please -- process of --

25          Q.       What the -- the process of how they went

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1 about to benchmark the DYNAMO code.

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

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

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

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

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

16 MR. GAUKLER: March 2002 Singh/Soler  
17 deposition.

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

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

22 Q. Have you had a chance to review it?

23 A. Yes, sir.

24 Q. Has that refreshed your recollection  
25 generally?

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1 A. Yes, sir.

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

6 A. Yes, sir.

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

9 A. Yes, sir.

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

15 A. That's correct.

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

19 A. That's correct.

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

22 A. Yeah.

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

25 A. No, sir.

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1 Q. You have not sought to obtain it?

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

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

11 Yes.

12 Have you used it for any cask stability  
13 analysis?

14 The answer is no.

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

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

25 A. The code has not -- I don't know if the

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1 code has changed, but 12 to 14 problems that were  
2 mentioned, I believe they are compared properly. I  
3 believe they have been validated correctly. So I  
4 just state it on the face value.

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

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

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

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

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

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

22 Q. That was your understanding of that?

23 A. That's correct.

24 Q. I'd like to have you look at the bottom  
25 of page 36 and 37. That's -- in addition to

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1 talking about the validation in the validation  
2 report, they also refer to the fact that they had  
3 run DYNAMO against a comparison with ANSYS,  
4 correct?

5 A. That's correct, sir.

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

8 A. That's correct.

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

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

18 THE WITNESS: There was no question --

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

21 Mr. Gaukler?

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

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

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

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

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

15 A. Is it in regards to your Question No.  
16 36, has -- the HI-STORM cask stability reserves for  
17 PFS has been benchmarked with another computer  
18 code?

19 Q. I'm just asking a general question.

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

22 (A discussion was held off the record.)

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

25 MR. GAUKLER: Let me rephrase the

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

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

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

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

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

24 I think this is what my -- in my  
25 Question and Answer 36, this is what I'm saying, is

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1 that when we were -- when we were asking do you  
2 have analysis by ANSYS, and the answer was no.  
3 There was no question about validation. Validation  
4 part has been done as a part of re-racking and with  
5 other cases with ANSYS. So answer is DYNAMO is --  
6 if there's a confusion, DYNAMO is validated against  
7 no problems and against ANSYS based on what  
8 Dr. Soler and Dr. Singh say.

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

12 A. I --

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

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

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

23 MR. GAUKLER: Excuse me. I need to have  
24 the last kind of answer read back to me to make  
25 sure I understand it before I either ask or don't

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1 ask any more questions on this.

2 (The answer was read.)

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

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

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

25 JUDGE FARRAR: If you ask more than one,

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

2 MR. SOPER: Fair enough, Your Honor.

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

7 A. I can't say for sure.

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

10 JUDGE FARRAR: Okay.

11 (A discussion was held off the record.)

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

15 JUDGE FARRAR: Certainly. You mean just  
16 in place?

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

19 JUDGE FARRAR: Okay.

20 (A recess was taken.)

21 JUDGE FARRAR: Mr. Gaukler?

22 MR. GAUKLER: No further questions.

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

25 MR. SOPER: I believe so, Your Honor.

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1 Thank you.

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

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

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

11 JUDGE FARRAR: Should we take a break ?

12 MS. MARCO: Yes.

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

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

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

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1 Singh/Soler deposition.

2 And for the court's -- for the Board's  
3 reference, I was able to -- I do have the original  
4 of 222, and before you Xerox, you can see that is  
5 1E.

6 JUDGE FARRAR: All right. Thank you.

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

9 MR. SOPER: No objection to 222.

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

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

13 JUDGE FARRAR: 222 will be admitted.

14 (APPLICANT'S EXHIBIT-222 WAS ADMITTED.)

15 JUDGE FARRAR: 223, the staff reg guide?

16 MR. SOPER: No objection.

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

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

20 (APPLICANT'S EXHIBIT-223 WAS ADMITTED.)

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

23 MR. SOPER: No objection.

24 MR. O'NEILL: No objection.

25 JUDGE FARRAR: All right. Then that

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1 document also will be admitted.

2 (APPLICANT'S EXHIBIT 224 WAS ADMITTED.)

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

6 MR. GAUKLER: No, I'm not.

7 JUDGE FARRAR: Okay. Mr. O'Neill?

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

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

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

24 JUDGE LAM: Well, Dr. Khan, one reason I  
25 ask the question is because I see the word

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1 "potential" and then "possible." To me anything is  
2 possible.

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

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

23 THE WITNESS: Judge Lam, I think it has  
24 to be done in a -- in a win/win situation where all  
25 parties would agree, in my judgment, to the input

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1 motion that has to be applied, okay, for any shake  
2 table testing. So doing a test where motion is  
3 still being questioned or there is a -- you know,  
4 any concern, then the test will be questionable  
5 after we have done it. So the motion that we are  
6 going to use to shake a test has to be agreed upon,  
7 all parties.

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

19 And unless those things are -- are done,  
20 I wouldn't recommend testing it because then the  
21 question will come, well, you didn't do testing  
22 this way, you didn't do testing that way. We  
23 should say this is the methodology, get as much  
24 information from the testing as possible, okay, and  
25 say that whatever tested data we are going to get,

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1 here is a method that we are going to use as a  
2 benchmark and, if we have to extend this to 8 cask  
3 or 4 casks, we all agree. So ground motion or  
4 motion at the top of the pad that we need to apply  
5 has to be designed by everybody, okay?

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

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

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1 JUDGE LAM: Thank you, Dr. Khan.

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

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

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

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

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

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

25 THE WITNESS: Okay. Let's say we could

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

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

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

17 THE WITNESS: Yes, sir.

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

25 THE WITNESS: Well, purely -- as a

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

4 JUDGE FARRAR: Okay. Thank you.

5 Mr. O'Neill?

6  
7 CROSS-EXAMINATION

8 BY MR. O'NEILL:

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

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

18 A. That is correct.

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

22 A. That's correct.

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

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

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

10          A.       That is correct.

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

13          A.       Approximately.

14          Q.       Approximately?

15          A.       Yes.

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

20          A.       That is correct, sir.

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

24          A.       That is correct, sir.

25          Q.       Okay. In response to Question 15 on

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

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

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

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

18 A. Okay.

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

21 A. Very limited, very, very limited.

22 Q. Very limited?

23 A. Yes.

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

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1 A. That is correct, sir.

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

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

6 Yeah, it has 72 finite elements.

7 Q. 72?

8 And degrees of freedom?

9 A. Each node -- if you look -- let's say  
10 there are 6 degrees of freedom at each node, and 1,  
11 2, 3, 4, 5, 6 -- and there are 8 of them so -- 1,  
12 2, 3, 4, 5, 6 -- there are 6 nodes per element --  
13 let's see. 48 times 6, I believe.

14 Q. Okay.

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

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

21 A. No, sir.

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

24 A. That is correct.

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

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

4           A.       No, sir.

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

7           A.       No, sir.

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

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

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

25          A.       That's right.

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

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

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

11 A. No, sir.

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

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

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

21 A. Yes, sir.

22 Q. -- for -- you know, that -- that you  
23 reviewed the Altran report under. So my  
24 understanding is that the individuals who -- I  
25 think you called them the verifiers -- who reviewed

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1 the report focused largely on the numbers  
2 themselves, like, to give computational accuracy,  
3 per se?

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

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

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

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

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

8 I'm referring to page 59 of your March  
9 5, 2002 deposition transcript. It's one of -- one  
10 of the pages included in that handout. I'll give  
11 you a moment to find that, page 59.

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

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

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

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

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

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

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

13          A.       Yeah.

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

17          A.       That is correct. We do --

18          Q.       But -- I'm sorry.

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

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

25          A.       That is very correct, sir.

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

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

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

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

22 Q. Has Altran Corporation specifically been  
23 audited by NUPIC?

24 A. That is correct. We -- we have been  
25 audited, actually, the last two years -- every two

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1 years they come and audit, and we have been  
2 audited, I believe, last year.

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

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

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

18 A. Yes, sir.

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

22 A. I -- I don't really know from the report  
23 where the damping description was given except for  
24 contact stiffness damping was, so as far as -- if  
25 you model a cask as a rigid body and all you have

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1 is 6 spring and you're applying damping, then the  
2 motion of the entire cask is being dominated by  
3 those springs and associated damping. If you were  
4 to model the cask as beam elements and then you  
5 have damping, then you will have additional  
6 dampings with those elements.

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

10 A. Yes, sir.

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

15 A. Yes, sir.

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

18 A. That's correct, sir.

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

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

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

6           A.       That's right.

7           Q.       -- the applicable value?

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

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

19          A.       When -- when I am saying cask frequency,  
20 I'm talking about rotation of the cask, okay? And  
21 that rotational stiffness, rotational springs that  
22 will cause this cask to move will have certain  
23 damping, and it will have certain frequency  
24 associated. That model -- that behavior was to be  
25 chosen, say, from a certain frequency range. And

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1       you choose it from 1.5, hertz, 2 hertz, 3 hertz.  
2       You put in a range of values if you don't know the  
3       frequency.

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

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

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

17          A.       Yes, sir.

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

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

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

4 A. Yes, sir.

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

11 A. 1 g, greater than 1 g.

12 Q. 1 g.

13 A. Correct.

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

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

20 Q. .695, yes.

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

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

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1 case, would it?

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

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

11 A. Yes, sir.

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

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

25 And, again, here is the reality in

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

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

10 A. Sure.

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

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

23 Q. Well, with respect to shake table  
24 testing, you would agree that that particular  
25 process or approach is not devoid of limitations

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1 and complexities as well, right -- I mean correct?  
2 In particular, if you were to attempt to perform  
3 such a test with a scale model, you would have to  
4 extrapolate those results to the full scale cask,  
5 correct?

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

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

24 So what you -- what you are doing is  
25 you've got to ratio the cask parameter down to a

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1       manageable level where you say that I'm going to  
2       use this input motion. Motion is not changing. It  
3       is the cask geometry you are trying to shrink it  
4       down.

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

8           A.       Sure --

9           Q.       -- correct?

10          A.       -- sure, significantly.

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

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

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

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

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

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

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

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

17 A. I wish I did.

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

20 THE WITNESS: Thank you, sir.

21 JUDGE FARRAR: Does the State have any  
22 redirect?

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

25 JUDGE FARRAR: Okay.

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

9  
10 REDIRECT EXAMINATION

11 BY MR. SOPER:

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

14 A. Yes, sir.

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

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

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1 VisualNastran.

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

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

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

20 Q. Yes, it is.

21 A. Okay.

22 Q. Do you see that portion there on page  
23 43?

24 A. Yes.

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

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

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

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

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

12 A. Yeah, it --

13 Q. -- and so forth?

14 A. Yeah, it could be DYNAMO.

15 MR. SOPER: Thank you.

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

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

20 THE WITNESS: DYNAMO, sir.

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

24 THE WITNESS: The small deflection  
25 program.

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

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

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

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

13 (STATE'S EXHIBIT-195 WAS MARKED.)

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

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

25 MR. SOPER: Well --

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

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

15 JUDGE FARRAR: Okay. Thank you.

16 And this exhibit has been marked as  
17 what?

18 MR. SOPER: State 195.

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

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

24 A. That's correct, sir.

25 Q. And have you done any work to

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1 demonstrate what you mean by that statement?

2 A. Yeah. I guess what I did was I took the  
3 PFS time histories for 2000-year return period and  
4 I plotted generated response spectrum for 1-percent  
5 damping, 3-percent damping, 5-percent damping and  
6 40-percent damping. Now, this is for the actual  
7 time histories that were provided to us by PFS.

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

10 A. That is correct, sir.

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

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

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

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

23 Q. It appears to me that the vertical  
24 acceleration for 1-percent damping at approximately  
25 3 hertz is only about -- or less than half of the

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1 response in the vertical direction at approximately  
2 6 hertz. Is that --

3 A. That's correct.

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

7 A. That is correct.

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

10 A. The conclusion was that if you look at  
11 40-percent damping for -- for the time history that  
12 we have, there is practically no amplification.  
13 That means your system is acting as a rigid system.  
14 For 5-percent damping, you see amplification which  
15 is consistent with what one would see.

16 Then you have at 3-percent damping -- at  
17 1-percent damping -- let's say if you -- if your  
18 structure is -- has a vertical frequency of about 6  
19 1/2 hertz, you will see a spectra or acceleration  
20 on that body of about 4.1, 4.2 g. If you change  
21 the frequency, actually increase the frequency and  
22 you increase the frequency to 8 hertz, your  
23 acceleration goes down to 3 g. If you make the  
24 frequency 8 1/2 hertz, it jumps back up to 4.1  
25 hertz. You reduce it to 9 hertz, it goes back down

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1 to less than 3 -- around 3.3 g's. And it continues  
2 on.

3 So what this shows is if you have a  
4 smaller or lower damping system and you change your  
5 stiffness -- and even, let's say, if you go all the  
6 way to 30 hertz, the acceleration in the vertical  
7 direction is much higher than 1 g, and so you will  
8 see jumping effect of the casks. And when you see  
9 the ZPA which is given of .7 or -- I'm not exactly  
10 sure. Let's see. The vertical acceleration of  
11 .695 at a hundred hertz is less than 1 g.

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

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

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

23 Q. The following page of State 195 which  
24 bears the heading "2000 Return Period RESPONSE  
25 SPECTRA -Vertical," can you tell me what is

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1 represented on that page, page 2 of -- the pages  
2 aren't numbered but --

3 A. I lost it.

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

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

12 A. Yeah, east to west.

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

15 MR. SOPER: Me too.

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

21 A. Unfortunately, I unstapled it.

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

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

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

3 JUDGE FARRAR: And now you want to talk  
4 about which one?

5 MR. SOPER: The second page.

6 THE WITNESS: The second page is the  
7 digitized values for those vertical spectras. The  
8 third page is north-south response spectra,  
9 response spectra north-south for 200 (sic) years  
10 return period --

11 Q. (By Mr. Soper) Can you describe what  
12 that shows for us, please, and why that's  
13 significant?

14 A. Again, if you look at the response  
15 spectra, at 40-percent damping there is no  
16 amplification. For this time history, if you are  
17 analyzing a structure, it will basically behave  
18 like a rigid structure.

19 For 1-percent damping there is a  
20 significant variation. If -- again, in the  
21 horizontal direction if rocking frequency happened  
22 to be at about 4 hertz, you will see a pretty high  
23 peak of about 4 g. And if you go down and change  
24 the rocking frequency or even, in this case, soils  
25 frequency to about 5 hertz, your response is going

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1 to be about 2 1/2, 2.7 g's. If you go and look at  
2 6 hertz, so if you fine tune your soil to 6 hertz,  
3 your response should go up to 3.6 g's,  
4 approximately. You go to 7 hertz, it goes down  
5 again. 7 1/2 hertz, it goes back up again.

6 So for 1-percent damping your system  
7 should become very sensitive in the amplified  
8 region, and if you choose contact stiffness --  
9 actually increasing the frequency does not  
10 necessarily mean you'll get a lower response.

11 Q. Thank you.

12 And then the page following the response  
13 spectra north-south is -- can you describe that for  
14 us, please?

15 A. Digitized values for north-south  
16 spectra, and the last -- fifth page, hows the  
17 response spectra for east-west direction.

18 Now, this is even more interesting. If  
19 you look at the 1-percent curve, if you choose a  
20 structure that happens to have a frequency of about  
21 8 1/2 hertz, the response at 1-percent damping,  
22 3-percent damping and 5-percent damping are very,  
23 very close to each other. If you look at -- if  
24 your soil happens to be in that direction or a  
25 structure happened to be about 6 1/2 hertz, you are

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1 seeing an acceleration of about 4 g's. If you  
2 choose your structural frequency at 11 hertz, your  
3 response becomes much higher than what you would  
4 see at about 7 1/2 hertz.

5 So as you could see, the ground motion  
6 itself is giving you response that's going to be  
7 significantly varying, depending on what one  
8 chooses.

9 Q. And the last page, sir, of this exhibit?

10 A. Is the digitized values for the -- for  
11 the east-to-west response spectra.

12 Q. And what does this study say with  
13 respect to your conclusion that --

14 A. At least from these curves, it shows  
15 that 40-percent damping would be fairly high to get  
16 any dynamic amplification.

17 Q. What does it say with respect to your  
18 testimony that a range of stiffness values at  
19 various frequencies and a range of damping values  
20 ought to be used to -- to study this model?

21 A. This clearly indicates a variation in  
22 response that would be observed if one chooses  
23 contact stiffnesses which would be varying or  
24 stiffnesses that would be varying and also the  
25 damping that one chooses. I'm -- I have not

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1 plotted 2 percent, 1 1/2 percent. You know, you  
2 could plot many damping. But the behavior at low  
3 frequencies is going to be like this. And if you  
4 go less than 1 percent, it would be more erratic.

5 Q. It also appears, if you tuned your  
6 system to 33 hertz, you would miss most of the g  
7 acceleration.

8 A. That is correct.

9 Q. And that's for all directions.

10 A. That is correct, sir.

11 MR. SOPER: I would offer State  
12 Exhibit 195.

13 JUDGE FARRAR: Before I ask for any  
14 objections, Dr. Khan, how did you generate these  
15 curves? You took the time histories --

16 THE WITNESS: I took the time history  
17 and applied to a single degree of freedom system  
18 whose frequency ranges from very small all the way  
19 to 33 hertz. So that's the response spectra for  
20 the PFS time history.

21 JUDGE FARRAR: Now, when you did that,  
22 did you use a model you developed to do that or is  
23 that just a routine calculation that everyone in  
24 the room would generate the same curve?

25 THE WITNESS: Everyone -- everybody

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1 should be able to generate the same curve.  
2 5-percent curve was already generated by PFS for  
3 this -- for their time history. And those values I  
4 compared with, and they're fairly close.

5 JUDGE FARRAR: Okay.

6 THE WITNESS: And then all I did was  
7 change the damping to 40 percent to see whether  
8 this input motion amplifies at any frequencies, and  
9 at 40-percent damping, no amplification. Then I  
10 said, What happens to 1-percent damping? And then  
11 your response just becomes very sensitive.

12 JUDGE FARRAR: Okay. Thank you.

13 Any objection to the admission of this  
14 document?

15 MR. GAUKLER: I've just seen this  
16 document for the first time, Your Honor, so I need  
17 to talk to my experts, et cetera.

18 JUDGE FARRAR: Okay. Why don't you --  
19 Mr. O'Neill, what's the Staff's position, or do you  
20 want to do the same thing?

21 MR. O'NEILL: Yeah. I was going to say  
22 I adopt a similar position. I'd like to confer  
23 with my experts here.

24 JUDGE FARRAR: And while you're  
25 conferring with your experts, I have something I

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1 want to confer with my experts on, so we'll all do  
2 this at once.

3 (A recess was taken.)

4 THE COURT: We're back on the record.  
5 Mr. Gaukler?

6 MR. GAUKLER: Yes, your Honor. We would  
7 object to the introduction of this exhibit. We  
8 believe that it's irrelevant and potentially  
9 misleading. My understanding is it's a  
10 representation of a linear spring mass system. The  
11 apply a time history to has shown no relation to  
12 the casks that we would have at PFS, the system we  
13 would have at PFS, and as such it's A, not  
14 relevant, and B, by allowing it in it could be  
15 misleading, that people could interpret it as being  
16 applicable to the casks at PFS.

17 Like generating multiplication tables is  
18 one way to look at it, your Honor. You just take a  
19 spring and a mass system and you will apply  
20 different frequencies for the spring, different  
21 frequency, and you generate these curves for time  
22 histories applied to it.

23 JUDGE FARRAR: By people who could be  
24 misled by it, do you mean us or the jury?

25 MR. GAUKLER: Well, I'm sure that your

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1 Honors have very good technical advice on the  
2 Board. I'm concerned further down the line where  
3 it gets further up, okay?

4 JUDGE FARRAR: We won't tell the  
5 commissioners you said that.

6 MR. GAUKLER: I'm thinking about beyond  
7 the commissioners.

8 JUDGE FARRAR: You mean the Court of  
9 Appeals?

10 MR. GAUKLER: Court of Appeals I'm  
11 thinking of, your Honor.

12 JUDGE FARRAR: Mr. O'Neill?

13 MR. O'NEILL: Yeah, I would object on  
14 essentially the same grounds, your Honor. These  
15 particular figures appear to represent response  
16 spectra for freefield ground motions, for the  
17 ground motions and not ground motions that were  
18 applied at the base of the cask. In that sense we  
19 consider them to be misleading and not relevant to  
20 the action or site characteristics or phenomena  
21 that we will be observing at the site.

22 JUDGE FARRAR: Mr. Soper?

23 MR. SOPER: Your Honor, all the  
24 objections that have been raised are  
25 cross-examination matters, and they can examine

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1 Dr. Khan about the particulars. But they show  
2 exactly what the witness says they show, the  
3 sensitivity of damping and frequency response to  
4 this sort of modeling, which is the whole point.  
5 It's highly relevant here.

6 (The Board confers off the record.)

7 JUDGE FARRAR: The Board thinks these  
8 are relevant for the purposes, limited purposes  
9 offered. Demonstration that they don't show other  
10 things are matters that you gentlemen can establish  
11 on further examination with this witness. So we'll  
12 overrule the objections, but we think on the  
13 condition that in case some of those other people,  
14 Mr. Gaukler, to whom you referred get this document  
15 without -- you know, and see it independent of the  
16 transcript, that maybe this could have a better  
17 label on it that says freefield or says something  
18 that's more descriptive of or more narrowly  
19 descriptive of what it is.

20 So Mr. Witness, you can -- Mr. Soper,  
21 you can confer with your witness or I can just ask  
22 him what he, having heard this discussion, what he  
23 thinks would be a better label, or you can suggest  
24 one.

25 MR. SOPER: I might suggest this. The

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1 objection that this represents a freefield ground  
2 motion I think is not well taken because I think  
3 that's exactly what the ground motion applied by  
4 Holtec was. In fact, the 5 percent damping curves  
5 shown here are the same numbers that Holtec came up  
6 with. So I'm not sure labeling this freefield  
7 ground motion somehow sets it apart. It in fact is  
8 consistent with what's been done. I think -- I  
9 don't want to put words in the witness's mouth, but  
10 we would be happy to title this in any way that's  
11 helpful to the Board. But with that notion in  
12 mind.

13 MR. O'NEILL: Your Honor, it's my  
14 understanding, too, that there's a difference  
15 between applying -- and obviously I don't want to  
16 testify, and that's not my intent. There's a  
17 difference between applying freefield ground  
18 motions at the base of the cask itself and at the  
19 base of the soil column.

20 MR. SOPER: Well, I think no matter what  
21 we label it, it will all become clear, precisely  
22 clear on the questions and the responses. So I'm  
23 not sure that we can label it to everyone's  
24 satisfaction, but I think we can develop  
25 cross-examination that will --

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1 MR. GAUKLER: I think a label should be  
2 applied to the exhibit. I'm just going to throw  
3 one out. I don't know if it's even correct  
4 exactly. My colleague here -- response of  
5 theoretical single degree of freedom system to  
6 input ground motion. I'm just giving that as an  
7 example that I believe at least is partially if not  
8 totally descriptive of what this shows.

9 THE WITNESS: There is a description  
10 already given in Geomatrix report that says  
11 "comparison of time history and design response  
12 spectra." One could say that design response  
13 spectra at 1, 3, 5, and 40 percent damping for  
14 2,000-year return period.

15 JUDGE FARRAR: Okay, tell you what we'll  
16 do to save some time. Why don't we -- we'll defer  
17 action on the motion to admit. When we get to it  
18 we'll do the cross-examination and then we will  
19 admit it with a title that you all will agree upon  
20 at the end of that cross-examination. So it's  
21 going to be admitted, we'll do the cross, and then  
22 we'll come up with a title for itj.

23 (STATES'S EXHIBIT-195 WAS ADMITTED.)

24 MR. SOPER: Very well. Thank you, your  
25 Honor.

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1 JUDGE FARRAR: Given the break in the  
2 action --

3 (the Board confers off the record.)

4 JUDGE FARRAR: Before you go on, let me  
5 ask the witness something that I'm trying to get a  
6 visual image of. This may or may not be an  
7 intelligent question.

8 I understood gravity when I studied it  
9 about things falling down. I'm having a little  
10 trouble with things falling up. If on a pad, any  
11 old pad, you had some pebbles and you had a boulder  
12 the size of that speaker and you had a cask and  
13 they all got hit with a sustained 2 g pulse,  
14 vertical, what would the pebbles do and what would  
15 the boulder do and what would the cask do? Would  
16 they all jump up the same distance?

17 THE WITNESS: They might or they might  
18 not.

19 JUDGE FARRAR: Thank you. Okay, go  
20 ahead.

21 THE WITNESS: It depends on what the  
22 condition is, how the CG of these things are  
23 sitting with respect to the vertical, with, you  
24 know, contact conditions.

25 JUDGE FARRAR: Make them all the same

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1 shape, like little tiny --

2 THE WITNESS: Then they should jump  
3 about the same.

4 JUDGE FARRAR: Little tiny cylinder-like  
5 pebbles and a boulder that looks like a cylinder  
6 and the cask.

7 THE WITNESS: Yeah. If you hit it with  
8 identical vertical acceleration, they should see  
9 the same thing. But where they could differ if  
10 they are frequency dependent somehow, then it  
11 breaks that off.

12 JUDGE FARRAR: Go ahead, Mr. Soper.

13 MR. SOPER: Thank you, your Honor.

14 Q. (By Mr. Soper) Dr. Khan, with respect  
15 to State Exhibit 195, I believe you testified a  
16 minute ago that the 5 percent damping curve was  
17 very close to representing what PFS or what Holtec  
18 has submitted with respect to their 5 percent  
19 damping for the 2,000-year return period. Is that  
20 correct?

21 A. It was given by Geomatrix.

22 Q. Excuse me, Geomatrix.

23 A. That is correct.

24 Q. Dr. Khan, can you explain to us the  
25 significance of freefield ground motion with

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1 respect to this study?

2 MR. GAUKLER: "This study" being Exhibit  
3 195?

4 MR. SOPER: Exhibit 195.

5 A. This is directly coming from the  
6 freefield input motion based on what we have seen  
7 in Dr. Luk's report. There would be -- it's scaled  
8 up accordingly, depending on the damping values  
9 used on the top of the pad. So they have a direct  
10 effect on what the pad is going to see when these  
11 motions are applied and what damping is selected.  
12 And so if you select certain damping values, let's  
13 say for beyond design basis 1 percent damping was  
14 used, then the spectra corresponding to 1 percent  
15 damping would be further amplified based on the  
16 results that we have seen from Dr. Luk's report,  
17 and then that would become effective.

18 Q. You also testified, Dr. Khan, that in  
19 addition to the system being sensitive to damping  
20 value and stiffness values, that the modeling of  
21 the system was also important. By that I don't  
22 mean what computer code is used, but the way that  
23 the system is contemplated or modeled. Can you  
24 explain any difference in modeling that you used  
25 and Holtec used and/or Dr. Luk used?

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1           A.       I would just attempt. I'm not 100  
2 percent sure the actual model have been described,  
3 but based on the calculations which are in some of  
4 the appendices that I saw, cask was modeled as a  
5 rigid member with masses and mass moment of inertia  
6 applied at its center of gravity. It wasn't very  
7 clear from the report whether there was other  
8 masses along its height, but that was what I  
9 understood from the report.

10                   The modeling that I did was, I've got  
11 beam elements that aid vertical position of zero,  
12 45 degrees, 90 degrees added on the radius, and  
13 each beam element has a mass lumped at these nodes.  
14 And they are rigidly connected to members so there  
15 is a better mass distribution. I did not calculate  
16 mass moment of inertia. The program automatically  
17 uses beam elements to calculate the mass matrix for  
18 these elements.

19                   And so if one goes and changes the  
20 model, there could be some more changes in the  
21 results. So I'm not really sure, if one wants to  
22 go and model this as a shell element with  
23 everything modeled the way the cask truly is, you  
24 might have some different result.

25           Q.       You were asked earlier today whether or

1 not a coefficient of friction of .8 would  
2 necessarily cause a tipping of a cask. Can you  
3 explain your reasoning as to why or why not that  
4 high coefficient of friction may or may not be  
5 significant in the cause of tipping?

6 A. High coefficient of friction would try  
7 to lift the cask up as opposed to lower coefficient  
8 of friction which will tend to slide the cask. So  
9 at a high coefficient of friction if your  
10 instantaneous velocity becomes significant that it  
11 can overcome the potential energy, then because of  
12 the kinetic energy there's a potential that it  
13 could tip over. So as the coefficient of friction  
14 gets higher and higher, then the potential for  
15 tipping increases.

16 Now, what one has also observed is if  
17 your vertical motion gets high or exciting the cask  
18 due to rocking motion, then you could have a  
19 solution that you can never -- you may not be able  
20 to predict whether .7 could be more sensitive or .8  
21 could be more sensitive or .6 could be more  
22 sensitive. It depends on the dynamics. If the  
23 vertical motion amplifies the dynamics of the cask  
24 where it starts lifting up and then, you know, you  
25 could see significant velocities that could take

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1 over.

2 Q. For example, if the vertical motion were  
3 to cause the cask to lift up off the pad and the  
4 pad slides with respect to the cask, at that  
5 instant in time the coefficient of friction would  
6 be not meaningful or not important. Is that right?

7 A. That's correct. All those instances  
8 when the cask is above the floor, then coefficient  
9 of friction is not acting.

10 Q. You were asked on cross-examination if  
11 you at any time did anything to test the  
12 limitations in the SAP 2000 reference document, I  
13 believe it was a training document, and you  
14 answered that you did not. However, you had  
15 testified previously you hadn't found any  
16 limitations. Can you explain your testimony of  
17 that?

18 A. Yeah. Limitations programs is a dynamic  
19 analysis, and I think Mr. Gaukler has shown what  
20 elements it can use. It's a small deflection  
21 program. It's not a program that will be able to  
22 handle large rotations because of change -- it will  
23 not accurately predict the large rotational  
24 effects, but it can predict the sliding  
25 displacement for what amounts there would be.

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1 Q. Anything about -- excuse me. Were you  
2 finished?

3 A. So limit of sliding displacement is not  
4 imposed on this program.

5 Q. So there's nothing about the SAP 2000  
6 program that would in any way invalidate your  
7 results?

8 A. Sliding displacement, no, sir.

9 Q. Dr. Khan, can you tell me how you  
10 calculated the response spectra for the 5 percent  
11 damping that's shown in Exhibit 195?

12 A. Response spectra is calculated by  
13 applying the PFS time history at the base of the  
14 single degree of freedom system which has a  
15 frequency given on the X axis, the horizontal axis.  
16 So let's say, pick, for example, 5 Hz. Okay? So a  
17 single degree of freedom system which has a 5 Hz  
18 frequency, you apply the base motion and you get  
19 the maximum acceleration of the mass that is  
20 vibrating, and that acceleration is given in the Y  
21 axis. That's in g's, so you just vary the  
22 frequency and you get those results.

23 Q. Did you use the time history from  
24 Geomatrix?

25 A. That is correct, sir.

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1 Q. Did you change that in any way?

2 A. Nothing. It's identical input that I  
3 got from the State of Utah.

4 Q. Is this the same time history used in  
5 the Holtec 2,000-year analysis?

6 A. I believe so.

7 Q. Do you know whether or not Holtec  
8 assumed the storage pad was rigid in its analysis?

9 A. I don't know, sir.

10 MR. SOPER: That's all I have. Thank  
11 you, your Honor.

12 JUDGE FARRAR: Mr. Gaukler, you have  
13 some recross, I assume?

14 MR. GAUKLER: Yes, I do. Can we take  
15 about a five-minute break, if that's possible?

16 JUDGE FARRAR: Mr. O'Neill, you'll have  
17 some?

18 MR. O'NEILL: Yes.

19 JUDGE FARRAR: Both of you will go into  
20 the areas with Mr. Soper's examination okay. Let's  
21 take a -- do you just want to consult?

22 Let's take a -- it's two minutes after.  
23 Let's come back at ten after.

24 (A recess was taken.)

25 JUDGE FARRAR: All right, go ahead,

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1 Mr. Gaukler.

2

3

RECROSS-EXAMINATION

4

BY MR. GAUKLER:

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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  $1$

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1 divided by 2 pi times the stiffness divided by the  
2 mass of the system, and then basically ran that for  
3 four different damping values, correct?

4 A. Yes, sir.

5 Q. So you ran the -- for each frequency you  
6 generated four solutions at each point?

7 A. That is correct, sir.

8 Q. What program did you use to run this?

9 A. SAP 2000.

10 Q. SAP 2000. And it's what you would call  
11 a single degree of freedom system?

12 A. That is correct, sir.

13 Q. And what does it consist of?

14 A. It's one mass and one -- let's say if  
15 you call it a beam member, it has a stiffness, it  
16 has a mass. And it is very similar to what  
17 Geomatrix has done, or identical to what Geomatrix  
18 has done in their report when a spectra was  
19 generated. So it is a standard method to generate  
20 spectra from a given time history.

21 Q. So you have a single mass and it has a  
22 spring value, a spring with it, and it only can  
23 move in one direction, either the X direction, the  
24 Y direction, or the Z direction?

25 A. That is correct, sir.

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1 Q. And you generated, you did separate runs  
2 for each one of those three directions?

3 A. That is correct, sir.

4 Q. That's what is seen in Exhibit 195?

5 A. That is correct, sir.

6 Q. Now, what was the mass that you used in  
7 doing your run?

8 A. I did not use any mass. Program  
9 automatically selects the frequencies corresponding  
10 to these. So there is no mass that you have to  
11 select, there is no stiffness that you have to  
12 select. It's all built into the program.

13 Q. So you don't know what the stiffness of  
14 the mass is at any particular point?

15 A. No, sir.

16 Q. But you do know that the frequency is  
17 equal to 1 divided by 2 pi times K divided by the  
18 square root of M?

19 A. I believe the program does it. This is  
20 a very --

21 JUDGE FARRAR: Implicit in there was  
22 like the mass varies?

23 THE WITNESS: If you look at the  
24 frequency of a single degree of freedom system, you  
25 could vary mass and stiffness to have a frequency

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1 value. So either you can increase the mass or  
2 decrease or vice versa.

3 JUDGE FARRAR: I understand that. But I  
4 guess I'm having trouble visualizing -- this graph  
5 is not just the result of this formula.

6 THE WITNESS: That is correct, sir.  
7 There are -- hundreds of time history analyses have  
8 been performed to get the response for each of  
9 those frequencies.

10 Q. (By Mr. Gaukler) Now, you're not  
11 representing that these graphs in any way represent  
12 the accelerations that would be seen by the cask or  
13 the pad at PFS, correct?

14 A. They would be affected by this, because  
15 this is coming from the ground motion that we are  
16 applying.

17 Q. But the values are not what you  
18 necessarily would see with respect to the cask and  
19 pads at PFS, correct?

20 A. Yeah, it would be significantly  
21 different, because if you go back and look at  
22 Dr. Luk's report, this is spectra for various  
23 damping values that I plotted would be applicable  
24 to the freefield location, at the freefield  
25 location. And from there what happens, the model

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1 filters it, amplifies it and makes its own  
2 determination. So this would be changed or being  
3 affected by soil damping and other effects.

4 Q. And also by SSI effects, correct?

5 A. That's what I said.

6 Q. And also in terms of, for example,  
7 whether or not these graphs would have any  
8 relevance to, say, what the casks, how the casks  
9 would respond would depend upon whether the natural  
10 frequency of the casks coincided with some of  
11 these -- with the frequency on these graphs,  
12 correct?

13 A. It will have significant effect. This  
14 is the basic of the design.

15 Q. I'm saying in terms of whether you're  
16 saying -- in terms of resonance that we were  
17 talking about before, whether or not in terms of  
18 stiffness and resonance it would depend upon the  
19 natural frequency of the cask to -- or the cask and  
20 pad.

21 A. That is correct. Cask and pad response  
22 or frequencies would be whatever the frequency is.  
23 But what is being input is going to excite the  
24 response. The input is only used as an excitation  
25 force, and it reacts to the physics of the cask and

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1 the pad system. And so, for example, let's say if  
2 you happen to have a frequency of the system at 5  
3 Hz, okay, that's one of the cases that Dr. Soler  
4 presented, then you would see that it would be  
5 affected by the accelerations that are shown in  
6 these curves at 5 Hz.

7 Q. Now, the accelerations here are only  
8 illustrative of your single mass system, correct?

9 A. Excuse me, sir?

10 Q. Your accelerations here are only  
11 illustrative of your single mass one degree freedom  
12 system, correct?

13 A. This is the representation of a response  
14 spectra for the time history that PFS has provided.

15 Q. And the applicability of these curves  
16 depend upon your K and your M, correct?

17 A. No. It is not my K and it is not my M.  
18 It is the frequency at which each single degree of  
19 freedom system will vibrate if this input motion is  
20 applied.

21 Q. But that single degree of freedom system  
22 has a particular K and a particular M that  
23 corresponds to that frequency, correct?

24 A. That's how it is generally obtained.

25 Q. And so therefore you're taking a K and M

1 that represents that frequency for the formula that  
2 we just discussed about earlier, correct?

3 A. Let me clarify again. If you give this  
4 time history to Geomatrix, okay, which has provided  
5 us this time history, say, go and plot this  
6 response spectra at 1, 3, 5, and 7 percent damping.  
7 They should get very, very close to what I've got  
8 here. And any program, dynamic program can  
9 generate this response spectra.

10 Q. And in terms of response spectra, in  
11 terms of time histories, you're making a point  
12 that, say with a 1 percent damping you go from a  
13 value of, say, at 5 Hz you go from 2.5, and if it  
14 goes to 7 Hz, you go up to above 4. You're making  
15 the point that you have spikes in that damping --

16 A. That's right.

17 Q. -- in that curve, correct?

18 A. That is correct, sir.

19 Q. Now, isn't that really true that in any  
20 type of time history you have spikes in terms of  
21 your -- the accelerations at the different  
22 frequencies? In other words, a raw time history is  
23 not a smooth curve that shows no spikes in it,  
24 correct?

25 A. Yeah. And that's again the reason why

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1 when you vary the frequency you would then collect  
2 the effect of all peaks and valleys that may happen  
3 because of the peaks and valleys that you observe  
4 with this spectra. This is what's being applied as  
5 an input. I have not generated anything new. This  
6 is a part of the ground motion that's given to us.  
7 And your system will behave to that input motion if  
8 you choose 1 percent damping, 2 percent, 3 percent,  
9 whatever you will choose.

10 Q. And this does not say, your curves here  
11 do not say what the particular or what the  
12 appropriate damping should be, correct?

13 A. That is correct, sir.

14 Q. And by the same token, none of these  
15 curves here represent what a particular contact  
16 stiffness and associated frequency would be,  
17 correct? With respect to the pads and the cask,  
18 correct?

19 A. It definitely shows one thing, that 40  
20 percent damping you will not excite a structural  
21 response for this time history. Means your  
22 structure is behaving practically rigid all the way  
23 from low frequency all the way to high frequency.

24 Q. Isn't that really true for most single  
25 oscillator systems, as you increase damping you're

1 going to dampen out the spikes a bit? Isn't that  
2 true, generally speaking, for this type of system?

3 A. It has nothing to do -- this is a  
4 single -- this is a response spectra. That's the  
5 fundamentals of the design.

6 Q. Yes. But I'm saying in terms of you  
7 saying that it shows no response, isn't it true  
8 that as you increase your damping for a single  
9 oscillator system that you're going to dampen out  
10 the various spikes you would otherwise see at a  
11 lower damping, correct?

12 A. If you choose -- if you choose a very  
13 high damping, then you would see no amplification.  
14 That means you are basically acting as a rigid  
15 system. Everything is tied and there is  
16 amplification. But if you choose a damping which  
17 is showing some amplification, that basically shows  
18 that system is responding and there is some -- you  
19 apply an input, you get a response, the response is  
20 higher than input, and so you have an  
21 amplification.

22 Q. And whatever particular -- what damping  
23 you should use would depend upon the particular  
24 system, correct?

25 A. That is correct, sir.

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1 Q. And this says nothing in terms of what  
2 particular damping you should use?

3 A. That is correct, sir.

4 Q. And it also says nothing in terms of  
5 what particular contact stiffness --

6 A. That is correct, sir.

7 JUDGE FARRAR: Mr. Gaukler, before you  
8 change subjects --

9 MR. GAUKLER: Getting ready to do that.

10 JUDGE FARRAR: Maybe we shouldn't have  
11 had a two-week break, because I seem to have  
12 forgotten some of the things I learned.

13 This formula, the 1 over 2 pi formula,  
14 it I understand plays some role in generating this.

15 THE WITNESS: That's right.

16 JUDGE FARRAR: What mass do you use in  
17 that formula?

18 THE WITNESS: I did not select any mass.  
19 The programs, these programs automatically select a  
20 frequency, okay, that gives them the X axis value  
21 and apply a ground motion and gets the response.  
22 So you could choose, depending on the program that  
23 you are using. It's really immaterial. No matter  
24 which program you use, no matter who does it, your  
25 solution is identical.

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1 JUDGE FARRAR: Now, explain to me in  
2 simple terms again the relationship between, if  
3 any, between contact stiffness, coefficient of  
4 friction, stiffness of spring and damping.

5 THE WITNESS: If you apply --

6 JUDGE FARRAR: Start with coefficient of  
7 friction, because I know what that is.

8 THE WITNESS: Coefficient of friction?

9 JUDGE FARRAR: Right. I know what that  
10 is. Now, how is contact stiffness related to that?

11 THE WITNESS: Contact stiffness is  
12 assumed between two surfaces which are in contact  
13 with each other. And stiffness becomes effective  
14 to model the motion, rocking motion and compression  
15 stiffness when an object is interacting with each  
16 other. So it's like impacting each other, you have  
17 stiffness between two objects.

18 JUDGE FARRAR: But some of that would  
19 have a bearing instantaneously on what the  
20 coefficient of friction would be?

21 THE WITNESS: Yeah. Coefficient of  
22 friction is going to be when two surfaces are  
23 rubbing against each other. And the stiffness is  
24 going to have two items are hitting against each  
25 other, are applying force against each other.

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1 JUDGE FARRAR: Okay. Now, how about  
2 stiffness of spring?

3 THE WITNESS: The stiffness is, if you  
4 take a spring and you apply a unit load and you  
5 deflect, you measure the deflection. So this is  
6 nothing but force per unit deflection.

7 JUDGE FARRAR: Okay. So in this  
8 context, how, if at all, is that related to the --  
9 help me here.

10 THE WITNESS: Yeah. What is -- how this  
11 is related with the contact stiffness structure.  
12 See, the structural behavior is excited by what you  
13 apply as an input motion, okay? If you apply  
14 static load it will deflect statically. If apply a  
15 dynamic load, it will act dynamically. So if your  
16 ground motion has important frequencies that are  
17 capable of exciting the structural frequencies,  
18 then you may have a resonance at that point.

19 So let us suppose that I see a peak at 5  
20 Hz, for example. And if your structure happened to  
21 be at 5 Hz, then my response is going to be very  
22 high. And that's how they relate.

23 JUDGE FARRAR: Thank you.

24 Q. (By Mr. Gaukler) Dr. Khan, I have one  
25 other area I want to follow up on briefly. Counsel

1 for the State handed you a page from I think State  
2 Exhibit 120, which was part of the deposition of  
3 the Singh/Soler March 2000 deposition. Do you have  
4 a complete copy of that exhibit by any chance, sir?

5 A. You said March 6th, sir?

6 Q. State Exhibit 120, which should be  
7 attached to your testimony. Do you have that?

8 A. 120, yes, sir.

9 Q. And that's the exhibit that you were  
10 asked about with respect to page 43 by counsel for  
11 the State. Now, if you recall back on May 7th when  
12 we first were discussing this, we were discussing  
13 it in the context of question and answer 26 of your  
14 testimony. Do you remember the discussion that we  
15 were having in the context of your question and  
16 answer No. 26?

17 A. I have to go back and look. I'm trying  
18 to find it here. Okay.

19 Q. If you look at the last paragraph of  
20 your answer on answer 26, and you say about the  
21 third sentence from the bottom of that answer that  
22 "Holtec did not conduct its analysis at Diablo  
23 Canyon with DYNAMO because it was concerned with  
24 the accuracy of DYNAMO." Do you see that in the  
25 last paragraph of your answer 26?

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1 A. This is answer No. 36, right?

2 Q. 26.

3 A. 26. This is on page 10?

4 Q. I believe it's page 11, top of page 11.

5 I believe -- excuse me. It's on the bottom of

6 answer 26. Go up one, two, three -- it's the

7 fourth sentence up. "Although anchored casks will

8 experience limited rotation at Diablo Canyon,

9 Holtec did not conduct its analysis at Diablo

10 Canyon with DYNAMO because it was concerned with

11 the accuracy of DYNAMO." Do you see that sentence?

12 A. Yes, sir.

13 Q. Now, does what -- is there anything on

14 page 43 of State Exhibit 120 which counsel for the

15 State pointed to earlier today that says that

16 Holtec did not use DYNAMO at Diablo Canyon even

17 though it would experience more rotation because it

18 was concerned with the accuracy of DYNAMO?

19 A. The DYNAMO was stated that it was for

20 small rotations. And if you would expect larger

21 rotations, then it would not be accurate, it would

22 not -- it probably would not give accurate

23 solution.

24 Q. Right. And you're saying here,

25 "Although the anchored casks will experience

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1 limited rotation at Diablo Canyon, Holtec did not  
2 conduct its analysis at Diablo Canyon with DYNAMO  
3 because it was concerned with the accuracy of  
4 DYNAMO." That's what you say in your answer 26.

5 A. Holtec in their testimony said several  
6 things. They did studies with DYNAMO with  
7 unanchored casks. That's what was said in the  
8 testimony. Then they did anchored casks. Anchored  
9 casks final design was done with NASTRAN, visual  
10 NASTRAN.

11 Q. And my question to you was very  
12 specific. On page 43 of the Singh/Soler deposition  
13 which was pointed to you out by counsel for the  
14 State today, is there anything in that page of that  
15 deposition that says why Holtec did or did not use  
16 DYNAMO at Diablo Canyon?

17 MR. SOPER: On that page only  
18 particularly? Is that the question?

19 MR. GAUKLER: You pointed to that page  
20 and said that was the enlightening page, so I'm  
21 just asking him a question.

22 MR. SOPER: Well, that mischaracterizes  
23 the question to him with regard to that page.

24 JUDGE FARRAR: I think he pointed it to  
25 it as the enlightening page not for the subject

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1 you're talking about but for pointing out where my  
2 question went astray. As I think we said before,  
3 at page 7196 of the transcript I thought I was on  
4 to something because I misread and so did the  
5 witness at that time page 43. So under Mr. Soper's  
6 question the witness straightened that out, so he  
7 and I were looking at the wrong thing on May 7th.

8 Now, you've got a different question.  
9 And so Mr. Soper's objection is -- if you're  
10 following up on his question, which is what the  
11 purpose of this examination is, we have a -- you're  
12 asking a broad question and limiting it to the  
13 specific paragraph which we talked about for a  
14 different purpose.

15 MR. GAUKLER: If I could just briefly  
16 state what I believe was happening, okay. On May  
17 7th we were discussing the various -- State Exhibit  
18 120 specifically with respect to whether the  
19 witness had any support for his position for his  
20 statement that Holtec had chosen DYNAMO at -- used  
21 at Diablo Canyon for the reason stated in the  
22 sentence I just read from his testimony. It was in  
23 that context that your Honor asked the question  
24 that counsel for the State clarified, and I thought  
25 that counsel for the State was therefore saying,

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1 this gave the reason why Holtec -- gave the reason  
2 why the witness believed Holtec chose DYNAMO. In  
3 fact, if you look just at the sentence above it, he  
4 cites the page -- he sites page 43 there just above  
5 that sentence.

6 JUDGE FARRAR: Well, why don't we  
7 simplify this and get right to the point. And  
8 whether it's within the scope of recross or not,  
9 just ask him about Diablo Canyon. Forget the  
10 question I asked on 7196, forget the correction  
11 about it today. Just ask him about Diablo Canyon.

12 MR. GAUKLER: Okay.

13 JUDGE FARRAR: He makes a statement in  
14 question 26 that Holtec didn't use DYNAMO.

15 MR. GAUKLER: Right.

16 JUDGE FARRAR: We want to know where he  
17 got that from.

18 MR. GAUKLER: That's my question.

19 JUDGE FARRAR: Let's leave out what I  
20 said and what he said and what Mr. Soper said.

21 Have you got the question? What's your  
22 basis for saying they didn't use DYNAMO?

23 Q. (By Mr. Gaukler) For the reasons stated  
24 in your testimony.

25 A. The testimony was because of large

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1 rotation as described on page 43. Holtec used, at  
2 least based on what we believe, Holtec said that  
3 they tried to -- they used DYNAMO for an unanchored  
4 system. They did several studies at Diablo. In  
5 the final analysis they chose NASTRAN. Okay, why  
6 NASTRAN was used even though the casks were  
7 anchored, we don't know. Why DYNAMO could not have  
8 been used, we don't know. The only thing we could  
9 figure out was there was a limited rotational issue  
10 associated with DYNAMO.

11 Q. So therefore, in your testimony when you  
12 say, "Although the anchored casks were experiencing  
13 limited rotation at Diablo Canyon, Holtec did not  
14 conduct its analysis at Diablo Canyon with DYNAMO  
15 because it was concerned with the accuracy of  
16 DYNAMO," you're saying you really don't know why  
17 Holtec did not use DYNAMO at Diablo Canyon. Is  
18 that correct?

19 A. That's correct. And the only place  
20 where we got the accuracy answer is in this 43  
21 where it's modeled with large rotations.

22 MR. GAUKLER: No further questions, your  
23 Honor.

24 JUDGE FARRAR: Staff?

25 MR. O'NEILL: Your Honor, could I have a

1 few minutes just to collect my thoughts?

2 JUDGE FARRAR: Okay. We're going to  
3 finish this gentleman tonight? Soon?

4 MR. O'NEILL: Yes.

5 JUDGE FARRAR: Okay, go ahead.

6

7 RECROSS-EXAMINATION

8 BY MR. O'NEILL:

9 Q. You ready, Dr. Khan?

10 A. Yes, sir.

11 Q. Dr. Khan, does a response spectra  
12 identify the characteristics of the input time  
13 history? Yes or no?

14 A. Yes, sir, it represents the  
15 characteristics of the time history.

16 Q. Does the response spectra not in fact  
17 identify a response of a series of damped single  
18 degree of freedom structures whose frequencies  
19 cover the range of concern to the input time  
20 history?

21 A. Yes, sir.

22 Q. How is that consistent with your first  
23 response?

24 A. Basically you look at the frequencies of  
25 concern from 1 to 33 Hz, for example, and each

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1 frequency could be excited by an earthquake motion  
2 and a time history is given, and from each -- from  
3 that time history on each frequency you obtain  
4 acceleration for a single degree of freedom system  
5 that forms the spectra, that becomes the spectra.  
6 And at various damping values you plot those. So  
7 for PFS, for example, 5 percent spectra is given  
8 for range of frequencies all the way up to 100 Hz.

9 Q. For a given response spectra you could  
10 have multiple time histories, correct?

11 A. That is correct, sir.

12 Q. With respect to the figures contained in  
13 State Exhibit 195, your Y axis is labeled as  
14 acceleration. Wouldn't response acceleration be a  
15 more appropriate label for that vertical axis?

16 A. If you look at the response spectra  
17 plots that generally are plotted on Y axis, all you  
18 define is acceleration, and on X axis you define  
19 frequency or period, and then the title is usually  
20 response spectra.

21 Q. But isn't what this graph is showing,  
22 this particular figure is in response acceleration?

23 A. That is correct, sir. You could call it  
24 any term that will make you feel better, but in  
25 general it represents the acceleration of a single

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1 degree of freedom system, maximum acceleration of  
2 the single degree of freedom system.

3 Do you have a spectra given in Reg Guide  
4 1.60? Do you have Reg Guide 1.60? Let's just look  
5 at the --

6 Q. We don't have a copy with us.

7 A. But if you look at -- basically it  
8 defines acceleration. Now, if the definition is  
9 different you could use that, but we use  
10 acceleration and frequency or period.

11 Q. Dr. Khan, you make frequent references  
12 to "system," the word "system" in your testimony.  
13 What does your definition of system include?

14 A. System could be a cask by itself; a  
15 system could be a pad and a cask; a system could be  
16 soil, pad, and a cask. It could be as huge as you  
17 would like it to be. So depending on what you are  
18 analyzing, you could define that system. System  
19 would be more than --

20 Q. What specific system did you use in  
21 State Exhibit 195?

22 A. In Exhibit -- I simply used program  
23 that generates response spectra from a time  
24 history. No, I did not use any cask, I did not use  
25 any pad. The only thing I used was the input time

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1 history of PFS.

2 Q. So you're not looking at a system that  
3 would include a cask, a pad, soil cement, a soil  
4 foundation?

5 A. Yeah. It's immaterial. This is the  
6 ground motion. This is earthquake. I used the  
7 earthquake which is given in terms of acceleration  
8 and time and converted that into frequency and  
9 acceleration.

10 Q. So the earthquake you used was a  
11 freefield seismic ground motion, or a ground motion  
12 associated with it?

13 A. Whatever PFS has given me in the  
14 digitized form for normal, for parallel and  
15 vertical.

16 Q. You would agree that -- excuse me. I  
17 lost my train of thought here.

18 Well, if you were to take into account  
19 the underlying soil foundation, that would filter  
20 the freefield response, would it not? There would  
21 be some frequency filtering effects?

22 A. There would be some, and I think that  
23 has been shown by Dr. Luk's report to some extent.

24 Q. Should you account for the radiation  
25 damping associated with the soil?

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1           A.       Yes, sir. Dr. Luk's report included all  
2 the effect of soil damping and it calculates the  
3 response at the top of the pad or at the bottom of  
4 the pad, and therefore when you apply these time  
5 histories that effect is already taken into  
6 consideration.

7           Q.       Do you have an opinion as to what the  
8 magnitude of this radiation damping should be?

9           A.       No, sir.

10          Q.       And we're talking about the casks, but  
11 with the input motion of the pads, wouldn't that  
12 also be filtered by the soil?

13          A.       Yes. I keep on going back to the  
14 results which Dr. Luk has presented. It has all  
15 been done. Let's say we agree to his results. You  
16 will see the spectra, amplify the spectra. And  
17 motion seems to have been amplified significantly,  
18 and therefore whatever soil damping effect,  
19 radiation damping effect, filtering effect that he  
20 has modeled so far is all there.

21          Q.       What about the damping for reinforced  
22 concrete structure in Reg Guide 126.1? What is  
23 that based on?

24          A.       My understanding is a lot of information  
25 in the Reg Guide is based on test data.

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1 Q. What are the typical values that are  
2 indicated in Reg Guide 126.1?

3 A. If you are doing a stress analysis of  
4 the pad, then that damping could be as high as 7  
5 percent for a large earthquake. For a smaller  
6 level earthquake it could be less. It could be 5  
7 percent, maybe 3 percent. For equipment in general  
8 it could vary anywhere from 1 percent to 4 percent  
9 depending on site, depending on the technical  
10 requirements.

11 Q. Your particular model for the cask used  
12 beam elements. I believe we discussed that  
13 earlier. Correct?

14 A. Yes, sir.

15 Q. Did you calculate yourself what the  
16 natural frequency would be?

17 A. The program is, there's so many elements  
18 and so many masses, it automatically calculates it  
19 internally. So I was not able to do it by hand  
20 because it's a one degree of freedom system, but  
21 one can obtain it.

22 Q. But did you make any attempt to figure  
23 out what it was?

24 MR. SOPER: Let me object to the  
25 question at this point. Excuse me. I've been

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1       trying to be patient here, your Honor, but as you  
2       noted, the examination was supposed to be limited  
3       to my redirect, and these are all subjects that  
4       were not included in my redirect.

5               MR. O'NEILL: One of your specific  
6       questions dealt with how he was characterizing his  
7       model, I mean, the frequency in his model. I think  
8       he had raised some questions, too, about frequency  
9       at 30 Hz, for instance.

10              JUDGE FARRAR: When the State introduced  
11       this exhibit they introduced it for a limited  
12       purpose, and I expected the cross would deal with  
13       just locking in that limited purpose to avoid any  
14       confusion. So if you can make sure that you focus  
15       your questions that way, we'll get to the end  
16       sooner. Mr. Gaukler?

17              MR. GAUKLER: I was going to say, there  
18       was some separate testimony, though, in terms of  
19       modeling in terms of beam element. I don't know  
20       whether Mr. O'Neill is going towards that or  
21       Exhibit 195. And there was some separate redirect  
22       with respect to beam elements in Dr. Khan's model.

23              MR. O'NEILL: I know he did specifically  
24       discuss beam elements in his model.

25              JUDGE FARRAR: Right.

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1 MR. O'NEILL: And I think it's in the  
2 advantages of that particular approach.

3 JUDGE FARRAR: We'll overrule the  
4 objection for now.

5 THE WITNESS: There would be many  
6 frequencies because of multi degree of freedom  
7 system. Program automatically calculates it  
8 depending on the stiffness that you use at the base  
9 and the mass that you have. And it could range  
10 anywhere from very low frequencies, 1 Hz, all the  
11 way to 100, 200 Hz. So depending on how many nodes  
12 you would be able to excite. Yes, you can  
13 calculate by fixing it at the bottom and you can  
14 get all sorts of frequencies.

15 Q. (By Mr. O'Neill) But is that a function  
16 of you having looked at a range of parameters and  
17 contact stiffness values? You didn't attempt to  
18 ascertain what you might consider a realistic  
19 frequency, realistic natural frequency of a system  
20 at PFS?

21 A. I wish I knew what the realistic  
22 frequency would be, and that's why a range was  
23 chosen. Had I known a specific frequency, then I  
24 would have picked values that would have matched  
25 those. And that's the reason a range is given.

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1 And frequency will change as the stiffness is  
2 changing.

3 MR. O'NEILL: No further questions.

4 Thank you.

5 JUDGE FARRAR: Mr. Soper?

6 MR. SOPER: Your Honor, we do have one  
7 more. As it turns out, it's Ms. Nakahara's area.  
8 Could she ask one question?

9 JUDGE FARRAR: Yes, certainly.

10 MS. NAKAHARA: For the record, I'm  
11 Connie Nakahara. I'd like to have this marked as  
12 State's Exhibit 196, which are a cover page from  
13 the development of time histories for 2,000-year  
14 return period design spectra, and the second page  
15 is dated March 21, 2001, Rev. 0, and Table 1 which  
16 consists of page 12, 13, and 14.

17 JUDGE FARRAR: All right. We'll have --  
18 the reporter will mark that.

19 (STATE'S EXHIBIT-196 MARKED.)

20

21 FURTHER REDIRECT EXAMINATION

22 BY MS. NAKAHARA:

23 Q. Dr. Khan, is it correct you testified  
24 that the response spectra you calculated for 5  
25 percent damping in State's Exhibit 195 was very

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1 similar or identical to the response spectra  
2 developed for -- developed by Geomatrix for the  
3 2,000-year return period?

4 A. Yes.

5 Q. What's been marked as State's Exhibit  
6 196, are you familiar with this document?

7 A. Yes.

8 Q. And I'd like to just quickly ask you to  
9 compare some values for your 5 percent response  
10 spectra and those obtained by Geomatrix. If you'll  
11 compare the -- for frequency of 5, the 5 percent  
12 response spectra in the vertical direction, what  
13 was the value you obtained?

14 A. 1.47 g's.

15 Q. If you'll compare that to the value that  
16 Geomatrix obtained, which should be on page 13, for  
17 5 percent damping in the vertical direction.

18 A. Is 1.47945. My values are two digits,  
19 so -- and they have 5 digits.

20 Q. And is it your understanding that  
21 default normal time history is in the north-south  
22 direction?

23 A. That's my guess at this time, I believe  
24 so.

25 Q. Under that assumption will you identify

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1 the 5 percent damping acceleration for 5 Hz that  
2 you obtained in the north-south direction?

3 A. That -- my value is 2.13 g's.

4 Q. And if you'll compare that to the value  
5 that Geomatrix obtained.

6 A. 2.14129.

7 Q. And if you'll identify for the 5 percent  
8 damping acceleration that you obtained for 5 hz in  
9 the east-west direction.

10 A. I'm having a hard time locating. My  
11 value is 2.18. I'm trying to see which column that  
12 should be. One, two, three, four, five --

13 Q. You anticipated the next question. If  
14 you'll compare that to the Geomatrix value for the  
15 fault parallel.

16 A. I'm not sure, or at least I'm not seeing  
17 the 5 -- let's see. Okay, at 5 Hz would be -- I  
18 believe is 2.188, and my value is 2.18 g's.

19 JUDGE FARRAR: This compares to to the  
20 five digits 18846?

21 THE WITNESS: That is correct, sir.

22 Q. (By Ms. Nakahara) If you'll go through  
23 this exercise for 10 Hz just to compare. If you'll  
24 identify your 5 percent damping value for  
25 acceleration at 10 Hz in the vertical direction.

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1           A.       In the vertical direction at 10 Hz,  
2 Ms. Nakahara?

3           Q.       Yes.

4           A.       At 10 Hz is 2 g.

5           Q.       Compare that to the value obtained by  
6 Geomatrix in the vertical direction.

7           A.       2.00011.

8           Q.       If you'll identify the acceleration you  
9 obtained for 5 Hz damping at 10 Hz in the  
10 north-south direction.

11          A.       My value is 1.57 g's.

12          Q.       And if you'll identify the value  
13 obtained by Geomatrix.

14          A.       Is 1.58448.

15          Q.       And finally, identify the value in the  
16 east-west direction for 5 percent acceleration  
17 value in the east-west direction for 5 percent  
18 damping at 10 Hz.

19          A.       At 10 Hz my value is 1.60 g's.

20          Q.       And compare that to the value obtained  
21 by Geomatrix.

22          A.       And Geomatrix value is 1.60646.

23          Q.       And Dr. Khan, is it correct you  
24 testified earlier that when you compared the  
25 response spectra for 5 percent damping that you

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1 obtained in State's Exhibit 195, was that obtained  
2 by Geomatrix that was very similar but not  
3 identical?

4 A. That is correct.

5 MS. NAKAHARA: And your Honor, I move to  
6 admit State's Exhibit 196.

7 JUDGE FARRAR: Any objection?

8 MR. GAUKLER: No objection, your Honor.

9 MR. O'NEILL: No objection, your Honor.

10 JUDGE FARRAR: Then it will be admitted.

11 (STATE'S EXHIBIT 196 WAS ADMITTED.)

12 MS. NAKAHARA: That's all we have.

13 Thank you.

14 JUDGE FARRAR: That was the one question  
15 Mr. Soper told me you had.

16 Does that generate any need for further  
17 cross? All right, good. Dr. Khan, then you're  
18 excused, I guess for now. Thank you for your  
19 testimony.

20 MR. O'NEILL: Your Honor, I think one  
21 thing we agreed upon was that we'd have to  
22 determine the appropriate agreed-upon title for  
23 this.

24 JUDGE FARRAR: Yeah, you'll do that, not  
25 in our presence.

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1 MR. O'NEILL: Just reminding you.

2 MR. SOPER: I was going to suggest, your  
3 Honor, that we use the same terminology that  
4 Geomatrix used on this Exhibit 196, design response  
5 spectra 5 percent damping and call it the fault  
6 normal, fault parallel and vertical.

7 MR. GAUKLER: We'll talk about it, your  
8 Honor.

9 MR. SOPER: Since it's the same numbers,  
10 almost, to the --

11 JUDGE FARRAR: Well, you all figure that  
12 out, and keep it simple.

13 All right, according to the e-mails you  
14 gave us, tomorrow we're going to have PFS's  
15 rebuttal to the Khan/Ostadan testimony in the form  
16 of Dr. Singh and Dr. Soler?

17 MR. GAUKLER: Yes. And I'm going to  
18 talk with the State, and they'll be ready to offer  
19 their rebuttal that they have with respect to  
20 Dr. Ostadan and Dr. Bartlett's testimony.

21 MS. CHANCELLOR: We need to talk about  
22 that, your Honor.

23 JUDGE FARRAR: We hadn't finished that.  
24 We in fact, Ostadan and Bartlett, we were --

25 MS. CHANCELLOR: Scheduled for Friday.

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1 MR. GAUKLER: This Friday.

2 JUDGE FARRAR: Bartlett and Ostadan,  
3 hadn't we finished them?

4 MR. GAUKLER: No. We were halfway.

5 JUDGE FARRAR: Oh, we had more  
6 questions. We hadn't done redirect.

7 MR. O'NEILL: I don't think Mr. Turk  
8 finished his cross of Dr. Ostadan.

9 MS. CHANCELLOR: It should be noted in  
10 the e-mail where we are at with each witness.

11 JUDGE FARRAR: I see. We had  
12 interjected some Board questions but he had not  
13 finished. And you all don't want to have rebuttal  
14 till --

15 MS. CHANCELLOR: We'd like to get the  
16 direct case on first before we have rebuttal, but  
17 I'm willing to talk to Mr. Gaukler, but it doesn't  
18 seem logical to have rebuttal before you can finish  
19 direct.

20 MR. GAUKLER: Well, we know we have  
21 certain rebuttal already based upon their direct  
22 and what they've said. We're prepared to put that  
23 on with Dr. Singh and Dr. Soler. It would be  
24 efficient to do so.

25 JUDGE FARRAR: To get them out of here?

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1 MR. GAUKLER: At least Dr. Singh, yes.

2 Dr. Soler is going to stay around.

3 MS. CHANCELLOR: We haven't even started  
4 redirect.

5 MR. TRAVIESO-DIAZ: We have rebuttal to  
6 Section B testimony by six PFS witnesses if you  
7 include Dr. Soler and Dr. Singh, and we have one  
8 day to do rebuttal. I think if we try to do all  
9 that rebuttal in one day, regardless of whatever  
10 measures we may take to expedite it, I don't think  
11 we're going to get done. I don't think we're going  
12 to be able to put rebuttal testimony by six  
13 witnesses and examination with respect to it in a  
14 single day. I don't see how that feasibly be done.  
15 Given, though, I'm volunteering to prefile some of  
16 it to expedite the process, but still --

17 JUDGE FARRAR: Who are the six  
18 witnesses?

19 MR. TRAVIESO-DIAZ: Dr. Soler,  
20 Dr. Singh, Mr. Trudeau, Mr. Ebbeson, Dr. Singh and  
21 Mr. Youngs. So our concern is that --

22 JUDGE FARRAR: Wait a minute.

23 MS. CHANCELLOR: I count six.

24 MR. TRAVIESO-DIAZ: Yeah, six.

25 MS. CHANCELLOR: I thought you said

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1 seven. Sorry.

2 MR. TRAVIESO-DIAZ: No, six.

3 If I may --

4 JUDGE FARRAR: And they're all going to  
5 say something different from what they said on  
6 direct?

7 MR. TRAVIESO-DIAZ: Yes. The problem is  
8 that the testimony of Dr. Bartlett and Dr. Ostadan,  
9 the one that they gave and the response they gave  
10 to my questions touched upon each of those  
11 witnesses' testimony. Some of the rebuttal is  
12 going to be very brief, but still you have  
13 potential of six people. So we're trying to  
14 anticipate and expedite some of the that rebuttal  
15 in areas that we know before Saturday. Otherwise I  
16 think all these people will have to go back to  
17 Washington, which I don't think anybody wants.  
18 That's what we're trying to avoid.

19 MS. CHANCELLOR: Could I ask a question  
20 about how long Mr. Gaukler or Mr. Travieso-Diaz  
21 thinks that it will take for Dr. Singh and  
22 Dr. Soler without rebuttal tomorrow, without  
23 rebuttal on D? Ostadan and Bartlett, I mean.

24 MR. GAUKLER: Rebuttal without  
25 Dr. Ostadan and Dr. Bartlett, just rebutting

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1 Dr. Khan?

2 MS. CHANCELLOR: Correct.

3 MR. GAUKLER: I had figured in my mind a  
4 half day of total, roughly, without breaking it  
5 out. But the great majority of it is with respect  
6 to Dr. Khan.

7 MR. TRAVIESO-DIAZ: It may very well be,  
8 but there will be no time tomorrow to get to  
9 Dr. Bartlett and Dr. Ostadan. But if time permits,  
10 I think it will be desirable to get that portion of  
11 rebuttal that we can get done tomorrow, to the  
12 extent that we know already what the rebuttal will  
13 be.

14 MS. CHANCELLOR: The alternative is to  
15 start Dr. Arabasz. Oh, and we have rebuttal with  
16 Dr. Khan.

17 MR. GAUKLER: How much rebuttal do you  
18 have with him, approximately? Do you know?

19 DR. KHAN: I thought I was leaving.

20 JUDGE FARRAR: Surrebuttal?

21 MS. NAKAHARA: Dr. Soler and Dr. Singh.

22 JUDGE FARRAR: You mean after they do  
23 rebuttal you'd have surrebuttal?

24 MS. NAKAHARA: And rebuttal on Dr. Soler  
25 and Dr. Singh's direct.

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1 MS. CHANCELLOR: Dr. Singh --

2 JUDGE FARRAR: Wait a minute. Wait. I  
3 thought they went -- they go first. I thought the  
4 purpose of your testimony is responding to their  
5 case.

6 MS. CHANCELLOR: But we -- we could  
7 respond to Dr. Singh and Soler's direct case with  
8 the rebuttal witness, Dr. Khan, and we could  
9 also --

10 JUDGE FARRAR: You all filed at the same  
11 time.

12 MS. CHANCELLOR: Right.

13 JUDGE FARRAR: So that's the  
14 disadvantage of that is that your testimony which  
15 in the ordinary course is rebutting their case  
16 isn't; you're trying to anticipate, you're saying  
17 you get another chance now?

18 MS. CHANCELLOR: I think we could finish  
19 all of cask stability tomorrow.

20 JUDGE FARRAR: Wait a minute. Are you  
21 saying that every set of witnesses you get two  
22 chances to respond, your prefiled chance and  
23 another chance?

24 MR. TRAVIESO-DIAZ: At least tomorrow.

25 JUDGE FARRAR: I heard that.

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1 MR. TRAVIESO-DIAZ: I would say,  
2 however, that the scope of each successive rebuttal  
3 should be narrower and narrower.

4 JUDGE FARRAR: I just had not focused on  
5 the simultaneous prefiling problem, that what's  
6 your rebuttal case is not --

7 MS. CHANCELLOR: Rebuttal and  
8 surrebuttal are different.

9 JUDGE FARRAR: Okay. Well, then we've  
10 just got to go.

11 MS. CHANCELLOR: Dr. Khan is only  
12 available tomorrow, so we would like to get through  
13 with our rebuttal and surrebuttal, whatever we're  
14 calling it, with Dr. Khan tomorrow.

15 JUDGE FARRAR: Let's do this for your  
16 planning. It's going to be hard enough for us to  
17 follow. We'll take Dr. Singh and Dr. Soler  
18 tomorrow, but only on the rebuttal to Khan, not on  
19 the rebuttal to the testimony we haven't yet heard.  
20 That's adding too much complication.

21 All right, so we'll do them, and then  
22 you want to put Dr. Khan back on in response to  
23 their earlier testimony?

24 MS. CHANCELLOR: We could probably do in  
25 response to their earlier as well as any

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1 surrebuttal and just wrap everything up with  
2 Dr. Khan so that we can get cask stability.

3 JUDGE FARRAR: Okay, great. All right,  
4 then we'll --

5 MS. CHANCELLOR: And then do I need to  
6 advise Dr. Arabasz to come tomorrow in case he's  
7 needed at the end of the day?

8 JUDGE FARRAR: Where is he located?

9 MS. CHANCELLOR: At the university, but  
10 I think he needs to bring a suit.

11 JUDGE FARRAR: When is Mr. Turk due in?

12 MR. O'NEILL: One-thirty or two o'clock.  
13 My understanding is he said he was going to try to  
14 catch an earlier flight if possible.

15 JUDGE FARRAR: Okay, get Dr. Arabasz  
16 here. If he's dragged down the hill unnecessarily,  
17 that's little or nothing.

18 MR. GAUKLER: I should say that he  
19 should probably bring a suit, but we can advise him  
20 how the day's going at noon.

21 MS. CHANCELLOR: Okay, I'll do that.

22 MR. GAUKLER: We'll know better tomorrow  
23 morning exactly how much rebuttal we have with  
24 Dr. Khan. Just giving a very rough estimate right  
25 now this evening.

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1 JUDGE FARRAR: All right, then fine.  
2 Then we'll see you all at 9 o'clock tomorrow  
3 morning.

4  
5 (The proceeding was concluded  
6 for the day.)  
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CERTIFICATE

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

Name of Proceeding: Private Fuel Storage, LLC

Docket Number: Docket No. 72-22-ISFSI

ASLBP No. 97-732-02-ISFSI

Location: Salt Lake City, Utah

were held as herein appears, and that this is the  
original transcript thereof for the file of the United  
States Nuclear Regulatory Commission taken by me and,  
thereafter reduced to typewriting by me or under the  
direction of the court reporting company, and that the  
transcript is a true and accurate record of the  
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/s/ Diana Kent  
Diana Kent  
Official Reporter  
Neal R. Gross & Co., Inc.