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UNITED STATES
NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF:

LONG ISLAND LIGHTING COMPANY

SHOREHAM NUCLEAR POWER STATION

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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In the matter of: :

SHOREHAM NUCLEAR POWER STATION : Docket No. 50-322-OL

(Long Island Light Company :

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State Office Building

Veterans Memorial Highway

Hauppage, New York

Tuesday, September 25, 1984

The hearing in the above-entitled matter was convened at 9:00 a.m., pursuant to notice. BEFORE:

JUDGE LAWRENCE BRENNER,
Chairman, Atomic Safety and Licensing Board

JUDGE PETER A. MORRIS,
Member, Atomic Safety and Licensing Board

JUDGE GEORGE A. FERGUSON,
Member, Atomic Safety and Licensing Board

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APPEARANCES:

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Washington, D.C. 20036

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C O N T E N T S

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PROCEEDINGS

Whereupon,

Arthur Sarsten,

and

Adam Henriksen,

resumed the stand and, having been previously duly sworn, were examined and testified further as follows:

JUDGE BRENNER: Back on the record. Good morning.

As a preliminary matter both, based on the Board's partial review of the transcript for Thursday, September 20, 1984, there are some production errors. I emphasize that the Board has only looked at part of it. We would like the parties to review that transcript very carefully, and the parties are entitled to include any corrections that they would normally include in their review. But in particular, the problem that is most serious from the Board's point of view is exemplified by the following that we have found. I will not give them in sequence. I'll give the two most important ones first and then give you an additional one.

At transcript page 23,170, there is material missing from the transcript. We believe the error may be a simple one to correct because, as you will note, transcript page 23,170 and 171, although bearing two numbers, is the

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same page. And it may be that when the real 170 is found and retrieved from the computer, that will solve the problem but we're not sure. But I need the parties' help to ascertain what is missing once the reporter provides us with that missing page.

And another portion of the transcript occurring between 23,192 and 195, approximately, there is material missing from the transcript and/or out of sequence in the transcript. That portion is not as simple as providing a missing page nor could I piece it together by changing the sequence of pages, which is an error that sometimes occurs in transcripts. So I need the parties' help to try to piece it together. It occurs at the point where Mr. Goddard is completing his final round of questioning of the witnesses and where I am excusing the witnesses. In addition to a sequence problem, I know there is some material missing at that portion.

I want the party to look for these kinds of problem throughout the whole transcript, rapidly. As I said, that was just a spot-check.

At another portion of the transcript, earlier in the day, I had a dialogue with Mr. Ellis regarding the LILCO letter to Mr. Denton and the fact that we regarded it only as an information copy, and that LILCO had not moved that the Board, timely or thereafter, to do anything with that

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information. In the course of that dialogue, I distinctly remember Mr. Ellis saying that he would either check with this client or pass the word to his client or inform his client. And I responded to the effect that his client was already three weeks late. That portion of the dialogue is missing. I don't cite that as the world's most important piece of dialogue, to be sure, but only as an example of a fact that there might be more material than just that missing.

At transcript page 43,113, the dialogue between myself and Mr. Ellis comes to an end and Mr. Dynner adds his comments. It might be right at that portion that there is material missing, but I'm not sure.

In addition, a new index page is going to be issued, which identifies the parties sponsoring the exhibits listed on the index page and, also which lists the testimony which was bound into the transcript.

I've given examples of the more serious types of errors that I want the parties to find.

Let's go off the record.

(Off the record.)

JUDGE BRENNER: The Board has no further preliminary matters, and if the parties have none we can have LILCO continue its cross-examination of this panel. It's 9:15 and we are hopeful that you can complete it within

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an hour and a half.

MR. ELLIS: I share the hope.

CROSS EXAMINATION (Continued)

BY MR. ELLIS:

Q Professor Sarsten, I asked you yesterday if you would look at your calculations that you made at 3200 kw and 3300 kw. Have you had a chance during the evening to look at those calculations?

A (Witness Sarsten) Yes, I have.

Q Did you conclude that the DEMA standard was met for all speed ranges at 3200 kw?

A At 3200 the value was checked at the upper end of the speed range where the stresses are highest. The value was found by interpolating between the value calculated at 3300 kilowatts and at 3100 kilowatts. The figure at 3200 kilowatts and 473 rpm was 7,052 psi when, if corrected for the small difference in frontend amplitude relative to the measured values, came out as 71,008 psi.

Q That's at 473 rpm, is that correct?

A That is correct.

JUDGE BRENNER: Wait a minute. You did not mean 71,000.

WITNESS SARSTEN: 7,100, I'm sorry if I said it wrong.

JUDGE BRENNER: 7,108?

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WITNESS SARSTEN: Right.

BY MR. ELLIS:

Q And what were the values at the synchronous speed and at the underspeed?

A (Witness Sarsten) These values were not interpolated. But I can give you the values for 3300 and 3100 kilowatts.

At 3300 kilowatts the value, at synchronous speed, was 6,405 from the calculations. Or, with an amplitude correction, 6,456.

At 3100 kilowatts the values were 6,214 psi and, if we would use the same correction, we would have to correct this, increase it by a figure of 8/10ths of a percent.

Q So, am I correct that at 3300 kilowatts, you're calculations show that the 13 x 12-inch crankshaft meet DEMA at the synchronous and underspeed conditions, but not at the overspeed conditions, is that correct?

A That is correct. However, I would like to add that these calculations were based on approximate values for the T sub-N figures. They were calculated on the basis of a series of coefficients given in a German reference book. We had to make both a program to do this -- type in all the over 300 constants employed -- and perform the calculations in the course of a weekend. I would have liked to have had

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more time and obtain T sub-N values, which were more in agreement with the measured T sub-N values supplied to us by the owner's group and which we have previously used for the calculations at 3,500 kilowatts.

There was a slight difference when employing these German values. The stress level corrected came out at 6,928. While we had roughly 100 psi more when we used the measured T sub-N values.

Q Did you use the same damping for the 3200 or the 3300 kilowatt calculations that you have just testified to as you used in connection with your revised numbers yesterday for your Exhibit 2?

A Yes. The same damping values were used for all calculations and, of course, the same mass elastic system.

I also, in terms of in interest of accuracy, used the same number of sampling points for the calculations, namely 720 sampling points throughout one cycle. That would be sampling of amplitudes and stresses at 1 degree intervals.

JUDGE BRENNER: Can I interject for a moment?

When did you make these calculations that you wished you had had more time to check, Professor Sarsten?

WITNESS SARSTEN: They were made over the weekend, roughly a little over a week ago at Brookhaven Laboratories, where I was given access to a VAX computer.

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JUDGE BRENNER: Why did you wait till then to make calculations of this nature?

WITNESS SARSTEN: Because there had not been much time previously and these were made because it was found to be of interest. Also to investigate lower kilowatt values than those used in the previous reports. I previously only investigated the 3500 kilowatts where I had the T sub-N values.

JUDGE BRENNER: Mr. Ellis?

BY MR. ELLIS:

Q Professor Sarsten, yesterday I asked you some questions about your Exhibit 2. Can we turn to that now please, sir, so that we can permit you to correct it as you see fit for the new damping values?

A (Witness Sarsten) With the new damping values employed, as I stated yesterday, the stress at 428 rpm which, rounded off to whole numbers of revolutions, correspond to the minus 5 percent of rated speed value. The stresses here were 7,051 psi. At the 5 percent overspeed the stresses were 7,851 psi.

Q So that I understand it, Professor Sarsten, that means that the 7,051 would replace the approximately 9,000 figure on your Ehxibit 2?

A That is correct.

Q And the 7,851 would then replace the figure that

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is approximately 8,000 -- a little over 8,000 -- and about 480 rpm?

A That is correct.

WRBeb

Q And with those figures then, Exhibit 2 would be corrected. Is that correct?

A There is also a slight hump at around 464 rpm due to a small resonance of another order. That hump would almost disappear when larger values of damping are used.

Q I see.

Any further corrections?

A No. But I must add that the curves of course will be displaced, and the curve for Shaft Number 6 will dip slightly below the DEMA limit at roughly 440, of course, when the end is displaced down.

Apart from that there is no corrections otherwise. And of course the values at 428 rpm for all of the other shaft numbers will be displaced downward correspondingly when the damping is employed near resonance.

Q Thank you.

Professor Sarsten, on the 3300 and 3200 kw I believe you testified that the only part where your calculations show that the 13 by 12 inch crankshaft does not meet the DEMA standard as you interpret it is at the overspeed position for both 3300 and 3200. Is that correct?

A That is correct. There is a short portion of the rpm line which rises above the 7,000. It is just below the plus 5 percent speed limit, roughly around-- For 3300 kilowatts it would roughly be at 466 rpm and above.

WRBeb

Q Given the governor response times that we discussed, that I pointed out to you yesterday, does that give you a basis for concluding whether the crankshafts would be adequate for -- the 13 by 12 inch crankshafts would be adequate for use at the 33 and 32 hundred kw levels?

A No. And let me explain the answer.

We are here looking only at one thing, the torsional vibratory stresses relative to a DEMA limit of 7,000 psi. The adequacy of the crankshaft is quite another matter, and a number of different things must then be taken into consideration. The alternating torsional vibratory stresses is but one of the many factors that must be considered when evaluating the adequacy of the crankshaft.

MR. ELLIS: I need the answer read back, please, just the beginning of the answer.

(Whereupon, the Reporter read from the record as requested.)

BY MR. ELLIS:

Q Professor Sarsten, when you say we are here looking at only one thing, that is whether the crankshaft meets DEMA, is that what you were commissioned to do then? That's the sole thing you were commissioned to do by the NRC Staff?

A (Witness Sarsten) I was commissioned to review the testimony presented, which includes a number of other

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things.

Q Well, what you said is what we are here to do solely is to determine whether the 13 by 12 inch crankshafts meet DEMA. Isn't that what you testified to?

A No. Let me explain. I think you have misinterpreted.

The figures here refer solely to whether the crankshafts meet the DEMA-specified limits of 7,000 psi. I did not say that I was solely looking at the DEMA requirements--

Q Well, let me go back to my question.

A -- in my testimony.

Q All right. Let me go back to my question.

You have testified that at 33 and 32 hundred kw, the crankshaft meets the DEMA standards for all but the 5 percent overspeed situation. And given the information I directed you to concerning the governor response and features of the Shoreham engines, does that give you a basis for reaching a conclusion that the crankshafts are adequate to withstand the torsional stresses they will experience?

A No, that does not give me a basis for doing this. It gives one of the inputs that would be required in evaluating the adequacy of the crankshaft, namely, the torsional vibratory levels.

Q All right. Let me come at it a different way.

WRBeb

Professor Sarsten, is there a difference between the stresses experienced by the 13 by 11 inch crankshaft and the 13 by 11 inch crankshaft?

A Yes. Obviously as the dimensions are different there must also be some difference in the stress levels experienced by the two crankshafts when running at the same load and firing pressure.

Q Do you know what difference the increase in the diameter of the crank pin from 11 inches to 12 inches makes in the stresses experienced?

A I have not calculated the previous crankshaft.

Q Do you think that's relevant to making an assessment of the adequacy of the crankshaft to withstand torsional stresses that it will experience in operation?

A It is perhaps one of the factors that might be employed in an overall view.

Q All right.

You indicated that you had not made any calculations. Have you reviewed the strain gauge and stress data, the actual data taken with respect to the 13 by 11 inch and the 13 by 12 inch crankshafts at Shoreham?

A Yes, I have briefly read through that part of the testimony and noted the differences in the stress levels. I cannot remember the actual figures, though, now.

Q Do you remember the percentage difference?

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A No, I do not.

Q Do you remember whether it was very significant or not when you reviewed it?

A There was a significant difference. Even looking at a calculation such as expressed in our figure -- I think it was Exhibit 2 in our testimony -- the difference in the section modulus would, if I can remember correctly off the top of my head, go as the third power of the difference in the diameter which is, in itself, a substantial difference.

Q And I think-- Last night I think we indicated to your Counsel we would like you to review Chapter -- Section 3 of the Exhibit C-17, which is the crankshaft report, LILCO Exhibit C-17, which is the crankshaft report. And there-- Did you review that last night?

MR. GODDARD: I would like to state on the record at this point, before Mr. Ellis continues his question, that a phone call received by Staff Counsel after 10:00 p.m., when Exhibit C-17 was not available, was in fact here in the courtroom, is hardly a basis for proceeding with this line of questioning on the assumption that this review has been thoroughly completed by the witness.

MR. ELLIS: Judge Brenner, the telephone calls were made much earlier, but apparently because they enjoyed going out to dinner, there was nobody there to take the call and a call was left to return the call and they didn't

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return the call. So I will not accept that we waited until ten o'clock.

JUDGE BRENNER: None of that is important due to the larger matter that Exhibit C-17 is clearly an important, underlying foundation document, and we're going to evaluate witnesses' knowledge based in part on their knowledge of important underlying information, of which LILCO Exhibit C-17 is one. So that is much more to the point than any of these last-minute or non-last-minute phone calls.

So now that we are past the point of pettiness, why don't you focus in on the particular questions you want to ask instead of generally "Are you familiar with the chapter?"

MR. ELLIS: Yes, Judge Brenner.

BY MR. ELLIS:

Q Look if you would, please, Professor Sarsten, at the figures that appear on 3-9 and 3-10 for the stresses in the 13 by 11 and 13 by 12 inch crankshaft.

A (Witness Sarsten) Figures 3- --

Q No, I didn't say "Figures." I said pages 3-9 and 3-10. You will see the stress figures there.

You will also direct your attention to the strain gauge data.

Do you see those figures?

A We are having difficulty finding-- Was it page

WRBeb

3-9?

Q Yes, sir, it was. I'm sorry I didn't make that clear. I should have.

A Yes, I have that.

Q All right.

At pages 3-9 and 3-10 you will see the figures there for the stresses. 13 by 12 inch is 24.6 ksi. Do you see that, sir?

A Can you repeat the figure? We have not found it yet.

Q Yes. It is on page 3-9, 24.6 ksi.

A Yes. Now we have found it.

Q And then there is another figure on page 3-10 of 33.7 ksi.

A Yes.

Q And related to that, I call your attention to the statement right above the table that indicates that there is a stress of approximately 15 -- I think it says 15 percent nigher than nearby location.

Do you see that? It is in the statement right above the table.

A Yes, I see that.

Q All right.

Would you agree that then that 33.7 ksi figure would have to be increased by 1.15?

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A I did not read the details of the strain gauge positions accurately. I did refresh my memory this morning over breakfast. I would have to look at that specific thing, but it appears that a correction of 15 percent would have to be applied, but I'm not sure of that. I would have to look into detail.

Q Well, have you reviewed the Stone and Webster reports which are referenced there and appear on page 3-12? And I refer you specifically to the ones listed at 3-2 and 3-6 in the references on page 3-12, Versell, E. and Hall, J. R., Field Test of Emergency Diesel Generator 103, Stone and Webster Engineering Corporation, April 1984, and Versell and Hall, Field Test of Emergency Diesel Generator 101, Stone and Webster Engineering Corporation, October 1983. Have you reviewed those?

A I have not reviewed those.

Q Did you know that NRC Staff Consultant, Mr. Clyde Herrick, had observed those tests of the diesel generator 101 and 103? Were you aware of that?

A I would assume that an NRC representative would b there. I was not aware of the name of the person.

Q You don't know who Mr. Herrick is?

A No, I have never met Mr. Herrick, to the best of my knowledge.

Q Well, I think, Professor Sarsten, you did say

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earlier that you would agree that the difference in the stresses experienced between the 13 by 11 and the 13 by 12 was significant.

Is that a relevant consideration in your mind in assessing the adequacy of the 13 by 12 inch crankshaft to tolerate or withstand the torsional stresses like to be experienced?

A Yes. There would have to be a significant difference in the stress levels if the replacement crankshafts were to be deemed adequate.

Q And you agree that there is a significant difference as reflected in this data?

A There is a significant difference, but if it is sufficient to deem the replacement crankshafts as adequate, that is another matter.

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JUDGE BRENNER: Is it relevant or significant how close to the synchronous speed that critical order is, in terms of assessing the adequacy of the 13x12-inch crankshaft?

A Yes The closeness of the critical speed will, of course, be reflected in the torsional vibratory levels experienced from the reports, although I have not calculated this myself. The original 13x11 crankshaft was closer to a critical speed and, therefore, experienced higher levels of torsional vibratory stresses than the replacement crankshaft would have received.

Q Professor Sarsten, do you know which was the order that was closest to -- the critical order that was closest to the synchronous speed for the 13x11?

A Yes. I do believe it was the fourth order that was closest to the synchronous speed.

Q And do you know which is the critical order for the 13x12-inch crankshaft?

A The 13x12-inch crankshaft lies between, really -- it lies below a fourth order and is above a five and a half order. There's also a fifth order and a four and a half, but they are less significant.

Q Does the combination of the facts that the critical orders are farther away from the synchronous speed on the 13x12-inch crankshaft and the fact that the

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diameter of the pin has been increased by one inch make a substantial difference in the adequacy of the 13x12-inch crankshaft to withstand torsional stresses that it will likely experience?

A I will have to say yes and no. The position of the fourth order, critical speed, of course, lowers the vibratory stresses experienced as does the increase in diameter. Both these factors contributed, but how much they contribute and how adequate the crankshaft is, is something that has to be assessed, using other values as well.

Q You can check my mathematics on this, Professor Sarsten but I believe, based on the figure that I've shown you on pages 3-8 and 3-9, the strain gauge data shows that the original shaft had stresses that were 57 percent higher than those in the 13x12-inch crankshaft.

A Well, without going through figures I wouldn't know that. But there is a good exposition shown in the Goodman diagram on -- if I can find the page now -- in figure 3-13. There the factor of safety is given as 1.40. That's the factor of safety; I'm sorry; you were referring to the.... Excuse me.

Q Really, what I was doing to make it simple was, the figure of 24.6 ksi and then 33.7 ksi times 1.15, I had calculated that to be 57 percent difference. And I was just asking for your concurrence on that?

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A I would have to read the report more in detail and go through the mathematics myself.

When reading the report I looked at the Goodman diagram, at the factor of safety given there calculated by Failure Analysis Associates, I did not review the numbers themselves.

Q I see.

If I am correct and the numbers, in fact, come out to be 57 percent, that is the difference between the stress that's experienced by the 13x11 or the 13x12 are 57 percent, would you agree that that's a very significant factor in assessing the adequacy of the 13x12-inch crankshaft?

A Yes, it is a significant factor. But in itself, I would not say that would give me a warm feeling as to the adequacy of the crankshaft.

Q Professor Sarsten, did you have an opportunity last night to review the calculations that I called to your attention yesterday in County Exhibit 35, the ABS calculations for the 13x12-inch crankshaft?

A Yes, I reviewed these briefly last night.

Q And were you able, on the basis of that review, to confirm that ABS in interpreting its own rules chose to sum two orders?

A Actually, it was not a true summation even of two

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orders. And for that purpose, or for a true summation, a computer program would, preferably, have to be employed.

This, as far as I could see, was an approximate summation of the five and a half order and the four and a half order. By taking the square root of the sum of the squares of these two orders-- And I would not like to call this even a summation of two orders. And, again, I'm referring to the fact that only a handcheck, quickly done, was made of these two orders by this approximate method. What ABS uses in their evaluation -- complete evaluation -- I do not know. I would assume they would use some sort of a computer program, for this in the year 1984.

Q Well, you don't have any knowledge one way or the other whether this is a complete evaluation or not, do you?

A I do not. I hope it is not.

JUDGE BRENNER: Mr. Ellis, you gave the wrong exhibit, I believe, or maybe I heard you incorrectly. I thought you said County Exhibit 35?

BY MR. ELLIS: I must have. I've written down 35. What's the correct number, Judge?

JUDGE BRENNER: I don't know because I don't have an index list from the County. But 35 is the Franklin Institute Report on the cover of the Board notification.

BY MR. ELLIS: Yes, I'll find that number and correct it, if I may. I did not -- I wrote it down

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incorrectly.

JUDGE BRENNER: Okay.

BY MR. ELLIS: It's the deposition of the --

JUDGE BRENNER: I know which one you mean, but I want to make sure that he's looked at the same thing you're talking about.

BY MR. ELLIS: Yes, sir. It'll just take me a moment.

JUDGE BRENNER: Maybe you are sure he looked at it, and maybe he's sure he looked it, but I'm not sure.

MR. SCHEIDT: I think Mr. Ellis is referring to Exhibit 43, County Exhibit 43.

JUDGE BRENNER: All right. Why don't you show him a copy of what you think he reviewed so I can know and the record can know that that's what he reviewed.

(Off the record.)

BY MR. ELLIS:

Q Professor Sarsten, I'm showing you County Exhibit -- a page from County Exhibit 43. An exhibit from the deposition of the ABS personnel. Is that the exhibit that you were referring to in connection with your testimony about the number of orders ABS summed?

A (Witness Sarsten) I have before me a sheet five of something or other, which is not legible. The heading is, "Critical Speed for Five and A Half Order." That is the

WRBpp

page I was referring to. I have only actually reviewed where these two numbers came from, nothing else in this calculation.

Q But that page does reflect, does it not, that however they were summed, two orders were the only orders summed?

MR. SCHEIDT: Judge Brenner, this document speaks for itself and Professor Sarsten, can't speak for what's in the minds of the ABS. And this whole line of questioning is objectionable on that basis.

JUDGE BRENNER: No, we'll permit it so far. We have given our warning, several times now, about crediting what may be in the minds of the ABS through the mouths of witnesses here. But Mr. Ellis is entitled to explore whether or not Professor Sarsten and his expertise can understand what it is here. I began to chuckle at your objection because this page may speak for itself to you, but I don't know what I'm looking at when I read it. But we haven't forgotten the fact that this is one witness trying to tell us what the ABS has done, and we'll examine the bases for what any witness says about what conclusion that witness reaches about what somebody else has done, in this case, the ABS.

Unfortunately for Mr. Ellis, this happens to be the page that has some things obliterated on the right side.

WRBpp

And you have to look to the next sheet and then try to piece it together. And whether or not any of that is important, I don't know either.

JUDGE MORRIS: Mr. Ellis, while we have an interruption, I would like to back up a minute to something that Professor Sarsten said. I believe, Professor Sarsten, that you did not think this was really the way that ABS would do their complete analysis. And I wonder if you had looked at page 1 of this group of six pages, particularly the first line.

WITNESS SARSTEN: The first line says, "A check of torsional vibration", yes.

JUDGE MORRIS: Does that reinforce your previous statement that you suspect there was another more sophisticated analysis done?

WITNESS SARSTEN: I would assume that any classification society today would have at its disposal and, normally, employ much more sophisticated methods of calculation than this. This, to me, appears only to be a rough check of some values to see that they're in the correct ballpark.

JUDGE MORRIS: Thank you.

MR. ELLIS: Thank you, Judge Morris.

BY MR. ELLIS:

Q One follow-up question on that.

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The page that Judge Morris referred you to, Professor Sarsten, is that a computer program for a calculation of natural frequencies?

A (Witness Sarsten) No, the page that I was looking at was the head page for the hand calculations, not the simple calculation of a Holzer natural frequency method.

Q What appears at the top of the page you're looking at, please?

A The top of the page that I am looking at says, "Check of Torsional Vibration, ABS, New York, dated 12 April, 1984, sheet 1 of 6."

JUDGE BRENNER: It's handwritten, Mr. Ellis; does that help?

MR. ELLIS: Yes, that does help.

Maybe I need even more help.

BY MR. ELLIS:

Q Professor Sarsten, when you were responding to Judge Morris's questions, what page were you referring to in the exhibit?

A (Witness Sarsten) This one.

JUDGE BRENNER: This one?

(Exhibiting.)

MR. ELLIS: Yes. I want him to show me.

(Witness Sarsten exhibiting document to

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Mr. Ellis.)

JUDGE BRENNER: He said it was-- The question identified the page, Mr. Ellis, Judge Morris's question did.

This is the first of a series of sophisticated handwritten, barely legible calculations that you've been spending a lot of time with.

JUDGE MORRIS: You had previously referred to page 5 of this set. What I was referring to was page 1 of the same set, the hand-done calculations.

MR. ELLIS: I see that now. Thank you.

BY MR. ELLIS:

Q Professor Sarsten, given that I represented to you yesterday -- and I think you were here to hear Dr. Chen's testimony -- that his calculations for the 13x11 was 9,000 psi for the summation of major orders, how many hours of operation at 3500 kw would you expect that crankshaft to withstand before failing?

A (Witness Sarsten) The stresses causing failures are often a summation of bending and torsional vibratory stresses plus other things. It is really not possible on the basis of torsional vibratory stresses alone to give an opinion of this. You have to look at the crankshaft scantlings dimensions, and so on.

Q Well, have you reviewed the number of hours at 3500 kw and above that the diesel generator 102 had on it

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at the time of the failure?

A I reviewed, among other things, the Franklin report. That, I believe, only had the total number of hours. The number of hours at 3500 and above is less -- I'm not quite sure how many hours the individual crankshafts went before a failure. I think it was somewhere in the vicinity of 400 hours.

JUDGE BRENNER: Mr. Ellis, I think things are taking longer than necessary to get to the point. If you have something already in the record that gives the number of hours, just point him to it. We can all look at it together and then you can ask whatever you want to ask about it. You have this witness speculating about things that he doesn't know, and it's a waste of time.

BY MR. ELLIS:

Q The number of hours, Professor Sarsten, look on page 3-10 of C 17, which is the crankshaft, FaAA crankshaft report.

JUDGE BRENNER: Professor Sarsten, out of perhaps an unnecessary abundance of caution, is the report you're looking dated May 22, 1984? Look on the cover page.

WITNESS SARSTEN: I'm looking at a report which I have before me dated April 19, 1984.

JUDGE BRENNER: That's what I was afraid of. That's not Exhibit C 17. It was incorrectly included

WRBpp originally.

WITNESS SARSTEN: I'm sorry.

JUDGE BRENNER: It's not your fault.

BY MR. ELLIS:

Q Section 3-10 -- I'm sorry -- page 3-10.

A Yes.

Q Do you see the reference there that the shaft had experienced 273 hours at equal to or greater than 100 percent load?

A Yes, I do.

Q All right.

Given the increase in the diameter of the crankpin from 11 to 12 inches, and given the fact that you've testified that the critical is farther away from the synchronous speed on the 13x12 than the 13x11, would you expect that the 13x12-inch crankshaft would be able to operate for substantially more than 273 hours at 3500 kw,than the 273 hours that the 13x11-inch crankshaft operated?

A Yes, I would agree that it should be able to operate at a larger number of hours before failure, other things being equal. This is an adequate number of hours or if -- let me see, let me rephrase that.

This does in itself, however, not prove the adequacy of the replacement crankshaft.

WRBeb

Q Professor Sarsten, on page 16 of your testimony, at the bottom of the page you indicate that the failure of the original crankshaft gave a benchmark, and that it was a single point of reference.

What did you mean by that?

A By that I mean we had one -- or actually three, if you want to be more precise -- data point for the calculation of the factor of safety. It's a very valuable piece of information.

Q Well, tell me in what way it is valuable.

A It gives some more, perhaps very-- Let me rephrase myself.

It gives an indication of one point on the S-N curve for admittedly another type of material, but it allows some conclusions to be drawn about the strength or adequacy of the replacement crankshaft. But I contend that it is in itself not sufficient.

Q What conclusions does it permit you to draw about the adequacy of the replacement crankshaft?

A By taking the number of hours and number of cycles into consideration, and the failure, you have a basis for constructing the Goodman diagram shown on Figure 3-13 in the crankshaft report just referred to.

Q And that Goodman diagram shows the factor of safety, doesn't it?

WRBeb

A It does show a factor of safety of 1.48.

Q What does "factor of safety" then mean in this context?

A It's the fatigue factor of safety. But again, it is based on certain approximate calculations. The finite element model employed has, in the interests of computing time and calculation of input, been modeled using planes of symmetry, and the number of elements employed is lower than one would perhaps like to use.

All this must be taken into consideration when employing this Goodman diagram. The factor of safety here I would say is not proven. It is based upon certain approximate calculations, and I would not like to base a determination of the adequacy of the replacement crankshafts in the Shoreham Nuclear Power Station upon such a basis.

Q The answer you have just given, Professor Sarsten, suggests to me that you believe that this Goodman diagram is based on finite element analysis. Is that correct?

A The diagram is not based on finite element analysis. However, the finite element analysis was employed to find the most adequate placement of the strain gauges.

Q Well, do you know where the place of highest stress is in the 13 by 11 and the 13 by 12 inch crankshaft for the Shoreham engines?

WRBeb

A You just referred to that the strain gauge read was placed slightly off the position of highest stress. There are curves in the report showing the calculated values of highest stress. One would have to go through these and look at the drawing in order to find out exactly where this is on the crankshaft. I have not done that in detail.

Q You don't have any information then about where the highest stress experienced in the 13 by 12 inch crankshaft that is any different from that that is reflected in the FaAA report. Is that correct?

A That is correct. They did not go into detail here.

Q And with respect to the Goodman diagram, your testimony then is that the finite element analysis was only used in connection with the location of the strain gauges. Is that right?

A No. It also calculated the stress levels.

Q Is that for the Goodman diagram, the finite element was used to calculate the stress levels? Is that your understanding?

A No. As I remember, the finite element calculations calculated the stress levels in the crankshaft, in torsion and in bending, but this did not give the true values. In one way it only gave perhaps bound values for these stresses.

WRBeb

Q Well, maybe we are not understanding each other.

I thought that you testified that the Goodman diagram, which reflected a factor of safety of 1.48, was, in your view, done on reliance of finite element analysis. Is that right or wrong?

A Let me clarify.

The finite element analysis was used to find the most optimum position for the strain gauges, as far as I understood it.

Q And the remainder of the Goodman diagram then is based on actual data, isn't it?

A Yes, it is.

Q Well, we started this by asking you what conclusions the failure of the 13 by 11 inch crankshaft at 273 hours of operation at 3500 kw and above permitted you to reach.

Am I correct that one of the conclusions that it permits you to reach is this safety factor of 1.48?

A I would not like to accept the safety factor of 1.48 because the premises perhaps are a little uncertain.

I would prefer, as I said, to base the evaluation of the crankshaft upon the -- as I mentioned, a large amount of data represented by the appropriate classification society's rules. And I have referred this to one of the major classification societies to obtain their report on the

WRBeb

adequacy of the crankshaft and the low levels of load at which the crankshaft would be deemed adequate.

Q Which premises are you talking about that you're not sure of for the Goodman diagram that leads to the factor of safety of 1.48?

MR. ELLIS: Judge Brenner, while he is thinking about that: I apologize, but before I asked that question I intended to move to strike that portion of his answer that indicates reference to some classification societies as being unresponsive and irrelevant.

JUDGE BRENNER: I'm not going to pay any attention to it, if that will help you.

BY MR. ELLIS:

Q Go ahead, Professor Sarsten.

JUDGE BRENNER: Let me add that the Staff is but one party before us, and any party that wanted to put evidence in had the opportunity to do that, as well as to move for any need to reopen the record, in effect, or maybe not that far, but anyway, file late testimony. We have been through that in several contexts already. We certainly haven't heard anything on that order from the Staff.

Moreover, if something does not fit within an issue, the Staff, as but one party before us, has an obligation to make it known, under due process to all parties and other similar considerations, that it wishes

WRBeb

to litigate an issue that does not fit within the contentions already admitted.

That is not to say that the Staff has to raise a contention in quite the same fashion as an Intervenor but, nevertheless, some issue-identification process. And none of that has occurred. We haven't heard anything from the Staff in that regard.

Go ahead.

WITNESS SARSTEN: To answer the question, I think I would have to refer back to the notes and re-read the report.

BY MR. ELLIS:

Q Well, you would agree with me, wouldn't you, Professor Sarsten, that the Goodman diagram that has the factor of safety is based on, one, finite element analysis that locates the area of highest stress and two, the actual test data taken on the engines. Isn't that correct?

A (Witness Sarsten) That is correct.

Q All right.

Now you have already testified that you don't have any information contrary to the FaAA information on the area of highest stress.

Do you have any information contrary to the FaAA actual test data on the engines?

A Not that I can remember now. Perhaps

WRBeb

Mr. Henriksen, who was responsible more for the testing, could add to this.

A (Witness Henriksen) No, I don't have anything to add other than that it is obvious that there is not listed a factor of safety for the failed crankshaft on the same diagram.

JUDGE BRENNER: Can I have the answer read back, please?

(Whereupon, the Reporter read from the record as requested.)

JUDGE BRENNER: Mr. Henriksen, I don't understand what you're trying to say. Maybe if you change your words that will solve my problem.

WITNESS HENRIKSEN: On Figure 3-13, on the curve representing the stress endurance limit from tests on the failed crankshaft, it does not have listed a factor of safety on it as on the endurance limit for the replacement crankshaft.

I think it would be appropriate to have that on, so one could make a comparison between the failed crankshaft and the replacement shaft.

WRBwrb

BY MP ELLIS:

Q All right, Mr. Henriksen, since you think it would be a good comparison to make, isn't it fair to say that that number can be calculated by comparing the figure of 33.7 ksi on 3-10 with 32.4 ksi that appears in the paragraph following that figure?

A (Witness Henriksen) I don't think you should have to go through the whole report to find this figure.

Q Well, I'm not asking you to go through the whole report. Look at page 3-10.

Do you see page 3-10?

A Yes.

Q Are there any figures on 3-10 that would enable you, as an engineer, to calculate a factor of safety for the 13x11-inch crankshaft?

A Yes. I have not calculated it, but we can calculate it.

Q Is that the 33.7 and the 32.4?

A Yes.

Q All right.

I have a calculator in front of me, and my calculator says .96; does that look right to you?

A That would seem correct.

Q Did you say "incorrect?"

A Correct.

WRBwrb

Q Correct. Thank you.

Now, you indicated that the .96, or the figure for the 13x11-inch crankshaft should be shown as well as the 1.48 for the 13x12-inch crankshaft. That's a fairly substantial difference in the factor of safety, isn't it?

A Correct.

Q Professor Sarsten, in your testimony that started this, I had asked you which premises you were uncertain about with respect to the Goodman diagram. We have been through the two factors on which it is based, namely, the location of the highest stress and the actual test data. Is there anything else that you're uncertain about with respect to that Goodman diagram?

Let me rephrase that question, if I may.

Is there any other basis for that diagram that you have a doubt about?

A I would have to carefully again review the complete report as it pertains to this specific diagram if I were to answer quite correctly. But I cannot now remember any-- Nothing springs to mind right now: let me put it that way.

Q On page of the testimony that started this you refer to a single point of reference. Would it be more correct to say that there are three points of reference?

A As all give roughly the same value, I would

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consider this a single point of reference, but it refers to three cases, the fact that three crankshafts failed roughly around the same stress level, yes.

Q But the fact that there were three gives you added confidence of the existence of that point of reference; isn't that right?

A That gives me added confidence in the factor of safety for the crankshafts that failed -- or the stress endurance limits for the crankshafts that failed; that's correct.

Q Professor Sarsten, in your calculations, you used the Stone & Webster experimental measurements of the frontend amplitude as a benchmark for the accuracy of your torsional analysis, is that correct?

A That is correct. I tried to refer the calculated values to the measured values.

Q In doing so, then, I take it you have some confidence in the accuracy of the measured values?

A Yes, but let me explain. The measurements of frontend amplitudes are normally more accurate than telemetrically transmitted strain gauge measurements. The instrument employed is the conventional type widely recognized in industry. There is, of course, always some uncertainty associated with such measurements. But it is relatively low. There may also be some spread in the

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measurements that was referred to previously in the testimony of Chen, where he referred to the Stone & Webster report.

I have, however here, used the value of .693 degrees as given by Failure Analysis Associates in their report.

Q You also used the T-sub-n or forcing function values used by FaAA. I take it, therefore, you are satisfied with the accuracy of those T-sub-n values used by FaAA?

A No, actually I am not completely satisfied with the T-sub-n values used by Failure Analysis Associates. I would consider them a lower bound on the true values.

I will explain why.

Initially, let me say that the probably error is not very large and, therefore, I have not addressed it before. The report from Failure Analysis Associates mentions the fact that the mechanical efficiency is 100 percent according to their measurements, while it should actually be 88 percent. This, I think, was addressed in a previous testimony also.

Let me here give a slight history and explanation of what this is all about, since it reflects on accuracy of the calculations. Normally, the pressure is measured inside the cylinder by appropriate transducers, and the turning

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moment on the engine is calculated on this basis. However, the output torque of the engine will be less than that theoretically given by the gas pressures, because there are mechanical losses in the engine.

Historically, one has neglected losses between the cylinder and the output and used the indicated pressure card, that is, the pressures measured in the cylinder as the basis for calculating the exciting moments acting on the crankshaft.

In recent times, however, some people have taken into account the power loss between the cylinder and the crankshaft, because there is a substantial friction in the cylinder mainly caused by the piston rings. However, there must still be a significant amount of work lost between the exciting moment and the output shaft. This is due to the friction in the other bearings. It's due to the power required to drive the camshaft, the valves, the fuel injection pump, and the numerous pumps which are sometimes placed for pumping water, fuel, et cetera, often at the forward end of the engine.

Q Professor Sarsten, you said you were not completely satisfied with those figures. You were satisfied enough with them, however, to use them, weren't you?

A In absence of other things, I did use the figures, recognizing that they represented a lower bound.

WRBpp

And let me finish my dissertation, or explanation rather, on the mechanical losses.

Some modern calculating methods subtract the power loss in the cylinder from the loss from the power going to excite the torsional vibrations. I know of one firm which arbitrarily says half the power loss is here, and assume, if nothing else is given, that the mechanical efficiency of the four-stroke engine is 90 percent, and that the mechanical efficiency at the exciting moment is 95 percent. They subtract a 5 percent loss.

In this specific case, a more accurate --

JUDGE BRENNER: Professor Sarsten, I'm going to exercise my prerogative and interrupt you. I think you're going way beyond the question. It is indeed a dissertation, rather than an answer. I understand how, in your mind, it may be connected, just as in the mind of lawyers with ingenuity, everything is material. Nevertheless, we will leave it to your counsel to come back on redirect if you and he later deem it important.

Mr. Ellis, go ahead.

MR. ELLIS: Thank you.

BY MR. ELLIS:

Q You said that the error was not very large. Have you made any calculation of what the error would be?

A (Witness Sarsten) It is difficult to say if the

WRBpp

error comes --

Q I asked you whether you had made any calculation of what the error would be?

A No, I have not made calculations. But I would like to add --

Q Thank you.

A -- that it's impossible to calculate the error. You would have to know if it was due to the displacement of the top dead center, or due mainly to the values of the pressures recorded.

Q Did you check the T-sub-n values used by FaAA by any other method?

A I calculated from the German book, referenced earlier by Dr. Pischinger, the T-sub-n values. The values came out slightly differently. The vibratory stresses were slightly lower, as mentioned earlier, than those calculated with the Failure Analysis T-sub-n values. However, by correctly -- or by manipulations with the firing pressures, combustion pressures and so on, these figures could have been brought more into correspondence.

Q Then the checks you made then agree with Dr. Pischinger's testimony that the T-sub-n's used by FaAA are, in fact, conservative?

A No, they do not. I would say they're slightly non-conservative. I don't know how much.

WRBpp

Q But you just testified that the checks you made using the German method gave you, actually, lower values than the FaAA T-sub-n's. Therefore, the check that you made would suggest that. At least that check shows that the FaAA T-sub-n's are conservative?

A No. I do not agree to that. The result of these calculations depend upon the input values, of course. And we chose input values which gave roughly the same values of the fourth order and five and a half order excitations. The total sum, however, gave slightly lower stresses. This could have been juggled up or down by using slightly different input values for the combustion pressure, for example.

JUDGE BRENNER: Mr. Ellis, we would like to take a mid-morning break, if this is a good point to take it. We'll give you 15 or 20 minutes more if you think you'll need.

MR. ELLIS: If you can give me just two or three minutes right now, that might even shorten it afterwards.

JUDGE BRENNER: Well, we'll take a break now.

MR. ELLIS: All right, fine.

JUDGE BRENNER: I'm sorry, I wasn't clear with the object, number one, of taking a break and, number two, of giving you time because we're going to stop you after 20 minutes.

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MR. ELLIS: All right, fine.

JUDGE BRENNER: All right. We'll come back at 10:45.

(Recess.)

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JUDGE BRENNER: Let's go back on th record.

Mr. Ellis, complete by eleven o'clock. I'm serious.

MR. ELLIS: I know you are.

JUDGE BRENNER: Okay. Your chuckle seemed to doubt that.

Go ahead.

MR. ELLIS: I don't doubt your seriousness. My chuckle was....

BY MR. ELLIS:

Q Professor Sarsten, your conclusion of a front end amplitude of .69 agreed very closely, didn't it, with the Stone and Webster measured front end amplitude of .693?

A (Witness Sarsten) Yes, it did agree very closely.

Q And what, in your view, does that reflect with respect to the T-sub-n's that you used?

A That reflects, among other things, that the total impact of the T-sub-n volumes are not unacceptably far off the true values. And again, as I previously stated, the fact that it was lower -- the front end amplitude calculated was lower slightly than the front end amplitude measured indicates that the T-sub-n values may represent a lower bound.

We must again remember that there is a certain

AGBeb

slight inaccuracy in the measurements also.

Q When you say not acceptably far off, it is fair to say that that means acceptably close, doesn't it?

A Yes. Because they were acceptably close, I used them as a basis for calculation in absense of other factors.

We are often not privileged-- Even though they might be slightly off due to the error in mechanical efficiency as explained, I must also say that it is not often one has actual measured values to operate with, and the results are probably more accurate than the standard, run-of-the-mill calculations based on tabulated values or approximated values of the T-sub-n.

Q Mr. Henriksen, --

A (Witness Henriksen) Yes?

Q -- I hope you haven't been impatient.

A No.

Q Turn if you would, please, to page 17 of your direct testimony, --

A Yes.

Q -- the question and answer that summarize conclusions.

I am correct, am I not, that the reference in the first sentence there-- The first sentence is the testimony then of Professor Sarsten, not of you. Is that correct?

AGBeb

A I don't know which paragraph you're at.

Q The first paragraph of the answer to the question, "Summarize conclusions."

A Yes.

Q So your answer is Yes?

A Yes.

Q All right.

And by the same token then, the last sentence in the second paragraph on page 17 is also Professor Sarsten's opinion?

A Yes.

Q With the exception of those two sentences, namely, the first sentence of the first paragraph, and the last sentence of the second paragraph, is the remainder of the answer your joint testimony?

A Yes.

Q I assume therefore, Mr. Henriksen, that you have not done any independent DEMA or ABS torsional stress calculations for the replacement crankshaft for Shoreham.

A You are correct.

MR. ELLIS: That completes LILCO's examination of this panel.

JUDGE BRENNER: County.

MR. SCHEIDT: One second, please, your Honor.

(Pause.)

AGBeb

JUDGE BRENNER: Did you want to make your statement now, Mr. Goddard?

MR. GODDARD: Perhaps I should, Judge Brenner.

This is with regard to Mr. Ellis' motion to strike comments by Professor Sarsten's referencing evaluations done by Det Norske Veritas.

JUDGE BRENNER: He didn't get that far in the answer actually.

MR. GODDARD: My comment is aimed primarily at--

JUDGE BRENNER: I meant he didn't get as far as to identify any society, but go ahead.

MR. GODDARD: I would direct my comments to those which were made by yourself with regard to apprising the parties of available information in this proceeding.

The Staff does not at the present time have an intention to use any material furnished by Det Norske Veritas in this case. Professor Sarsten has calculated on his own the torsional vibration or T-sub-n values which he has testified to today. He has submitted those values to Det Norske Veritas and asked them to run, if you will, a check on those figures along with an evaluation--

JUDGE BRENNER: Mr. Goddard, even though there is no jury here I think you can make whatever point you want to make without giving any evidence which might otherwise be ruled out.

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MR. GODDARD: I am not going to state the conclusion.

JUDGE BRENNER: It sounded like you were getting dangerously close. So just to make it easier for me, why don't you stay away from the evidence and make your point without that.

MR. GODDARD: Evaluations have been made by the society and will be furnished to the parties as soon as they are available in final form. Staff does not have an intention at this time to introduce those into evidence. They will be made available to the parties, as were preliminary reports using a different grade of material for the 13x12 crankshaft dimensions.

JUDGE BRENNER: Not only did the Staff not include anything in evidence, and not only did the Staff not seek to raise an issue of its own in this matter, but the Staff also supported LILCO's motion to strike the reference to Det Norske Veritas in the County's testimony, specifically approximately page 109, if not precisely page 109, of the County's prefiled testimony.

I don't want to receive any information on issues in controversy that is not going to be put into evidence, I believe. I want to think about it. But you either make motions and put things in evidence or don't.

I had a similar concern with the letter to

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Mr. Denton, and I have an even stronger concern with regard to this matter because of its even greater closeness to the matters in controversy before us. I recognize it is a difficult line and I want to think about it some more because there is also the requirement to keep Boards apprised of relevant information.

But some trade-off has to be made, and if the Staff is doing something further that it believes is material and relevant, there are requirements for the Staff, just as other parties, time requirements and then other requirements in terms of the way things are introduced into proceedings on issues in controversy.

Let me think about the whole subject, and I may have some more comments later.

Don't give us anything until you hear from us again.

MR. GODDARD: The Staff will not provide anything to the Board. It does indicate that it will provide them to the parties when available in final form.

JUDGE BRENNER: That's different, and it probably should provide it to the parties.

MR. GODDARD: That was what I indicated, your Honor.

JUDGE BRENNER: All right. I want to think about the subject anyway. And I'll hear from the parties on it

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perhaps after I think about it.

You can't have it both ways. You can't say you don't want to put something in evidence and then -- and moreover support that view by supporting the motion to strike, as I indicated, and moreover by not filing your own issue or otherwise making known that you want to litigate a point, and then, through some extraprocedural means, attempt to make known something that proper me to actually introduce in litigation in the proceeding were not employed for.

I want to think about the subject some more.

MR. GODDARD: The Staff is aware of its obligations. We are not trying to bring this in through the back door.

JUDGE BRENNER: You certainly are. And you've got a witness on there, and you're his Counsel, and it was not in the normal course of responding to questions that the witness brought it up twice, in my personal opinion.

Hopefully that gave you enough time, Mr. Scheidt.

MR. SCHEIDT: Thank you, Judge Brenner.

CROSS-EXAMINATION

BY MR. SCHEIDT:

Q Professor Sarsten, your testimony states that your calculations and the figures throughout your calculations are preliminary and subject to refinements and

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checks.

Other than the change in the damping value that you have testified to already, have there been any other refinements or checks that you have made since your testimony was written?

A (Witness Sarsten) Yes.

First let me say that the damping factor was one thing that I was aware of at the start. I did not just have time to run the calculations with a more reasonable value of damping.

Secondly I would add that I have made-- Apart from this there are no refinements. I must add that.

Secondly, you question if I've made checks. Yes, I have checked my calculations by sending by Telefax the vibratory system and the exciting torques to Dr. Haffner of Kloekner-Humboldt-Deutz in Germany, who redid the calculations using his own computer and Telefaxed the results back to me.

The critical or the most critical stress is the one in Shaft 6, and there our calculations agreed within .6 of one percent.

I must, however, add that I did not remember to stipulate the high number of sampling points I used for accuracy, so I would assume that Dr. Haffner's results use a sample to get maybe each five degrees, which is more normal

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in industry and which saves computer time. This may account for some of the slight discrepancies in our results.

Thirdly, I have also submitted the torsional system to Det Norske Veritas to get from them a completely independent torsional analysis because they have a program which automatically calculates the T-sub-n values from a theoretical diagram.

MR. ELLIS: Judge Brenner, here we would interpose an objection again, both to this and to the testimony about Dr. Haffner. It's the first that I've heard about that, and we would move to strike that. We don't have any such calculations. We don't think that should be admissible. And certainly the Board has already ruled with respect to any....

JUDGE BRENNER: All right. Det Norske Veritas is expressly not one of the societies referenced in the contention. Otherwise, there's a mockery of the whole process of specifying contentions. And we have already ruled in the context of the motion to strike, and we would refer to it here.

That takes care of that, unless and until somebody seeks to remedy that through some means that they think is proper.

In terms of the rest of the answer, I'm not sure what your point is.

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MR. ELLIS: My point is that he said he sent material to Dr. Haffner who has his own computer program, and we don't have an opportunity to know anything about that.

JUDGE BRENNER: That's hearsay upon hearsay.

MR. ELLIS: Yes, sir.

JUDGE BRENNER: If tht is your objection, it's sustained.

MR. ELLIS: Yes, sir.

JUDGE BRENNER: I don't have to actually strike something; it is not going to be relied upon. We've got enough calculations and analyses and papers before us, and enough difficulty dealing with those. And if other calculations and analyses were deemed material by any other party, they should have been put in evidence on a timely basis.

All right, Mr. Scheidt.

BY MR. SCHEIDT:

Q Professor Sarsten, did any of your calculations or checks take into consideration the possibility of one cylinder misfiring?

A (Witness Sarsten) Yes. To answer your question directly, if you refer to some of these other--

WITNESS SARSTEN: Judge Brenner, I am at a loss how to answer this question, because some of the

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calculations from Det Norske Veritas did actually check this.

JUDGE BRENNER: He is talking about your calculations and analyses as presented in your testimony.

WITNESS SARSTEN: All right.

If restricted to the analyses presented in my testimony, no. I have made other calculations of the effect of misfiring an eight-cylinder engine. If I remember correctly, these have not been presented.

BY MR. SCHEIDT:

Q And those are separate from anything Det Norske Veritas may have done?

A (Witness Sarsten) Yes, but they were in a rather sketchy form. I do not know if I still have the computer printout for this and can substantiate it because I did not consider it very important for this eight cylinder engine.

Q Professor Sarsten, at pages 13 and 14 of your testimony you refer to the stress levels for single order at 95 percent of rated speed at a fifth and a half order, and you state you do not consider that important as the actual stress values so near resonance will depend upon the damping values assumed.

Can you explain in more detail that answer?

MR. ELLIS: I'm sorry, which answer are you referring to? You were paraphrasing and I was not able

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to--

MR. SCHEIDT: I was quoting, Mr. Ellis.

MR. ELLIS: Where were you quoting from?

MR. SCHEIDT: From the top of page 14 of the Staff testimony.

MR. ELLIS: Thank you.

WITNESS SARSTEN: Yes, I will be glad to explain.

As earlier mentioned, my Exhibit 2 shows stress levels based on a negligible damping which was employed for all the crankshafts in a preliminary screening to see how high the stress levels were and to prevent any computer problems if we happened to land squarely on a natural frequency.

I anticipated that the stress levels associated with resonance conditions would fall drastically when larger and more realistic values of damping were employed.

As I have already explained, this has forced the roughly 9,000 psi stress down to a figure just over 7,000 psi on Exhibit 2. This is because the five and a half orders shown to the left on Exhibit 3 have dropped substantially.

So I could a priori say that if for damping were employed here or a larger value, then these figures would fall down and they would not be significant.

That is what I was referring to.

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Q Thank you, Professor Sarsten.

On page 13 of your testimony you refer to the crankshaft analysis performed by Failure Analysis; to be precise on the bottom of page 12 and carrying over to page 13.

A Yes, I see that.

Q And my question is you have stated that FaAA concluded that the stresses meet the DEMA recommendations on the basis of their motile superposition analysis, is that correct?

A I am just referring to their results, I do not agree with them.

Q What were the results that FaAA -- what were the values that FaAA obtained using its motile superposition method?

A I do not have the exact figures available. They were slightly below 7000 psi over the complete speed range.

However, I must also add that they used a motile superposition which in theory is not applicable when damping is present, at least not unless you place very severe restrictions upon the damping. However, for practical purposes, I would still accept with slight damping that a motile superposition would be correct to use, I would not argue on that.

However, we must again realize that there are

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slight inaccuracies in the results. This may be the cause for one of the slight discrepancies between my values and those employed by Failure Analysis Associates.

Q Well I will refer you to the exhibit C-17.

A Yes, we are.

Q At Table 2.5 of that exhibit, which follows page 2-10.

A Yes, I see it.

Q Are those the values that you are referring to in your testimony when you say that FaAA concluded that the stresses met the DEMA standard practices?

A Yes, that is a part of it.

Q What are the other parts then, Professor Sarsten?

A There is, of course, the single order criterion which must be met also, which is met both in mine and Failure Analysis Associates' calculations.

Q Is the calculation of nominal sheer stresses usin_ the Stone and Webster measure free end amplitude a motile superposition method of summation?

A May I ask you to refer to -- which calculation are you referring to now?

Q The one that is represented in Table 2.5 which I just referred you to.

A The nominal sheer stresses in Table 2.5 are based upon, first, the half-peak to peak amplitude and, secondly,

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a, shall we call it, filtering or factoring out of the amplitudes of the individual orders from the front end measured curve.

Q Is that a motile superposition summation?

A The figures -- I would have to refer to... The figures to the right here from -- Let me get this straight now what this refers to.

JUDGE BRENNER: You had better ask him a foundation question as to what he knows about this table, Mr. Scheidt, because you're off asking him questions on the assumption that he's familiar with what it represents.

WITNESS SARSTON: There are very many tables. I would have to look back and see what they come from to really answer directly, that's my problem.

Could you refresh my memory as to what the figures --

JUDGE BRENNER: He's going to decide what he wants to ask you next.

(Counsel conferring.)

BY MR. SCHEIDT:

Q Professor Sarston, do you know whether the values that appear on the right-hand side of Table 2.5 in Exhibit C-17 are derived from FaAA's motile superposition analysis?

A (Witness Sarston) From what I remember, these are calculated by Failure Analysis Associates based on the

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front -- measured front end amplitude and are calculated by the motile superposition method.

Q Thank you.

Can you explain why, if you used the same T-n values that FaAA used, you obtained a calculated free end amplitude value of .69 rather than what FaAA obtained, which was .662?

A Not having gone in detail through the code, I can only make some assumptions as to where part of the discrepancy may lie.

One, it could be --

MR. ELLIS: Judge Brenner, I would object if he is going to speculate.

JUDGE BRENNER: I'm going to sustain that given his lead in. Of course I'm not sure fully of the witness' use of the word -- he didn't say "speculate," but he used a synonym which I forget, "assume."

I want to know whether he knows or not. I don't want speculation on the record either.

MR. SCHEIDT: That's my purpose, too, Judge Brenner.

JUDGE BRENNER: I'm not criticizing the question; in fact, we were going to ask it if you didn't. But given the lead in to his answer, I don't think it's going to be useful.

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WITNESS SARSTON: May I proceed?

JUDGE BRENNER: No.

MR. SCHEIDT: Judge Brenner, may I ask him if he does know?

JUDGE BRENNER: Surely. I didn't mean to cut off the line of inquiry.

BY MR. SCHEIDT:

Q Professor Sarsten, do you know why the values differ?

A (Witness Sarsten) I must state this: there could, of course, be some errors in the program itself. I cannot say that without going through the program.

But based on the assumption that there are no errors in the program, then the differences can be in part attributed to two things: one is the value of damping employed, which is I believe a relative damping of 2.5 percent which is rather large, it gives -- not exactly, but roughly a dynamic magnifier of 2 or lower; and, secondly, it's the use of the motile superposition method and distributed damping which is slightly inaccurate but I would say nevertheless acceptable for these calculations if you do not want very, very extreme accuracy.

JUDGE BRENNER: Professor Sarsten, speaking for myself, it doesn't help me unless you tell me specifically what FaAA did that you didn't do or what FaAA did different

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than what you did or what you did and what FaAA didn't do in very specific terms.

WITNESS SARSTON: We may end up in a treatise again, Judge Brenner, but I'll try to do my best.

The method used by Failure Analysis Associates employs a so-called motile superposition where the node shape or vibratory shape at each natural frequency is calculated, the excitation of that specific frequency is calculated and the effect of these nodes are then summed to give the answer.

However, if there is damping present to a significant degree or damping is not distributed rather evenly through the system, there will be changes in amplitudes between the masses, a slight twist in the vibratory shape which accounts for a slight inaccuracy.

My method and the method also used by Dr. Chen, I believe -- even though it is referred to as a motile superposition -- takes and calculates the true vibrations of the system, taking the damping into account -- the damping may be arbitrary, it does not affect the validity of the calculations; however the computational effort required to do this may be somewhat larger than when a motile superposition is assumed.

I must also add that I believe from the testimony that Failure Analysis Associates has used the one node

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vibratory form as a basis for calculating their stresses. This is a very good near approximation but not quite exact.

JUDGE BRENNER: Well for example on that last point what specifically did you do that I should contrast with what FaAA did and which one is more accurate in your view and why?

WITNESS SARSTON: Definitely if damping is present the method that I employed is -- and others -- is more accurate than motile superposition. If no damping is present the result should be exactly the same, provided that the true vibratory form is employed and not a one-node approximation.

JUDGE BRENNER: A few times in your immediate answer and the previous answer, when talking about damping in connection with what FaAA did, you used words like "if" damping is present and something "may" be this or "may" be that. Tell me what you know about the presence of damping in the real world case and how that is reflected or not reflected in FaAA's analysis and in your analysis.

WITNESS SARSTON: There is damping present. I have been inaccurate -- English is not my native language -- I should say "when" damping is present. There is always damping present. And it is often reflected by the term "dynamic magnifier."

There I have used values of 40 and related them

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to the predominant order.

I may add that other people use different, often slightly higher values and I know of one engine firm which deals almost exclusively with generators that uses values as high as 90 in order to get a good correspondence between measured values and calculated values.

JUDGE BRENNER: I'm sorry and I'm sure it's my fault, not your language fault. You used 40, I know that, I guess I knew that before.

What did FaAA use or not use and how do I know which is more accurate to represent the real world condition of these engines and why?

WITNESS SARSTON: The value of damping I used was slightly on the high side in order to get a lower bound for the stresses. I know that -- I'm sorry, again I have to refer to a classification society for their calculations -- uses 45 as an average value for the dynamic magnifier.

The value used by Failure Analysis Associates was much lower than my value.

MR. ELLIS: Judge Brenner, I hope we're not getting in the back door again when we're talking about --

JUDGE BRENNER: Don't worry about it.

You're not answering my question precisely:

Which use of damping value more accurately represents the real world condition of these engines and

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why?

WITNESS SARSTON: I can only answer what is the normally-accepted value of damping for generator engines and I can say a value of 40 to 45 is standard practice.

JUDGE BRENNER: Tell me again how you selected 40?

WITNESS SARSTON: I selected 40 to be on the favorable side. I knew that the T-sub-n values also were slightly lower than what they should be, so I wished to have something which reflected a safe lower bound on the stresses and to be fair as best as I could.

JUDGE BRENNER: What do you mean "on the favorable side?" You mean to end up with -- Well you tell me.

WITNESS SARSTON: To lower the stress. To not have a value which perhaps would be open to discussion. I don't think a value of 40 is considered to be a low value of damping today.

JUDGE BRENNER: So you're saying --

WITNESS SARSTON: I'm sorry, give a low value of damping to be a high value of dynamic magnifier, to be more precise.

JUDGE BRENNER: Say that again, please?

WITNESS SARSTON: I say that a low value of the dynamic magnifier corresponds to a higher value of damping.

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I am deliberately using a value which I know is slightly higher than I would otherwise have used in a similar situation.

JUDGE BRENNER: 40 is the damping value?

WITNESS SARSTON: 40 is the dynamic magnifier. You can refer that to a specific order of excitation and that will give you a value in torque per unit velocity, for example, which is used -- employed by the calculation.

JUDGE BRENNER: And you're saying in your view FaAA used a dynamic magnifier of about 20, is that what you said?

WITNESS SARSTON: I said they have referenced damping in another matter, they have referenced it as the 2.5 percent of critical damping. If we convert this to dynamic magnifier -- there are formulas for this, but -- I can calculate the exact value given time, but I think it's roughly around 20.

JUDGE BRENNER: So they used a lower dynamic magnifier which would be --

WITNESS SARSTON: -- a higher one.

JUDGE BRENNER: -- less favorable, that is, it would show higher stresses.

WITNESS SARSTON: It would show lower stresses.

JUDGE BRENNER: I guess I got confused by your use of the term "more favorable" before. You told me by

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"more favorable" you meant it would show lower stresses.

WITNESS SARSTON: Maybe I have been explaining myself incorrectly. It's more favorable to Failure Analysis, it would show lower stresses, yes.

JUDGE BRENNER: Which would show lower stresses?

WITNESS SARSTON: A higher value of damping or a lower value of the dynamic magnifier shows lower stresses in general.

However I must add that at the speed we are here speaking of, the stresses are not very much influenced by the damping employed, because resident conditions are quite a ways to each side.

JUDGE BRENNER: Professor Sarsten, as interesting as damping values might be to be in another context, the reason I got onto damping value was not for its interest but because you, in answer to previous questions, identified that as one of the significant factors in explaining the difference between your result and FaAA's result. That's what I'm interesting in learning.

WITNESS SARSTON: All right.

JUDGE BRENNER: So now you're telling me, a, it's not a significant factor at these speeds, b -- moreover FaAA's approach would end up with lower stresses rather than higher stresses just looking at that one factor, am I right so far?

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WITNESS SARSTON: You're right so far.

JUDGE BRENNER: So clearly this isn't one of the things you should have included in your answer to explain why it is that FaAA and your result differ, is it?

WITNESS SARSTON: There is a slight inaccuracy, here, yes, perhaps --

JUDGE BRENNER: Tell me the important things about what I should look at in trying to compare your analyses and result with FaAA's result so that I can figure out who's right and what the benchmark is in part which would better represent the real world experience of these engines?

WITNESS SARSTON: The real world experience of the engines is best reflected by a method of calculation where damping is present and where the damping can be arbitrarily distributed throughout the system, not a motile superposition.

But I also said that the errors are not great. The difference between our calculations -- results are less than 5 percent, 4.5 percent as I recall. But I would regard my figures as being the more accurate ones.

JUDGE BRENNER: And what's your basis for your last statement?

WITNESS SARSTON: Because the method employed is, in theory at least, more accurate.

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JUDGE BRENNER: What else, other than damping values, should I look to in evaluating the basis for your statement that your method is more accurate?

WITNESS SARSTON: Also the method of finding the stress values inside the system. The report, and also testimony previously, has indicated that a one-node vibratory shape was assumed when obtaining the torsional stresses in Shaft 6 from the results. If this was done in every case, then I would say that this is a near approximation but not as accurate as the true calculated values using all the different modes of vibration as is done in my program.

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JUDGE BRENNER: I think I have other questions but I'm also beginning to tread more than I intended to on Mr. Scheidt's cross plan. Let me turn it back to you, Mr. Scheidt, and maybe the Board will come back at it again, depending on what you get in answer. It's not clear in my mind yet, if that's any hint to you, as to the point that you've been pursuing, and that is precisely and specifically the differences between Professor Sarsten's approach and result and FaAA's approach and result. And, of course, later we'll add the County's witnesses views to this, to the extent they're able to give views, and try to relate all this to what we would expect in a real world operation of these engines.

BY MR. SCHEIDT:

Q Professor Sarsten isn't one indicator that your method is the more accurate method, the fact that your calculated value of free end amplitude is in much closer agreement with the measured free end amplitude by Stone & Webster?

A (Witness Sarsten) I would answer yes to that question.

Q Can you explain why you believe that that is an indicator of greater accuracy?

A Because the stress levels throughout the system will be roughly proportional to the frontend amplitude. The

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higher the front -- or the more closely the frontend amplitude coincides with the measured values, the more accurate the results throughout the system should be.

I would also add that it is often customary to scale up or scale down the calculated values in accordance with the difference between calculated and measured frontend amplitudes.

This gives, again, more accurate stresses throughout the system.

Q And is one reason why you believe that your dynamic magnifier value is more appropriate because the Tn values are, in your view, slightly too low?

A The Tn values are slightly too low but, again, we have -- I would say in all fairness -- better Tn values than one often has when one has to revert to a set of published Tn values.

Q So the Tn values that were used by FaAA, although not completely accurate in your view, are more accurate than those used by TDI and Dr. Chen, isn't that true?

A That is true.

Q And the values, the Tn values that were used by FaAA and yourself in your program, will more closely approximate the actual stresses in the shafts, isn't that true?

A That is true.

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Q Does your calculated value of free end amplitude suggest that your calculations are more consistent with the real world than FaAA's?

MR. ELLIS: May I have that question read back please?

MR. SCHEIDT: I, perhaps, can rephrase the question and make it more complete.

JUDGE BRENNER: All right.

BY MR. SCHEIDT:

Q Does the fact, Professor Sarsten, that your free end amplitude calculated value corresponds more closely with the measured value? Does that fact suggest that your calculations are more consistent with real life stresses on the shaft than FaAA's?

MR. ELLIS: I object. I think that was asked and answered. I may be wrong, but I think it was.

JUDGE BRENNER: I thought it was also, although, in the context of the Tn values and the input to get those results. But, I will allow it again just to air in that direction, since the terms were changed slightly.

WITNESS SARSTEN: Yes, I would say so. But I must also add that the discrepancy or difference between our results is not very large, in all fairness. But again, we are here discussing compliance with 7,000 psi and the calculated results are very close. Some small differences

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really here, are very important for the end result.

JUDGE BRENNER: What end result, Professor Sarsten?

WITNESS SARSTEN: If the crankshaft complies with DEMA or not.

JUDGE BRENNER: Are they important for the end result of determining whether the crankshafts will fail, or not, the differences between your result and FaAA's result?

WITNESS SARSTEN: That requires a large number of other deliberations and, in the overall picture, it will affect the factor of safety slightly, but not as much of a percentual difference in our two figures.

JUDGE BRENNER: For your information, and then I'll ask the question again -- the way I view it as one judge -- we have to decide whether a crankshaft will fail or not fail or, more precisely, whether LILCO has provided reasonable assurance, as the party with the burden of proof, that it will not fail. And we don't have to decide whether it meets DEMA or not, as an end result. That may be part of the means to get to our result and it may not be, as we put the evidence together.

So am I correct that your testimony does not present a view on whether you believe these crankshafts will fail or not for the intended service?

WITNESS SARSTEN: That is correct. That is a

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completely different calculation.

JUDGE BRENNER: Do you have a view on that question?

WITNESS SARSTEN: My view is we do not know. We've stated that the evidence, in our view, is inconclusive at the load of 3,500 kilowatts.

BY MR. SCHEIDT:

Q Did you attempt, in any way, to verify the accuracy of the Tn values used by FaAA -- I should say the gas pressure measurements obtained by FaAA and put into the Tn values?

A (Witness Sarsten) I have separately, in another context, calculated the gas pressure values for this engine, assuming certain facts about the nossle holes and other things. But I did not compare the measured values with these calculated values of the gas pressure diagram obtained by a computer program. So the answer must be, no, I have not. But I have previously today, referred to approximate calculations done in another context using the MAASS formula.

Q Those are the German Tn values referred to?

A You can refer to them as the German Tn values. But again, these values will vary slightly with the input used in the program. And I could not verify exactly the T-sub-n values employed by Failure Analysis Associates.

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But again, pointing to the close coincidence between the measured and calculated frontend amplitudes, I do not conclude that the error, if present, is substantial.

Q Yesterday, Mr. Henriksen, you testified that you had contacted certain members of DEMA to ascertain, I believe, their practices with respect to summation of the orders. Is that true, Mr. Henriksen?

A (Witness Henriksen) That was not the main reason I called them, but I did.

Q And what was the main reason why you called them.

A To get their interpretation of DEMA with regards to load versus torsional levels.

Q And what did they tell you --

MR. ELLIS: Judge Brenner, I object unless we know precisely. The question that I asked was whether they had inquired with respect to a number of orders summed for purposes of DEMA, not for any other purposes, and we're getting to much more now.

JUDGE BRENNER: Yes, this is getting into the area of unreliable hearsay. Even too unreliable for loose administrative proceedings, if I have to worry about what somebody said in a phone call to somebody else, and then try to figure out what was meant by it in the full context and so on -- especially when the question asked is as broad as you asked it. So we're going to sustain the objection to

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the question. If you want to ask him whether he specifically knows what DEMA requires on a certain specific thing, you can ask him and then we'll probably find out why he thinks he knows and evaluate it in that light. But I don't want to sit here and hear a rendition of what he heard in a phone call.

MR. SCHEIDT: Judge Brenner, I'd just like to note that I believe Dr. Chen testified to telephone conversations that he had with a number of members of DEMA.

JUDGE BRENNER: We'll evaluate it in that light. I didn't hear objections at that time -- although sometimes I jump in on my own, I don't always. And we'll also evaluate it as to how specific the material is he related and whether it is supported or not supported by other material in evidence.

The bottom line in this testimony was, he couldn't get very straight answers from DEMA on a lot of these subjects. But if there's something in particular that varies from that, I'll look at when I look at the transcript.

MR. SCHEIDT: Judge Brenner, does your ruling prohibit me from questioning Mr. Henriksen on what the practice of those DEMA members is as to summation of the orders?

JUDGE BRENNER: No, but either get a foundation

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in or ask some specific questions. What you ask him, as I recall -- and it's been a few minutes now -- was tell us what they told you when they were chatting with them on the phone.

MR. SCHEIDT: I will, Judge Brenner.

BY MR. SCHEIDT:

Q Do you know, Mr. Henriksen, what the DEMA interpretation is regarding summation of the orders if, in fact, there is an interpretation?

A (Witness Henriksen) I do not believe there is a firm interpretation. I think if you question several members, you will get different answers.

Q Did you do that, Mr. Henriksen?

A No, the ones I question all used 24 at the time, at this present time.

MR. ELLIS: I object, Judge. That's coming in again by the back door. I move to strike it. I think the question was, did he know. He doesn't know whether there's a practice. Not having laid a foundation, that should be the end of it.

MR. GODDARD: If the Staff may be heard, Judge Brenner. Yesterday, there was a very lengthy attempt by Mr. Ellis to discredit Professor Sarsten on his knowledge of the summation of orders by major diesel engine manufacturers who are members of DEMA, inasmuch as Dr. Sarsten was

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familiar with the European community. Now, Mr. Henriksen is a former employee for a very long time with a member of DEMA and, in fact, has made contact with individuals who he knows to be high in the management of other DEMA manufacturers, those who are personally known to him.

JUDGE BRENNER: You're going a lot further than that question and answer went, I can tell you that.

MR. GODDARD: I think he can provide the answer to that. And this is material which he, as a professional engineer, could rely upon in determining how to interpret the DEMA rules himself.

JUDGE BRENNER: Mr. Goddard, do you see any distinction between an expert knowing what the practice is by other experts in the area, as opposed to having to call somebody up and saying tell me what you do, and then coming here and telling us what that out-of-court declarant, in a phone call no less, told the witness and then relating it to us?

MR. GODDARD: Judge Brenner, the Staff would concede it is clearly hearsay. But it submits it's the kind of hearsay on which an engineer would rely in the evaluation of the DEMA rules?

JUDGE BRENNER: Your buildup in your comment was that here's somebody who knows what the practice is, and Mr. Ellis was questioning about the practice. And I'm

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asking you isn't the knowledge of the practice different than what I could do.

I could call somebody up and say, tell me what you did. And then I can come back before you and say, gee, this is what Joe said he did. And it's a phone call. So the first time you ask me about, well, did Joe mean he did it for this or just for that or for all the things, I'll have to say, gee, I didn't ask Joe that. Or I don't know.

And being a -- it's rank hearsay, it's not just hearsay.

Give me a moment.

(Brief recess.)

MR. GODDARD: Hearsay is hearsay, in the opinion of the Staff.

JUDGE BRENNER: Well, you're wrong. Because when it gets far removed I get concerned, anyway, I don't know if you do. When it's based on a written document, sometimes there are even problems there. When I can see there are problems of context and interpretation. And now you're basing it on a phone call.

I don't even know if he heard he speaker correctly, although, that's a somewhat different point.

MR. SCHEIDT: Judge Brenner?

JUDGE BRENNER: Give me a moment.

(Board conferring.)

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JUDGE BRENNER: We're going to grant the motion to strike the answer of Mr. Henriksen relating what he learned in a phone call.

And we don't have to physically strike it but by that ruling you know that we're not going to rely on it at all, as I said it is just hearsay which is not worthy of credit because it deprives the parties of examining into it and we have no basis ourselves upon which to credit it. That is far different than an expert witness being able to talk about what he knows either by direct observation or experience from working in a field as to what a practice is or what else is done. And if it was important to a party to find out what other people in the field are doing -- whereas the witnesses present can only say what those other people told them -- then those other people should have been brought in by whatever party thought that was important.

BY MR. SCHEIDT:

Q Mr. Henriksen, in your professional experience do you know the number of orders that are summed by DEMA members?

MR. ELLIS: He doesn't say for what purpose and I think that would be an important point --

JUDGE BRENNER: Mr. Scheidt, given the ruling and the ten minutes we've just spent on this, you're going to need a foundation before you can lead into that. Now

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sometimes we can get it after the question and answer but given what we just went through it behooves you to get it before or else the witness isn't going to understand everything we just went through -- that's to his credit perhaps -- and he's not going to be able to distinguish what he heard on a phone call or the kind of information that we would be willing to credit. So in order for it to help your case on behalf of the County, you're going to have to get the foundation so I can then make that distinction when we hear the answer.

MR. SCHEIDT: Okay.

BY MR. SCHEIDT:

Q Mr. Henriksen, you work for Norberg, isn't that true?

A (Witness Henriksen) Correct.

Q And Norbert is a DEMA member?

A It was. Norberg no longer manufactures engines.

Q It was a DEMA member at the time of -- in 1972?

A Yes.

Q Do you know what Norberg's practice was with respect to summation of the orders for purposes of complying or not with the DEMA limits on torsional vibratory stresses?

A I cannot recollect exactly what that was at that time.

Q Do either of you have an opinion as to whether

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the DEMA recommendations require the summation of major orders of torsional stresses at overload?

A Norberg's representation was that it included overload.

MR. ELLIS: I object. I don't think that -- I move to strike. I don't think that was responsive. He asked if he had a professional opinion.

JUDGE BRENNER: I thought it was responsive. I'm afraid about the ambiguity of the use of the term "overload," but I wouldn't have interrupted on my own for that.

But as long as there was an interruption I will put that comment in the record in case Mr. Scheidt wants to do something with that now. But you don't have to.

The objection is overruled, Mr. Ellis.

MR. ELLIS: Yes, sir, I thought he was referring to a phone call. I may be wrong.

JUDGE BRENNER: You can tell the Appeal Board that I was wrong.

BY MR. SCHEIDT:

Q And when I mentioned "overload," did you understand me to mean 110 percent of the rated load, Mr. Henriksen?

A (Witness Henriksen) I understood it to mean 10 percent overload as specified in DEMA.

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Q Have either of you done any calculations concerning the levels of vibratory stresses in this overload condition?

A (Witness Sarsten) I, myself, have not made any calculations at the overload conditions because mainly we did not have -- or at least I did not have adequate T-sub-n values at the time.

Q Do you have adequate T-sub-n values now to make that calculation?

A I now have a program which will calculate the approximate T-sub-n values for such a calculation if necessary, yes.

Q Yesterday, Professor Sarsten, you mentioned that in your opinion the DEMA limits were high, especially compared with Lloyd's, isn't that true?

A Yes, that is true.

Q Do you know whether the replacement crankshafts would meet the requirements of Lloyd's Register?

MR. ELLIS: Object. The question is irrelevant. Lloyd's is irrelevant to this proceeding.

MR. SCHEIDT: It's clearly a part of the County's contention, Judge Brenner, and I think it's clearly relevant to the proceedings.

JUDGE BRENNER: I don't want to trust my memory so give me a moment to pull out the contention but it

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certainly sounds familiar to me.

MR. ELLIS: I think it is in the contention, Judge Brenner, but there is no direct testimony about it at all.

JUDGE BRENNER: Could you tell me again what question you asked, Mr. Scheidt? If not, I'll have it read back if you prefer.

MR. SCHEIDT: I asked Professor Sarsten whether he knew whether the replacement crankshafts would meet the requirements of Lloyd's Register.

JUDGE BRENNER: He doesn't have any testimony on it, Mr. Scheidt, and I'm concerned -- I'm putting this out for you to respond to -- I'm concerned about getting into an area that is not in his testimony at all and thereby end up in a violation of the requirement to have prefiled written direct testimony. It's a matter of degree, and certainly there are many things asked about that are not precisely in the direct testimony; that's the purpose of further examination, whether it be cross-examination or examination by a not-so-unfriendly party or redirect examination.

But here we have one of the express subparts of the contention which would be a severable area and yet there's no testimony by the Staff witnesses on that subject whatsoever and you're going to ask him a conclusory question, which you did, and we have no information as to

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how he arrived at his conclusion and so on and in order to get that we'd have to sit here and in effect get the testimony orally that should have been in the written direct.

MR. SCHEIDT: Judge Brenner --

JUDGE BRENNER: So you can tell me why I shouldn't worry about that.

MR. SCHEIDT: I have no control what went into the written direct testimony, as you know.

JUDGE BRENNER: That's right.

MR. SCHEIDT: This witness has also testified that he is most comfortable with the Lloyd's rules and the classification society rules.

JUDGE BRENNER: Well he should have talked about that in his testimony then, right?

MR. SCHEIDT: Well --

JUDGE BRENNER: I'm not ruling now, I want to hear from you.

MR. SCHEIDT: On pages 16 and 17 of his testimony he refers to the classification societies and states that he would prefer to assess the adequacy of the crankshaft based upon the data represented by those rules and their experience in interpreting those rules and I suspect that because he is most familiar with Lloyd's that he may be referring to them.

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JUDGE BRENNER: No, he was asked about what he meant there. Nice try, but you can't use that sentence as an entre into a whole new area.

I thought maybe you were going to tell me that other witnesses for other parties testify on Lloyd's and we should take advantage of the presence of other experts in the area to get their views, even though it's not in their direct testimony. At least I, myself, raised that possibility as a reason.

Dr. Chen, didn't the LILCO witnesses talk about Lloyd's in responding to the contention?

Can you help me, Mr. Ellis?

MR. ELLIS: Judge Brenner, give me a moment. I was not present during that --

JUDGE BRENNER: How about even just in the direct testimony?

MR. SCHEIDT: I can respond to that. I believe Judge Morris asked a question of Dr. Chen and Dr. Pischinger concerning the Lloyd's calculations that were performed by Professor Christensen, for one area of inquiry.

JUDGE BRENNER: I asked particularly -- we are interested, as other parties are, in the accuracy of the T-sub-n values and Judge Morris, as I recall, asked about the basis for the different T-sub-n values and some of them were Lloyd's values and we got some answers as to where

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Lloyd's got those values.

MR. SCHEIDT: I don't disagree with that.

JUDGE BRENNER: That's a little different than what you're asking.

MR. SCHEIDT: I also believe that another question was asked in that area concerning Professor Christensen's calculations under Lloyd's rules.

JUDGE BRENNER: How much do you want to ask about this?

MR. SCHEIDT: Judge Brenner, I don't even know if he's done any calculations under Lloyd's. I would ask him --

JUDGE BRENNER: I don't either.

MR. ELLIS: We have never been furnished with any and don't know of any. And it would be unfair, I think, for us to have to deal with calculations that we don't know about.

JUDGE BRENNER: Mr. Goddard, he's your witness, what say you to all this?

MR. GODDARD: The Staff will concede that it was not addressed in the direct testimony of Professor Sarsten, I think perhaps most appropriately because he stated in page 10 of that testimony these rules were devised primarily to deal with the rating of marine diesels.

I do believe --

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JUDGE BRENNER: That much even I know. But tell me about whether we should allow the question and why or why not.

MR. GODDARD: Well the contention, of course, stated that the crankshaft should comply with them. The position of Staff was it was not necessary to comply and we did not address it in the direct testimony. However it is my belief that Dr. Sarsten has in fact --

JUDGE BRENNER: Wait, Mr. Goddard, you keep making that mistake. I tell you if there was a jury here you would have mistrial after mistrial.

MR. GODDARD: I was going to say no calculations. I think the answer to the question would be no and we can proceed elsewhere.

JUDGE BRENNER: I guess I'm too subtle. I'm rarely accused of being too subtle.

(Laughter.)

JUDGE BRENNER: Do you understand what I'm saying, when we're arguing a point of evidence it isn't necessary and in fact is usually to be avoided to get to what the witness' answer would be when the thing I'm trying to decide is to let him answer and I'm trying to decide on a point of law and not on the basis of what his answer would be?

Now there are exceptions to every rule, but I

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don't see it as an exception here. And there are offers of proof later and so on.

I don't want to overemphasize it, I'm not as worried about it as I would be if there were a jury here, but I wanted you to stop doing it because it makes it easier for me when you don't do it. And I like to make life easier for me.

MR. GODDARD: Acknowledged.

JUDGE BRENNER: Give us a moment now. I know it's time for us to break for lunch but if we can give you a ruling now that might help you. If we can't, we'll break.

(The Board conferring.)

JUDGE BRENNER: We're going to sustain the objection in this instance. I want to emphasize that, as I mentioned in passing in my previous comments, that it is a matter of degree. We are not going to strictly limit cross-examination or examination by a not-so-unfriendly party but other than a sponsoring party to the direct testimony. So I don't want to encourage objections that every time a question is asked and it is not precisely in the direct testimony that it is objectionable, that's not the case. And parties are entitled to try to make their case by cross-examination under several Appeal Board decisions.

However when you get into a whole new area that

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is not covered at all in the witness' testimony when that witness had plenty of notice and opportunity that that was certainly fair game to be addressed in the testimony, the matter goes too far and it would deprive the Board and other parties of the opportunity to have direct testimony on the subject as a basis so that evaluation could have been made and preparation could have been made. And we're sustaining it for that reason.

Let me also emphasize another kind of question that we would not find objectionable -- in fact, it's the kind of question that the Board likes to ask as parties may have noticed:

If there are particular statements and analyses in testimony of other witnesses, we certainly permit questions of the witnesses on the stand as to how they can explain their disagreement, if there is one, between the testimony of the other witnesses and their own testimony. But here you've got an area where there is no testimony by this witness to compare on that particular subject. So as to that particular question, the objection is sustained.

I think we are at the point of breaking for lunch.

Could you give me an estimate of how much more you'll have, Mr. Scheidt, and then tell me how good your estimate is?

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MR. SCHEIDT: I didn't catch the last part.

JUDGE BRENNER: Give me the estimate and also how good you think the estimate is.

MR. SCHEIDT: I think a real good estimate, Judge Brenner, is between 15 and 30 minutes.

JUDGE BRENNER: Okay.

Staff, can you estimate your redirect?

MR. GODDARD: Minimal.

JUDGE BRENNER: Really? Okay.

The Board may have a fair amount of questions. I'm going to exercise our prerogative and not put an estimate on it.

(Laughter.)

JUDGE BRENNER: But I wanted the parties to know that in terms of time frame estimates that I expect our questions will be certainly greater than minimal.

Yes.

MR. DYNNER: Judge Brenner, an unrelated matter which I just want to bring to the Board's attention. You did ask us to do some work on the transcript for Thursday and I am informed that we have not yet received the Thursday transcript although we have requested it several times so we will follow up on that. But we don't have it yet and that's why we were sort of at a loss of what you were saying. We have been pursuing it.

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JUDGE BRENNER: Let's go off the record.

(Discussion off the record.)

JUDGE BRENNER: Back on the record.

Let's break until 1:40.

(Whereupon, at 12:08 p.m., the hearing in the above-entitled matter was recessed, to reconvene at 1:40 p.m., this same day.)

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AFTERNOON SESSION

(1:45 p.m.)

JUDGE BRENNER: Good afternoon. We are back on the record.

Whereupon,

ARTHUR SARSTEN

and

ADAM HENRIKSEN

resumed the stand and, having been previously duly sworn, were examined and testified further as follows:

JUDGE BRENNER: We will have the County continue with its cross-examination of this panel.

CROSS-EXAMINATION (Continued)

BY MR. SCHEIDT:

Q Professor Sarsten, I will refer you to pages 16 and 17 of your testimony, the bottom of page 16 and carried over to page 17.

A (Witness Sarsten) Yes.

Q Do you believe that there are any limitations in using the failure of the original crankshafts as a benchmark for determining the adequacy of the replacement crankshafts?

A Well, this is perhaps more a metallurgical question that should be addressed by a man with a metallurgical background.

Q Why is that?

WRBeb

A Because the factor of safety in the Goodman diagram is based very much upon strengths, tensile strengths, methods of determining these, and so forth. I would perhaps not be the correct person to express an opinion on that.

Q Well, why would you prefer to assess the adequacy of the crankshaft on the large amount of data represented by the classification society rules and your experience in interpreting those rules?

A This is based on a very large amount of data. I might, for example, mention that the proposed CIMAC rules are based, at least in 1979 when I read a review of this, on a serious study of 100 failed crankshafts, the stress levels and conditions of failure, et cetera.

They have access to a large number of such failed cases, and I would have much more confidence in a calculation based upon this extensive material.

Q Have you performed any calculations under the CIMAC draft rules?

MR. ELLIS: I object to the question on the same basis that we objected to the others.

JUDGE BRENNER: Fill in for my own mind, since it operates a little slower, the "others." You mean his direct testimony does not contain anything on that subject? Is tht right?

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MR. ELLIS: Yes, sir, that's correct, nor have we been furnished with any calculations or have knowledge of any calculations relating to CIMAC.

JUDGE BRENNER: I'm inclined to sustain the objection on the same basis as the earlier one unless you can distinguish it from the earlier ruling, Mr. Scheidt.

I understand he is not your witness, and I am certainly not blaming you as to why certain things within the scope of the contention were not covered in the direct testimony. However, you had your own witnesses through which you could have covered such things and presumably did cover those things you wanted to cover. So that is where we're at.

MR. SCHEIDT: Judge Brenner, I believe we are entitled to delve into the bases for his opinion in this particular question that I referenced. And this situation is different from the prior situation. I referred to this section as an instance where he referred to classification societies in the context of a prior discussion concerning Lloyd's.

Now he has directly testified to the meaning of this particular testimony, and he has encompassed within that testimony the CIMAC rules.

JUDGE BRENNER: But he has presented no testimony whatsoever, not even a scintilla of testimony on the

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calculational methods and/or his approach or results under the proposed CIMAC rules. And their conclusion cannot suffice for the absence of advance written direct testimony on the subject.

I didn't put his testimony together either. Neither did you. But that's the testimony we have to deal with.

MR. SCHEIDT: Well, Judge Brenner, it is a follow-up to his direct testimony. He said he would prefer to have assessed it this way. And my question is: Did he?

JUDGE BRENNER: Why didn't he in his testimony?

MR. SCHEIDT: We don't know, Judge Brenner.

Judge Brenner, we don't know whether he did or he didn't.

JUDGE BRENNER: He didn't in his testimony. We know that.

MR. SCHEIDT: No, whether he did assess it. He says he prefers to assess it, and we don't know whether in fact he did or did not.

JUDGE BRENNER: That wasn't my point. My point was he didn't in his testimony.

MR. SCHEIDT: No, but the point is this is follow-up from his direct testimony. It is specifically referring to a specific phrase in a sentence he used.

JUDGE BRENNER: I understand that. That was your

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opening argument.

MR. SCHEIDT: It's relevant; it's material.

JUDGE BRENNER: Staff?

MR. GODDARD: Again, the Staff would admit that the CIMAC rules are not discussed in the testimony. This is the IACS he has referred to in the contention himself.

Dr. Sarsten's testimony went strictly to the calculation of the torsional vibratory stresses. And he then subsequently ran a number of evaluations or comparisons which are not included in the testimony. That's clear.

JUDGE BRENNER: Do you want to advise me on what the ruling should be on the objection, and why?

MR. GODDARD: Literally, the objection is sustainable. However, I think in the interest of presenting a full and complete record, without regard to certain procedural niceties or the rules of evidence, the answer may very well have probative value.

And with that, I will return the ball to your court, Judge Brenner.

JUDGE BRENNER: Thanks.

These are not procedural niceties, Mr. Goddard. If it was just a procedural nicety, it would be easy for me to say I'm not going to worry about that, I want to get the relevant and material information in the record. And I have certainly been capable and able to do that in terms of

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objections of a technical nature.

This is a different, quite fundamental point raised by Mr. Ellis, namely, that it is important in this complex litigation -- at least the AEC and then the NRC, in setting up its rules of procedure, thought it was important to provide for written direct testimony. And as I discussed earlier, like many things in life, it is a matter of degree.

But here there is a case where there is not one iota of information on the subject. I understand Mr. Scheidt's argument, but I don't agree with it, that through that sentence it would open the door to say that it is indeed covered in his direct testimony sufficiently to allow inquiry, so if he has done anything on it -- and I don't know if he has, and I don't want to know right now -- then we're going to sit here and have to pull it out orally, and then have to have the parties react to it rather quickly, especially since, as I understand your position as Staff Counsel, in the Staff's view it was not pertinent to the Staff's analysis leading to the conclusions in the Staff's testimony.

The problem is we may not agree with that view when we put all our findings together.

MR. GODDARD: The Staff would also point out that these witnesses, through the good graces of this Board, have been called out of turn because of the unavailability of

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Professor Sarsten. In the event the County had presented its testimony first, presumably they will present testimony on, or they have presented testimony which will be introduced, on the rules of the International Association of Classification Societies about which Dr. Sarsten could subsequently have been asked in turn whether he agreed or disagreed with that testimony, and whether he had performed any calculations supporting or refuting that testimony.

I'm afraid here we have the cart before the horse perhaps.

JUDGE BRENNER: I'm going to do you a favor and not comment on that argument by you, since you did recognize why it is that these witnesses are being called out of turn.

Also getting-- Well, I will comment on the argument but only taking the high road and commenting on the substance of the argument, it is still open to ask these witnesses about matters in the written direct testimony of other witnesses. That is not the point here.

But that's only open, as I said before, to compare the differences in conclusions, but he has said nothing on the subject; that is, Professor Sarsten.

This is a problem when testimony is put together that really doesn't address everything in the contention, and then another party wants to take advantage of a

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witness' presence.

There was also discovery available to the County, and I don't know whether they asked Professor Sarsten anything on discovery on this subject or any subject.

MR. SCHEIDT: He was not available to us during the discovery period, Judge Brenner, for deposition. I don't believe he was identified as a Staff witness at that time.

JUDGE BRENNER: Is that right, Mr. Goddard?

MR. GODDARD: I'm not sure of the date that Dr. Sarsten became available to us as an expert witness, Judge Brenner. It was late in the game.

JUDGE BRENNER: Well, if you're not sure, I certainly don't know.

MR. GODDARD: I would have to verify that with Dr. Laity of PNL.

JUDGE BRENNER: I will accept the County's representation then unless somebody disagrees.

MR. GODDARD: I would not refute that.

JUDGE BRENNER: You know, when parties do their job right in preparing for the case we can deal with substantive matters and not have these digressiions.

Give me a moment.

(The Board conferring.)

MR. ELLIS: Judge Brenner, I might--

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JUDGE BRENNER: Are you going to say something new?

MR. ELLIS: Yes, your Honor.

I may not have it exactly right, but there is testimony of the County on page 117 of their testimony that says:

"Have you performed any calculations to determine the sufficiency of the dimensions of the replacement crankshafts under IACS rules?"

And the answer is:

"No, not directly."

Followed by a further answer:

"This testimony was filed I guess prior to the Staff's testimony."

And we again would reiterate that we think it falls under the same ruling that the Board has made with respect to other classification societies.

The sole purpose of the Staff's testimony is to assess the adequacy of the crankshaft by DEMA lights, and that is what we should focus our inquiry on here.

JUDGE BRENNER: That's your theory of the case.

MR. ELLIS: No, that's the thrust of their testimony -- Professor Sarsten's testimony.

JUDGE BRENNER: All right.

I misunderstood your first remark in your

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explanation. I admit it. I understand it now.

I guess we need to talk about it as a Board again.

Off the record.

(Discussion off the record.)

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JUDGE BRENNER: Back on the record.

We're going to sustain the objection for the same reason we sustained the previous objection.

I want to candidly state one of the considerations that we factored into our conclusion, as everyone concedes, the objection was sustainable legally. However, our thinking went beyond that, to consider whether or not a party should be entitled to educe evidence of a direct nature for the first time at the hearing for a witness for another party. And the party attempting to do that has been a party without its own expert witnesses available, both as advisors in the discovery period, and as witnesses here. We might have been more willing to bend the rules and permit the question, even though legally objectionable. But in this case, the County has had available to it it's advisors in the discovery period and had plenty of time to develop for itself, without regard to whether Professor Sarsten was available for discovery, whether these crankshafts would meet or not meet CIMAC draft rules or any other rules specified in the contention. And moreover, the County has had an opportunity to put in its own direct testimony on that subject to the extent that it saw fit.

So we see no reason to vary what the proper legal ruling would be in this case. And, in accord with that

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proper legal approach, we are sustaining the objection.

BY MR. SCHEIDT:

Q Do either of you have an opinion as to the adequacy of the replacement crankshafts for operation at 3900 kw?

A (Witness Sarsten) I do not have an opinion on the adequacy of these crankshafts at 3900 kilowatts.

Q Mr. Henriksen?

A (Witness Henriksen) I do not either.

JUDGE MORRIS: Mr. Scheidt, just so there isn't any ambiguity, could you specify the time you had in mind when you asked that question?

MR. SCHEIDT: I had in mind at that time the operation of the engines pursuant to the DEMA recommendation the two hours every 24 hours continuous operation.

JUDGE MORRIS: Did the witnesses have that also in mind in your answer?

WITNESS HENRIKSEN: No, I didn't at the time.

WITNESS SARSTEN: I do not either. I was thinking of unlimited life.

BY MR. SCHEIDT:

Q Well, given the modification, do you have an opinion as to the adequacy of the replacement crankshafts at that condition?

A (Witness Henriksen) As I've stated before, the

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only way to find that out would be to run the engine at 3900 to tenth to the seventh cycle. There is no data that really is adequate.

JUDGE BRENNER: Now, on page 17, both of you --

JUDGE MORRIS: Excuse me, Mr. Scheidt.

Professor Sarsten, did you want to --

WITNESS SARSTEN: I just wanted to confirm that my answer was no, also.

BY MR. SCHEIDT:

Q Is it your testimony that the evidence is inconclusive as to whether the crankshafts are adequate, the replacement crankshafts?

A (Witness Henriksen) I didn't hear the question.

Q I'm sorry.

Is it your testimony that the evidence is inconclusive as to whether the replacement crankshafts are adequate?

A Yes.

A (Witness Sarsten) Yes.

Q Are there any particular facts or additional information that you would need to know before you could come to a conclusion on the adequacy or the inadequacy of the replacement crankshafts?

A (Witness Henriksen) I would feel comparable if it was run at ten to the seventh cycle at that load.

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A (Witness Sarsten) I would concur with that opinion.

Q Other than testing, is there any other information that you need to know in order to render an opinion on the adequacy or not of the replacement crankshafts?

A I would not like, personally, to render an opinion upon the adequacy of the crankshaft. One, it can be tested, as we stated. Two, it can be tested against the rules of the classification society, taking the different environment into consideration and considering that it is not a marine engine.

JUDGE BRENNER: I guess I'm stimulated to ask, Professor Sarsten, given all the dialogue we have had on related subjects with objections and so on, why didn't you do that in your testimony?

WITNESS SARSTEN: The calculations were not available at the time the testimony was filed.

JUDGE BRENNER: Because you didn't do it, is that right?

WITNESS SARSTEN: I will have to think back to when the testimony was filed.

JUDGE BRENNER: It was filed late, near the end of August.

A (Witness Sarsten) I did have contacts with that

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classification society in August. I can find the date exactly.

JUDGE BRENNER: My question is a simple one. You say in the passive voice, the information was not -- the calculations were not available. My question is: These unavailable calculations you're talking about -- a lot of it is whether work was performed by you or initiated by you, in an earlier timeframe. Isn't it dependent on that?

WITNESS SARSTEN: The work was not initiated by me early enough to be submitted in our testimony.

JUDGE BRENNER: All right.

Mr. Scheidt?

BY MR. SCHEIDT:

Q Do you know whether the replacement crankshafts meet the DEMA limits on the 7,000 psi for some of the orders at 3900 kw, even if only six orders were summed?

A (Witness Sarsten) I would have to make calculations to verify this. But as the increase, if I remember correctly in the calculations from 3500 to 3900, was roughly 250 psi, I a priori would think that, the jump from -- did I get you right. If only six orders were --

With only six orders I might come under, but I would not like to make a firm commitment without checking this again.

Q Mr. Henriksen, do you know whether the

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replacement crankshafts met the DEMA limits of 7,000 psi for summation of the orders at 3900 kw, even if only six orders were summed?

MR. ELLIS: I object, that's been asked and answered. And I think it is speculative even if it was answered. But it certainly was asked and answered, I think.

JUDGE BRENNER: It was asked of Professor Sarsten just in the immediate preceding question.

MR. ELLIS: I beg your pardon. I'm sorry.

JUDGE BRENNER: And Mr. Scheidt is now putting the identical question to Mr. Henriksen.

MR. ELLIS: Mr. Henriksen, I believe, said he made no calculations at all.

JUDGE BRENNER: We will allow the question and if that's the case, we'll hear it again.

WITNESS HENRIKSEN: No, I don't know that.

BY MR. SCHEIDT:

Q Professor Sarsten, you stated that you had reviewed FaAA's finite element analysis and had an opinion of that analysis. What is your opinion of that analysis?

MR. ELLIS: I object to that on the ground that I don't think it correctly characterizes his testimony, saying that he had an opinion as to FaAA's finite element analysis.

JUDGE BRENNER: I think the witness can straighten that one out, one way or the other. We'll allow

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the question.

WITNESS SARSTEN: The finite element analysis of the crankshaft utilizes three planes of symmetry and assigns certain boundary conditions to these. This is a very efficient method. It brings down the number of elements and nodal points required. But it is also clear that it is only an approximation. However, I must stress that Failure Analysis employed this largely to find the correct positions for the strain gauges in their subsequent analysis.

I would also say that in some cases the symmetry assumed is, perhaps, approximate. But it gives also some meaningful results if the shortcomings or minor inadequacies of the system are realized -- are remembered.

BY MR. SCHEIDT:

Q Is the finite element analysis oversimplified, in your opinion?

A (Witness Sarsten) For the purpose that it was used it -- and if used with caution, it may not be oversimplified. Of course, if one wished to have the two stresses and go to a more exact analysis, one would normally use a larger number of elements. One would normally use a more complete section of the crankshaft.

There are also assumptions in there about the effect of the rest of the crankshaft, which are difficult to assess. And we have made measurements on engines and find

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that, in order to get the bearing loads accurately, you must also account for the elasticity of the bearing supports, the bearings themselves, the oil film, and so on.

Q Did FaAA take those into consideration?

MR. ELLIS: I'm sorry, I didn't hear the question. Is your microphone on?

JUDGE BRENNER: The question is: Did FaAA take those into consideration?

WITNESS SARSTEN: No, but FaAA did approximate the effect of the rest of the crankshaft in not an accurate manner, but for the purposes I would say, it was sufficiently accurate. You have to remember the premises and the purpose of this calculation.

BY MR. SCHEIDT:

Q Finally, Professor Sarsten, Mr. Henrikson, I'm going to ask you a number of questions on your calculations of the -- under the ABS rules relating to crankshaft webs.

How did you calculate the I-span between the bearings?

A (Witness Sarsten) The I-span between the bearings was calculated on the basis of the ABS testimony.

Q Well, did you allow for the one-eighth chamfer of the bearing?

A I think that was taken into consideration. I would have to check it, but I believe that was included in

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the figure.

Q Could you check that from your Exhibit 1, the fourth page?

A Let me define your question. I think you are referring to the chamfer on the inside of the bearings, from bearing shell to bearing shell, is that correct?

Q That's correct.

A I interpreted the rules as using the dimensions from inside a bearing to inside of the opposing bearing, if I remember correctly.

Q Does that into consideration the one-eighth inch chamfer?

A I would have to go back into the figures, but I do not believe it takes the chamfer into consideration, only the edge of the bearing.

Q Professor Sarsten, do you have calculations that are documented that you can determine whether you took the one-eighth inch chamfer into consideration?

A I might be able to reconstruct this. I would have to go home and also look at the drawings. I cannot state it here and now, I'm not sure. That's all I can say now.

Q Professor Sarsten, is your interpretation of the ABS formulas relating to scaling or dimensions of the crankshafts, based solely upon the deposition testimony of

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the ABS witnesses?

A No, I do not believe it is, because their deposition did not cover all the variables that go into the formulas.

Q Well, with respect to the calculation of the web size, the web thickness, are you relying on the deposition testimony of the ABS individuals for your interpretation of the ABS rules?

A For the interpretation of the dimension 4.965 inches, I have relied upon their depositions, yes.

Q Which relates to what?

A The distance across the web.

MR. SCHEIDT: Judge Brenner, I would move to strike Professor Sarsten and Mr. Henriksen's testimony concerning the ABS calculations, on the basis that they are based on hearsay.

JUDGE BRENNER: Unlike at least one of your other motions to strike, on this one you'll have to tell me why you didn't file that on a timely basis during the schedule for motions to strike. What information was not available then that you now know?

MR. SCHEIDT: Like we mentioned earlier, we did not have the opportunity to depose either of these witnesses and we did not know what basis -- I'm sorry, I misspoke. With respect to Mr. Henriksen, we did depose Mr. Henriksen,

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yes.

JUDGE BRENNER: Well, let me be more precise on why -- I don't see why you didn't have the same information at the time you could have filed a motion to strike the direct testimony of the Staff that you now have. If I correctly follow the information you have obtained now on the record, it adds nothing to the information contained at the bottom of page 2 of the Staff's Exhibit 1, in which Professor Sarsten says there exactly what he said orally, except in more detail in the written exhibit, as to what his basis is for calculating the thickness of the web.

MR. SCHEIDT: Even at that time we were not aware whether Professor Sarsten or Mr. Henriksen were familiar with the ABS rules or independent of what Mr. Woytowich said in the deposition. And if they're only basing their interpretation upon what Mr. Woytowich stated at his deposition, then I believe we have a valid basis to object to the testimony.

JUDGE BRENNER: Do you recognize any inconsistency at all in your position here and your position in answer to LILCO's motion to strike some portions of the County's testimony?

MR. SCHEIDT: I've seen a lot of inconsistencies on a number of matters, Judge Brenner.

JUDGE BRENNER: Every once in a while, Counsel

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says one of my colleagues handled that, but maybe that's not the case here.

Give me one more, will you, then I'll see if we need to hear from other counsel on it.

(Board conferring.)

JUDGE BRENNER: We're going to deny the motion to strike. It is acceptable for an expert to rely on a source such as what the ABS said in that deposition under the Federal Rules of Evidence, I guess it is 703, as well as general precepts of use of expert testimony at our hearings. But even in a Federal court, I think it would be permissible. We will evaluate the weight of it based on how controversial what the evidence in the record aduced before us shows this point to be. And if there is a void in the record we will draw the, hopefully, correct conclusion from that Noard, remembering our caution as to what we're going to do with interpretations. Well, with what the ABS person said in the deposition, is the way we put it. We'll evaluate questions on interpretation of the rules depending on what these witnesses know or don't know about the rules.

So you can ask questions about it, but we won't strike it.

I also think, as a make-weight, that there was no reason why you could not have filed that motion on a timely basis after the Staff filed its direct testimony. But that

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is just an additional reason. The first reason I gave you was in independent and equally controlling.

BY MR. SCHEIDT:

Q Professor Sarsten, are you familiar with -- and Mr. Henriksen, are you familiar with the ABS rule relating to webs, crankshaft webs?

A (Witness Sarsten) Yes.

A (Witness Henriksen) Yes, I read the rules before the testimony or the depositions and I determined this was the way to interpret them at that time.

Q Is your interpretation any different right now, Mr. Henriksen?

A No.

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Q What is your understanding of the word "effective" in the formula under the ABS rules relating to webs?

A (Witness Sarsten) I would judge -- Do we have a copy of the rules so I can refresh my memory?

Q If you look in County Exhibit 35, which is the Franklin Research report, appended to that exhibit -- or appended to that report at p B-5 is an excerpt from the ABS rule which contains the rule relating to solid crankshaft webs.

MR. ELLIS: Judge Brenner, may I inquire whether Mr. Scheidt has a specific paragraph in mind that he might refer us to?

MR. ELLIS: Thank you.

WITNESS SARSTEN: I would interpret the word "effective" in "W equals effective width of web in millimeters or inches," as the actual metal that is there as shown in our Exhibit 1, I believe it is, on the drawing.

BY MR. SCHEIDT:

Q Well isn't it good or standard engineering practice when determining the effective resisting moment of the web in bending to look to the plane with the least or smallest moment of resistance?

A (Witness Sarsten) The web dimension to be used in such calculations varies from society to society. Some

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distinguish between undercut and non-undercut webs and use the direct horizontal distance between. But this is a matter for the individual classification society itself to interpret. It varies from society to society.

Q Well apart from how the societies consider it, is it good or standard engineering practice when determining what is the effective resisting moment in bending to look to the plane with the least or smallest moment of resistance?

A I believe I have actually answered that question. When doing this for crankshafts you have no recourse usually but to get your engine and the shafts approved by a classification society. You must use their interpretation of the rules.

However if you go outside crankshafts, you might consider what is engineering practice and that would depend upon the individual situation. Here we have no choice in the matter normally.

Q You say you have no choice in the matter.

Because of your interpretation of what Mr. Woytowich stated in his deposition?

A I was referring to calculation of crankshafts in general. We are there bound by the interpretation the classification society gives to its own rules. Normally it is more explicit than this and has drawings showing how these dimensions are to be determined.

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A (Witness Henriksen) We are aware of -- both Dr. Sarsten and myself are aware of Professor Christensen's calculations. We understand what he did. We disagree with his interpretation of the rules.

Q You're referring to the ABS rules?

A Yes.

Q Now apart from whether that is -- Professor Christensen's interpretation of the rule, as related in his testimony, is correct or not under the ABS rules, isn't Professor Christensen's calculation a proper and correct method to determine the effect of resisting moment of the web in bending, totally apart from whatever the ABS interpretation is?

A (Witness Sarsten) He appears to have -- I cannot answer it directly yes or no. All I can say is he appears to have followed a normally accepted path. I have not checked the calculations in detail because that would require very much work and because I consider the basis for the calculations to be in error. Therefore there is no point in doing this.

Q And the reason why you believe the basis for the calculation is in error is based upon Mr. Woytowich's statement in his deposition, isn't that correct?

A Partly on that. I also do not see why this section was -- when laid at an angle, was performed as it

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was by Professor Christensen.

He took a cut at an angle which yielded a moment of inertia and distance to the outermost fiber which is more unfavorable, I believe, than the method stipulated by the ABS representative.

Q Do you believe it is more conservative than that stated by Mr. Woytowich?

A I would have to check the figures but it could easily, put that way, be more conservative.

Q Other than the statement by Mr. Woytowich, do you have any knowledge of how the ABS interprets that rule as it relates to the effective resisting moment of the web in bending?

A No, I do not, but I do not need any other ruling on this really, in my opinion.

JUDGE BRENNER: I'm sorry, I just didn't hear your last phrase.

WITNESS SARSTEN: I'm sorry.

I believe I said no, but I do not need any other interpretation of the rules. I think it was very concise and I don't know where else I should go if I were to have an interpretation o the ABS rules by a second party.

JUDGE BRENNER: Okay.

MR. SCHEIDT: The County has no further questions at this time.

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EXAMINATION BY THE BOARD

BY JUDGE MORRIS:

Q A quick follow-up question:

Back to paragraph 34.17.4 of the ABS rule.

A (Witness Sarsten) I'm sorry, we closed the book, Judge Morris.

Q Page B-5.

A Yes.

Q If you read the last sentence in that paragraph, is it true that the Shoreham crankshaft geometry is as described here?

A That is correct. The pins and journals do overlap.

Q And is the thickness described here that that you have labeled 4.965 in your Exhibit 1?

A That is correct.

Q Thank you.

BY JUDGE BRENNER:

Q Just to make it explicit and to make sure I understand, are you saying that the measurement that you used for T is, in fact, using the words of the ABS rule: "...the minimum diagonal distance through the web?"

A (Witness Sarsten) That is correct.

BY JUDGE FERGUSON:

Q Professor Sarsten and Mr. Henriksen, I have been

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given the opportunity of filling in, perhaps, some things that the Board would like to have explicitly stated on the record. And what I would like to do with you in the next few minutes is to, perhaps, go back to a very early beginning point, and then sort of walk through with you the entire procedure that we have been discussing in detail for the past two or three days -- two days.

I'm going to ask a broad question to begin with, just to get you started, and then from time to time I would like to interrupt you to try to make sure that the point that you're covering is in fact the thing that will help enlighten the record.

The whole purpose of this wrap-up, as I will generally term it, is to try to bring together the things that we have been discussing at one place in the record that we can use sort of as a foundation to go back and talk about the great detail.

So let me begin by starting you by going back to the pistons. And I would like simply to say that I would like for you to start at the point of where pressure is applied to the pistons, the piston then exerts a force on the crankshaft, this up-and-down motion of the piston in some way gets converted to a rotary motion by the crankshaft which eventually turns, perhaps, the generator.

Now, all of the discussion we've had over the

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past two days talked about the device, the crankshaft that does basically that. But in the discussions we have had, several parameters have been introduced and explored in great detail, like, for example, free end amplitude, like T-n values, like torsional stresses. All of those parameters have been explored in great detail over the past two days.

So what I'm charging you with at this particular time is to start, if you will, from the point where the connecting rod is attached to the crankshaft where that up-and-down force is applied to the crankshaft, and how that force affects this thing called the crankshaft that eventually results in a twisting force on the generator. And as you step through this -- and I don't want to take up a great deal of time, but I want you to do it in enough time and in enough detail so that a layman looking at the record will understand the sequence of events that occur and the measurements that are taken to verify that this sequence of events is in fact done in a way that assures safety, and in enough detail so that a layman will be able to understand that, using, in the definition, the parameters I have just indicated.

Is the charge that I'm giving you clear?

A (Witness Sarsten) The charge is clear; the answer may not be. But I will try.

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Q Well, let's start.

A We have a firing pressure at -- or a cylinder pressure at top dead center. This does not give any turning moment to the crankshaft; it does, however, lower the crankshaft bending. But as the crankshaft slowly turns, the effective arm of the crankshaft will increase and the torque increases.

As the crankshaft makes two complete revolutions, the torque transmitted to the crankshaft by the firing pressure minus the inertia forces will pass through zero at the dead centers, because then you have no effective arm; there is no moment acting, the crankshaft is -- the connecting rod is in a vertical position.

Knowing the force in the cylinder at every instant of time throughout one complete cycle of two revolutions, it is possible, after deducting the inertia forces, to calculate the moment, or the variation of the moment, over two complete revolutions of the crankshaft.

However, we engineers are a stupid and lazy lot often, and in order to resolve this difficult question we try to break it down into a number of simpler problems. We take this turning moment and break it up into a series of sine waves which vary over one complete cycle, once per engine cycle, twice per engine cycle, and so on and so forth. Those are the orders we speak of, because we can --

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or we know how to calculate the torsional response of each of these orders in a rather easy manner.

Q So the orders, you would say, then, in some way describe the shape of this vibratory motion?

A They describe the shape of the torque input to the vibratory motion. You will not get the same response from each of these orders. That will depend upon how large the order is, of course, and how the dynamic situation is, how close is this to a resonant frequency of the crankshaft.

If one of these orders coincides, or is close, at least, to one of the resonant frequencies of the crankshaft, that response will be magnified greatly, and that order will be much larger than other orders.

Q Now, with that in mind, can you tell us, in the material we have gone over in the past two days, which order would be closest to that resonance?

A If we are looking at 450 revolutions per minute, there is a large fourth order of resonance above this speed. That's why, if you look, for example, at our Exhibit 2 -- or, better still, Exhibit 3 -- you will see lines increasing upward here. That is the response of the fourth order.

I must also add that the effect totally on the engine depends also upon the other cylinders and upon the phasing of these orders. Sometimes the orders may

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counteract each other; sometimes they may be additive and ca se great response. The fourth order is a so-called major order because the vectors are then in phase, and it causes a large torsional response of the system.

If we look to the left we see a 5-1/2 order which is nearing resonance. There's a line here, 5-1/2, which indicates that this order--

Q Excuse me, Professor Sarsten; you have to help the record by describing what it is you're talking about.

A I'm sorry.

I am describing now Exhibit 3, showing the stresses in shafts from single harmonics for this TDI eight-cylinder engine. And this is based on Owners Group data.

To the left of this figure we are approaching resonance for the 5-1/2 order. That's why you see the response. The stresses caused by this order increase to the left here.

I was here looking at the total response of the engine. We have at each of the eight cylinders excitations of, let us say, the first twenty-four orders, that is, orders from 0.5 to 12.

The engine response can be calculated by various means. One of them is the computer program I used; the other is the superposition method. If we look at all these

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orders we know from our previous calculation how these various orders are in magnitude and phase. We can add the effect of all these together and calculate the displacement at the front end of the engine.

Q Okay.

You did say-- I thought I just heard you testify that you know the phases of all the orders; is that correct?

A That's correct. That comes from the Fourier analysis of this turning moment curve for an individual cylinder. In this case it was based upon pressure measurements made in Cylinder No. 7 of the TDI engine.

Q Go right ahead.

A Knowing these orders and their phase angles, or phase relationship to each other, the computer can be asked to add these orders at various points in time. That would be called the sampling frequency. I sample with a frequency of 720 per revolution for this specific case. That is more than industry will use. You will then add all these twenty-four orders, the displacement, the stresses, together at each degree. And from that you can obtain the maximum excursion at the front end of the engine and the so-called one-half peak-to-peak amplitude at the front end of the engine, mass-1.

This can then be checked against measured values at the front end, because there we normally have -- or often

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have a free end where it is easy to attach a seismic instrument and, from that, measure the true value of the front end amplitude.

Q This front end amplitude is measured in degrees; is that correct?

A It is measured in degrees. In this case it was .693 degrees.

Q That is your calculated value; is that correct?

A That's the measured value.

Q The measured value is .693 degrees? Very good.

A Correct; measured value, rounded off, was .69 degrees when summing twenty-four orders.

WRBeb

Q You did, I believe in your testimony today, indicate that there was an uncertainty in the measured values.

Is there a range in this measured value of .693 degrees that you just mentioned, in the measured value?

A There is normally a slight uncertainty in all measurements. I would not like to speculate on the uncertainty here. That would be-- Perhaps an electronics engineer, one who made the measurements, would be more qualified to do this.

I just accepted the value given by Failure Analysis Associates as being correct.

Q I see.

Do you have Exhibit 17, C-17, I believe?

A Yes.

Q Excuse me just a moment.

(Pause.)

If you have 17 you must also have 18. That's the reference I would like to use.

A Yes.

Q And I guess I would like for you to turn to page 11 of that exhibit.

A Yes.

Q Is that entitled "Crankshaft Torsional Stress Calculations for an 8L 17x21 Engine Generator Set"?

WRBeb

A That is correct.

Q If you will look at the column headed "SWEC Test," at the bottom of that column you see "True Sum." And I assume this is the true sum of the orders. Is that correct?

A That is correct. This.... One moment.

It may be the true sum of the orders. It may be the measured value. I'm not certain.

Q Well, I was looking at the column headed "SWEC Test."

A Correct.

Q Would you think that was a tested number, an experimental number?

A I would think that was the.... I don't know.

Q You don't know.

A I would think that was a range of measured values, but I'm not sure.

Q All right. Very good. If you're not sure, that's the answer to that.

But when I looked at that -- and we referred to it earlier -- if I understood that table correctly, it looked as though there might have been a range of true sums that Stone and Webster got.

MR. ELLIS: Judge Ferguson, I believe there was testimony on that in the record, I believe from Dr. Chen,

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about that particular figure. I won't characterize it in view of the witnesses' being here, but I think there was testimony that explained that.

I will be happy to furnish the Board with the references to that if you wish.

JUDGE FERGUSON: Still to you, Mr. Ellis, I do remember that there was a portion of that page that was struck. Is that what we're talking about?

MR. ELLIS: Yes. I believe the .55 was struck.

JUDGE MORRIS: In answer to my question of Dr. Chen, the last sentence in the first paragraph which reads "The experimental spread was 0.55 to 0.69 degrees when several recordings were studied" was indeed struck.

JUDGE FERGUSON: Okay.

Are we to interpret that, or do you know -- I'm not asking you to give testimony, but since you did interject, do we interpret that to mean that there is no range in true sums that Stone and Webster actually provided?

I'm just trying to get a feel for the error, the experimental error.

MR. ELLIS: The value that was reported was 2693. No error was reported. I'm not sure it would be appropriate for me to comment any further.

.55 was indeed struck, and there was no range.

JUDGE FERGUSON: All right.

WRBeb

BY JUDGE FERGUSON:

Q I didn't mean to interrupt too long, Professor Sarsten, but I was concerned about that, and I do recall there was other testimony by another panel which indicated that the strain gauge measurements were accurate to within about 5 percent.

Are you aware of that?

A (Witness Sarsten) I have read that.

Q But you don't know of it? You just read it in the testimony. Is that correct?

A That is correct.

Q I see.

The only reason I interjected this point is that there has been great discussion about the difference in the free end amplitude, your value versus some other values, and the differences were not great. They were all within 4 or 5 percent.

And I thought you made a point earlier that your number was closer to the .9 -- .693, and therefore might be more reliable. But we'll get back to that.

I did interrupt you. I would like for you to proceed if you would, briefly, with your discussion that I asked you earlier to give us. I want you to remember to include your interpretation of Tn values, what they are and how they are calculated or measured.

WRBeb

A The Tn values are calculated from the trace or the digitized values of the cylinder pressure over one complete cycle. The effect of the interia forces upon the turning moment really affects only the first, second and third, and, to a very small degree, the fourth order. It has negligible effect on all other orders, and these orders are normally used as they come out of the calculations, without further corrections.

I should add there are other minor corrections sometimes made for other effects, the pendulum motion of the connecting rod, the weight of the components, but these are really insignificant and usually neglected in commercial calculations.

We now have the so-called T-sub-n values which are acting on the crankshaft. Previously it was customary to use these as is, without correcting for the slight loss in power from the friction in the cylinder itself.

Newer calculations sometimes account for this by subtracting some of the mechanical losses before they act upon the crankshaft.

When this is done, when such T-sub-n values are available, the torsional response of the crankshaft may be calculated.

I must add that in addition to the T-sub-n values, there is also a constant value or a turning

WRBeb

moment which of course drives the generator.

Q Yes.

A So each portion of the crankshaft has normally an increasing torque acting upon it. Superimposed upon this there is a vibratory torque from the torsional vibration, and the amplitude has often a mean value in time which may not be at the-- Strike that. This gets a little complicated.

We can just say that you have a superimposed value and half of the distance between maximum and minimum amplitudes or half of the stress values between minimum and maximum stress is used in the calculations. This is the amplitude you are looking at.

Q Yes.

Have you finished?

A I've finished, but probably not answered the question.

Q I think that's helpful.

Let me ask one or two questions.

I would like to return if I may to this free end amplitude which I think you described well. We have had a great deal of testimony on I would say three different categories of values of this free end amplitude: your number, .690, I would say -- well, the experimental number which you just quoted, .693, and another group of numbers

WRBeb

that all are around .66.

There is a difference of about perhaps 5 percent between those three categories. Is that correct?

A That's correct, 4.-something or other; close to 5 percent. That's correct.

Q Was it your testimony this morning that that difference is slight and may in fact be due simply--

Well, maybe rather than trying to characterize your testimony, why don't you tell us what you think the significance of that 4.5 or 5 percent difference is so far as the safety of the crankshaft is concerned?

I did not want a discussion of why one method would be preferred over the other.

A Right.

The crankshaft is subjected to numerous forces. One of the major forces acting on it is the torsional vibratory stress. We also have bending stresses acting upon the crankshaft. We have torque, and so on.

In the assessment of the adequacy of the crankshafts or their factor of safety against failure, modern methods will add the importance of both these types of stresses to their final stress figure. Often they are of roughly the same magnitude.

The torsional stresses, in this case the DEMA limits, are admittedly very high, higher than the

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conservative classification society rules normally allow. But that in itself does not imply that the crankshaft is inadequate.

One must look at the stress levels relative to the material at hand, the dimensions of the scantlings, et cetera, and also how large the bending stresses are.

If you would look at the significance of the 4.5 percent or the 5 percent, whatever it is, I would say the main significance is in seeing if the crankshaft meets or does not meet the DEMA limits. But if you look at the adequacy of the crankshaft itself, the importance of this 5 percent is diminished.

As I said, if there was a 50-50 spread, that only one-half of that would enter into your calculation of the factor of safety and maybe only 2.5 or 3 percent of this would be reflected in the factor of safety.

Q So is it fair to say that a difference in final numbers that we get for free end amplitude is not an important safety consideration?

A That would depend upon which factor of safety you end up with. If you have a very good factor of safety, it doesn't really matter all that much, but if you are on the borderline as it is, then you may have reservations about the adequacy of the crankshaft, even with such small numbers.

WRBeb

Q What would you consider a good order of -- a good safety factor? I thought you said a good safety factor.

A Yes. That again depends upon how the factor of safety is calculated. I have most experience with, as we have heard before, with th' rules of the classification societies. They, I think,--

One I know of uses a figure of 1.26 using their method for marine propulsion engines. If the engine is only four generator duties they have relaxed this factor of safety to a level of 1.2. This is for shipboard engines.

Taking into consideration the environment we have in a nuclear power station and the hopefully very good maintenance alignment, et cetera, we have, the absence of sliding motions of the vessel, and so on, I would consider the limit you could go down to using the classification society rule to be around 1.1.

Q 1.1 would be a reasonable--

A Not below that.

But again that refers to the method of calculation, and there is perhaps some small margin of safety baked into the method whereby the factor of safety is calculated so in essence it is slightly larger than this.

Q Let me turn for a moment to torsional stresses which I think you mentioned.

You did in fact calculate a lower limit on the

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torsional stresses, did you not, using both the single order and also the total vibratory stresses?

I think the number is in your testimony,--

A Yes, I did.

Q -- 3,608 for the single order, and 7,096 psi for the total vibratory stress.

These numbers you claim are higher than those calculated for the lower limit by TDI.

Have you had a chance to review TDI's calculations, say for the total vibratory stress?

A TDI, if I remember correctly, only calculates individual orders.

Q You do not think they calculated the total vibratory stress?

A They do not sum orders.

Q But did they calculate the total-- Did they have a number for the total vibratory stress?

A No.

But you may be referring to the failure analysis calculations which summed 24 orders. They had a number which was just below 7,000 psi, 6,600-and-something.

(Pause.)

I have a figure on Table 2-5 of the testimony giving half peak-to-peak amplitude of nominal shear stress as 6,626 at 3,500 kilowatts.

WRBeb

JUDGE BRENNER: Will you give me the figure again, Professor Sarsten?

WITNESS SARSTEN: Let me try to get it in the updated version.

JUDGE BRENNER: Just give me the value.

WITNESS SARSTEN: The value I have here is amplitude of nominal shear stress in psi of 3,500 kilowatts, half peak-to-peak is 6,626.

JUDGE BRENNER: And you're using C-17 but you may have the old volume, is that it?

WITNESS SARSTEN: I have the old volume, yes.

JUDGE BRENNER: Look at page 2-11 of the new volume and see if that's what you mean.

WITNESS SARSTEN: The same figure applies there too.

MR. ELLIS: Judge Brenner, I think that table says from Stone & Webster, not FaAA. The torsiograph.

JUDGE BRENNER: Give us a chance.

MR. ELLIS: I'm sorry.

BY MR. FERGUSON:

Q Professor Sarsten, I was just reviewing some of the testimony on page 15 and I was looking at the four numbers that are given there, that's page 15 of your testimony. Have I misinterpreted what your answer to the question at the top of the page says?

WRBeb

A (Witness Sarsten) In which manner?

Q There is a sentence, I think it is the second sentence, in your answer it says,

"TDI has calculated these values for the Shoreham engines and arrived at 3,357 psi for a single order, and 5,035 psi for total vibratory stresses at the limits that would be allowable for paragraph 34.47 of the 1984 ABS rules."

And then you go on to say,

"According to my calculation, you have two other numbers. And they are 3,608 and 7,096, respectively."

Am I comparing the right things when I say that you did, in fact, calculate the total vibratory stress and they also did? "They," meaning TDI?

A TDI did not calculate the total vibratory stress. They calculated the limits that would be allowed by paragraph 34.7 of the 1984 ABS rules.

Q I see.

A Perhaps it could have been stated clearer.

I must add that this assumes that their method of calculating the increased allowable stress levels would be approved by ABS. I cannot, of course, judge that.

Q There is one thing -- and I am backing up just a little bit -- this goes back to the free end amplitude

WRBeb

again, and the difference between the calculations. Although, I think we have arrived at the point that this percent may not be significant. But I thought you had testified that, using your program COMHOL, that was the program we used to get the .690; is that correct?

A That's correct.

Q You indicated that, I thought this morning, that there may be an error in the program. You were talking about, I think, COMHOL and perhaps another calculation. And I thought your words were, there may be an error in the program. And that kind of caused me to perk up. And I was wondering if you believe there is an error in COMHOL or an error in something else?

A No, I don't believe there is an error in COMHOL: it has been checked and rechecked, oh, dozens of times.

I may have then been referring to another program asked about, why there were discrepancies or differences. I could not answer explicitly, without knowing the program, if there were some minor errors in the program or not.

They did not refer to COMHOL.

Q Someone else's program that has the errors?

A I'm not saying any program has the error. But if you have to explain why there's a difference, it's one of the possibilities that springs to mind. So I do not believe that this is the case.

WRBpp

Q Let me go back to a statement that you made a moment ago, that pointed out omething in your answer that I think clarifies the record. This has to do with the 5035 psi for the total vibratory stresses -- stress limit -- that was calculated by TDI. Do you know how that was done? Do you know that -- how TDI made that calculation?

A They used -- we would have to look at the ABS rules and there is an exhibit covering this calculation giving the exact figures.

They took the pertinent section of the ABS 1984 rules and increased the allowable stress limits by showing the higher UTS of the steel they employed and arrived at the figure 5035. This is not a stress calculation. This is only an interpretation of the ABS rules to exceed the normal limit, because they had a higher UTS on the crankshaft material than was employed in forming the basis for the allowable figures set forth in the ABS rules.

Q Do you have Exhibit 4, your Exhibit 4, in front of you, and would you turn to page 21?

A Yes.

Q Okay.

In the middle of that page you do see total allowable stress?

A . at's correct that this is --

Q And my question is: Apparently that calculation

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says 150 -- I believe that is percent -- of 3337 equals 5035 psi?

Could you tell us where the 150 percent comes from?

A ABS allows -- have an allowable figure for a single order vibratory stresses. They allow 50 percent more for the sum or orders. That is where the 150 percent comes from.

Q I see.

That's in the rules?

A That's in the rules. The tensile strength of the shaft material here is 100,000 psi. That has been the basis they have used. The formula at the top of the page is where you put in the, as you see, the increased --

Q I understand.

Before I leave you, Professor Sarsten, I do appreciate your helping us to try to collect some of the concepts that we uncovered these past two days in one point in the record. I believe there are other questions that the Board might have and I might come back after they have been asked.

BY JUDGE MORRIS:

Q Gentlemen, particularly Professor Sarsten, I'd like to follow up a little bit on what Judge Ferguson was asking about, but directed toward your computer program

WRBpp

COMHOL.

Could you list for us easily at this time what inputs are needed to run that program?

A (Witness Sarsten) Yes, I'd be glad to.

First, you need the dynamic model of the system, all the mass moments of inertia, and the torsional spring constants. In addition, you want the damping values for mass damping or external damping to ground and also the damping values for damping between the individual cylinders, internal damping or shaft damping, as it is often called.

In addition to this, you wish --

JUDGE BRENNER: Could I interrupt for just a moment?

Could you start over and tell me, for each of these inputs, where they are obtained or how they are derived?

WITNESS SARSTEN: I'd be glad to.

As the vibratory system has been checked out repeatedly for natural frequencies and confirmed with measurements, I used the values from the FaAA reports. The damping values, where appropriate, are based upon a dynamic magnifier. As previously mentioned, I used a dynamic magnifier of 40, which yields a perhaps slightly higher damping than is customary. But I did this to be on the safe

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side.

Then you need the rpm at which the calculation is to be performed or, if you wish, to perform a set of calculations, the speed range, the stepping speeds and so on.

You also need to specify which of the masses are cylinders and the phase angle between the cylinders, which is reflected in the firing order of the engine.

You also need the T-sub-n values, 24 of them is normal, and their respective phase angles, again 24.

You would also want to specify if it is a V-engine or not, if you want additional excitation of any masses and so on, and how much printout you would require. But this is not essential for our discussion.

Q The T-sub-n's are derived from measurements?

A The T-sub-n's are -- may be derived from measured values as in this case. One is not always that fortunate and has to take T-sub-n values from the listings in the literature or from idealized cycles.

There are now available good approximate methods for calculating the T-sub-n values.

Q And the phase angles are determined from geometry?

A The phase angles are determined from the Fourier analysis of the turning moment. You get the results out

WRBpp

either as an amplitude and a phase, or sine and cosine components. The input of this program actually uses the amplitude and phase because it uses complex numbers and it's a little simpler.

Q The interaction between the crankshaft and its bearings, and the crank pins and their bearings, is contained in spring constants, or how is that taken into account?

A That is correct. The elasticity between the masses in your system are taken into account by the spring constants. Masses are normally placed at the centerline of each cylinder and include a part of the reciprocating mass, the rotating inertia of the throw, et cetera.

Q Well, of this list of inputs that you have just recited, is it your opinion that any of them is not well known for purposes of your analysis?

A No, they are all relatively well-known. One could, at times, discuss the value of the damping employed, but that is most relevant near a resonant frequency. In the case here, if we are looking at 450 rpm, there are slight variations in the damping coefficients or, if you wish, the dynamic magnifier. However, it does not influence the results to a great extent.

I must also add that we, if you want to be very accurate, if this answers your question, you may sometimes

WRBpp

have to take into account the so-called secondary resonance or the parametric excitation of the distant motion for the inertia forces of the piston. But normally this is of no concern in four-stroke engines. And it usually shows itself only on special occasions when the special order is near resonance and it doesn't apply here. So I would say the results -- the input here is sufficient for the calculation in this case.

Q I believe you answered the County before that a misfiring cylinder would not concern you. Could you explain that a little bit more to me, why that is not a concern?

A The misfiring of an individual cylinder is often required by the classification societies, if there is concern that this would greatly increase or substantially increase the vibratory stresses.

Normally, a misfiring will not last forever. And even though the stresses are slightly increased, the system can usually take of it.

The misfire of a cylinder is especially important in certain configurations of V-engines where there is a delicate balance between the exciting forces on the two V-banks. And the stresses may arise greatly if this delicate balance is lost and you are in or near a critical order.

It's also important if you have flexible

WRBpp couplings and gear trains in the system, because uneven motion of the crankshaft then can impart gear chatter into the system.

WRBeb

Q In the Delaval straight-8 engine, if there were a cylinder misfiring, how long would it take to detect that?

A That should be detected immediately if there is anyone near the engine. If it is misfiring, you can hear it, you see the exhaust temperature goes down and everything.

It may, for example, happen from an eruptive fuel line and you will certainly see the fuel spray around. So that is not normally something that should go undetected in a manned engine room.

We speak today of unmanned engine rooms where no one is there in the vicinity or checks the readings of the instruments.

Perhaps Mr. Henriksen would like to elaborate.

A (Witness Henriksen) Almost immediately it would be noticeable in the exhaust readings in the control room.

Q With respect to the computer program COMHOL, has there been the equivalent of what I will call a qualification of that program, a benchmarking? And if so, what is the extent of it?

A (Witness Sarsten) Yes, there has been an extensive benchmarking of the program and as time go on, you compare your calculations to other values and you see that when the same input is used, they coincide very well.

I can name some of the benchmarkings used.

WRBeb

You can generate hypothetical systems which have known solutions. For example, you can take a single degree of freedom system, just one mass which is fixed, and put -- and then you have a node point. You can make a mirror image of that, and then you have two masses vibrating against each other. Then you can make a mirror image of that and put in another system and add these two masses into one, and keep adding that until you may have, if you wish, a hundred masses.

Then you can compare the solution at one end of the system with the other and see how many significant digits are similar. That gives you a very good calculation of your arithmetic.

We have also compared the program with similar programs in another code written in ALGOL in the '60s -- This one was written in FORTRAN later -- and compared them, and the difference first showed up in the fifth or sixth significant figure between these two programs. So I believe that is a good verification of the accuracy of the program.

Q Could you turn for a minute to Exhibit C-18, to page 13, where the title on this page is "Crankshaft Torsional Stress Calculations," et cetera?

And there are some I guess 16 orders listed in the left-hand column, and then some values listed for TDI in the '73 - 1974 range, Lloyd's, TDI in 1983, and FaAA in

WRBeb

1984.

If we disregard the first TDI column, '73 - '74, and just take an overview of the numbers in the last three columns, could you comment on the degree of agreement among these numbers?

A Yes.

First I must add that the Lloyd figures are well-known to be somewhat too low. Actually in the German book by Maass and Kleir earlier referred to, he specifically refers to the LLoyd T-sub-n harmonics and says they are far too low, and actually warns against their use for more high-speed four-stroke engines.

This is in no way a slur on Lloyd's. These values are to be used in connection with their rules which again have specific allowable values on the torsional stress levels.

Otherwise, comparing these, I must add that these orders have, as far as I can see, not been corrected for the effect of the reciprocating inertia, at least for the second order which has the largest influence. There this I think would be slightly lower if there had been correction for the inertia effects.

I employed, if I can remember the numbers correctly, the figures in the right-hand column. Not all of them are given here. I received the total number of 24

WRBeb

orders from the owners' group, and I have used those.

I would have to have the complete number if I were to compare the TDI and the FaAA values. The Lloyd's column is acknowledged to be so low that it is not fair to use this in this context to compare with the others.

Q The FaAA numbers were derived from measurements and you considered them the most reliable?

A Yes, even though there is a slight inaccuracy due to the 100 percent mechanical efficiency, I would say they are sufficiently accurate and often more accurate than what you would otherwise get from tabulated values.

We must remember that these were measured on cylinder number 7, not the last cylinder. It's a slight twist of the crankshaft when in service. This throws the top dead-center off slightly, and the mechanical efficiency is very dependent upon an accurate determination of the top dead-center of the engine. This is well known, and it is very difficult actually to get the two top dead-centers, even in a laboratory engine.

Q In the DEMA standards or criteria, they provide two numbers, one for single orders and one for the sum of the orders.

Do the other classification societies provide comparable numbers? And by "comparable" I mean for the same single order and sum of orders.

WRBeb

A Yes. ABS, for example, just referred to, has two figures where the sum of the orders is 50 percent above that for the single order.

Other classification societies handle this differently. As far as crankshaft goes, for example, one classification society does not put any limit on the torsional stresses but they enter into their calculation of the allowable crank shaft dimensions together with the bending stresses. So they are implicit there but they do not have a special limit on the single and sum of orders.

So that is different between the various classification societies.

Q Do you know the basis on which the various societies have arrived at these criteria?

A The basis is long, long experience over the years with allowable stress levels, taking the marine environment into account, taking the extra stresses imposed on the shafting due to deformation of the hull, misalignment of the crankshaft, which occurs in service, and things of that nature.

They are originally based very, very much on practical experience. However, one is today more and more going toward a more refined calculation of the crankshaft, at least, and taking a summation of the bending and torsional stresses into account by some rule or other.

WRBeb

CIMAC uses Von Mise's, others use other rules for the summation of these stresses.

Q Well, is there some consideration of actual stresses imposed, plus knowledge of strength of materials, plus experience data?

A That would be correct, yes.

Q And is there any way to say how this is used, for example, analogous to an S-N curve?

A The rules are based on the premise that the component, the shaft, the crankshaft, will last forever. They are assumedly below the knee, at a stress level which does not bump into the knee or anything above that. And to give you a factor of safety, they are far below any S-N curve.

Q Do you mean far below the knee of an S-N curve?

A Far below the knee of an S-N curve. The stress levels should give a comfortable -- or should comfortably give an infinite life, even when aberrations such as we have discussed may occur are taken into account.

Q Can you at least semi-quantitatively say what "comfortable" or "far below" means?

A No. The stresses really are often very, very low. We are here speaking, for example, in this case of 7,000 psi for the DEMA, where a classification society may be speaking of four to five thousand. And we assume if the

WRBeb

crankshaft is correctly proportioned that you are below already at 7,000 psi, the DEMA requirement.

Q Do you have knowledge of what the normal result is when the crankshaft is proposed to the classification societies for approval as to how it compares in its analysis to the acceptable limits? Does it run around 90 percent, 20 percent, or can you discuss that at all?

A The rules have become more and more refined, and are more and more subject to discussion with the classification societies.

I know that one classification society says they will -- they demand, almost, if you have no prior submission of the crankshaft or similar crankshaft and similar materials, will almost make it mandatory to have a discussion and arrive upon suitable values for, for example, allowable fatigue limits, notch factors, and so on.

Some of the things are derived from curves in the rules, but not all.

Q Do the classification societies use fatigue analysis at all?

A Yes. Their figures, of course, are based on an infinite fatigue life, and actually when it boils down to what's behind the rules, they do look at the fatigue life of a crankshaft, for example, and make the rules -- make the factors so that they are safely below these fatigue limits.

WRBeb

So they are taken into consideration.

The material enters into their-- For example, for crankshafts, the forging process enters into the picture. If the grain flows with the crank throw, or if you forge it flat and cut across the crank throw, all this enters with factors into some classification societies' rules.

Q Does this include the specific properties of the specific metal that was used in the forging, or is it just the general class of conventional metals, a phrase we've heard earlier?

A It of course varies with the classification societies. Some use grade levels but some use the actual tensile strength of the material, and they calculate the fatigue limit from the tensile strength using various factors.

Q Well, given an accurate knowledge of the strength of materials and the fabrication processes and the fatigue lifetime of the materials for given stress cycles, would you feel more comfortable in approving a crankshaft design with that information than you would simply using a classification society guideline?

A I would feel much more comfortable with the classification society guideline.

Q And for what reason?

WRBeb

A Because of the wide experience they have in this. The large number of cases this is based upon.

Q Well, I think we have overrun our normal breakdown. Let's break at this time for 15-minutes, to come back at about five minutes to four.

(Recess.)

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JUDGE BRENNER: The Board has only a few more questions: we anticipate something on the order of ten minutes.

BY JUDGE MORRIS:

Q Can you tell me, gentlemen, why the requirement for calculations at 10 percent overload occurs?

A (Witness Henriksen) Standard practices, DEMA standard practices.

Q Do you have a reference within DEMA handy?

A Yes, I will look it up right now.

(Pause.)

Sorry, it appears it is not in this one (displaying document).

JUDGE BRENNER: I don't know if LILCO Exhibit 14 contains any different pages than what I believe you are looking at, but you might want to look just in case.

(Pause.)

We're not trying to give you a hard time. If we had a particular place we would point to it, as we have asked counsel to do in their cross-examination.

You may recall that one or both of you referred to the source for that requirement as the DEMA practices. We have looked at the DEMA practices and find no such source in it, so that's why Judge Morris asked his question.

(Document handed to the witness.)

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(Witness reviewing document.)

WITNESS HENRIKSEN: I'm sorry, I don't have it here.

BY JUDGE MORRIS:

Q Is it possible that such a requirement is contained in the IEEE Standard 387?

A (Witness Henriksen) That's possible.

WITNESS SARSTEN: I'm sorry, we do not appear to have C-4 here.

WITNESS HENRIKSEN: We do not have 1 through 15, I think.

BY JUDGE MORRIS:

Q It is your understanding that it is standard practice to require that overload test?

A (Witness Henriksen) Yes.

Q -- or calculation, I'm sorry.

It's a calculation, not a test, or is it both?

A I don't understand the question.

Q Pardon?

A I did not understand the question.

JUDGE BRENNER: Mr. Ellis.

MR. ELLIS: I am terribly reluctant to do this but I thought that we had established in our cross-examination of these witnesses that there was no foundation or no basis for them to know the DEMA practice

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with respect to calculation.

JUDGE BRENNER: Well maybe you did up to a point. We also saw a question by the County -- and this should remind us all as to the danger of leading questions, even when not on direct or redirect -- which assumed expressly in the question that the requirement for the 10 percent overload calculation was in DEMA and the witness readily agreed with the leading question and now we wanted to probe that some more and for all we know the probing may get us back to your point. But it would have been better not to have discussed this, as we just did.

MR. ELLIS: Yes, sir.

WITNESS HENRIKSEN: There is a reference to it in the IEEE, paragraph 3.7.2.

BY JUDGE MORRIS:

Q And what does that reference entail?

A (Witness Henriksen) That is C-4, Exhibit C-4.

Q What was the paragraph again?

A 3.7.2.

Q Do you know whether or not there is any requirement for testing of this 10 percent overload at anything other than synchronous speed?

A No, the idea is to test it at synchronous speed.

Q Thank you.

JUDGE BRENNER: I just have questions that I

AGBagb

believe will take a short amount of time.

BY JUDGE BRENNER:

Q Professor Sarsten, in answering some of Judge Morris' questions, you were referring to the knee of the S-N curve. We have had other testimony on that subject also from other witnesses.

Earlier in, I believe, cross-examination by Mr. Ellis he referred you to the experience at which the old crankshaft in the 102 engine operated, specifically in LILCO Exhibit C-17 at page 3-10.

Do you recall generally your having referred to that and his questions?

A (Witness Sarsten) Correct.

Q As I looked at that exhibit at the time it indicated that the number of hours that Engine 102 had been run with the old crankshaft at or above 100 percent load encompassed in terms of cycles four times ten to the sixth cycles.

Would you agree that the number of hours portrayed there would be that number of cycles, or would you have a reason to disagree with that?

A No. I know that roughly 740 hours gives ten to the seventh, so your figure should be somewhat above ten to the sixth.

Q Taken -- actually, as I say, it is FaAA's figure

AGBagb

which I have borrowed for the occasion -- using that figure and therefore taking as a fact that the old crankshaft failed at something like four times ten to the sixth cycles, does that tell us anything meaningful with respect to the number of cycles of testing that would be advisable for the new crankshaft in the context -- if you want to put it in that context -- of where the knee of the S-N curve might fall for the new crankshaft?

A The old crankshaft, of course, was evidently -- in the diagram -- to the left and above the inflexion point or the knee as it is sometimes called.

But we must remember --

Q Excuse me. Could you tell us which diagram? Do you mean the Goodman diagram?

A The S-N diagram. Not the Goodman diagram, the S-N diagram.

Q All right.

A With a pronounced knee on it.

We also must remember that we have -- in the new crankshaft have a different material, a higher UTS slightly. We also know the forging process that has been employed here.

And in order to evaluate the effect I would prefer to have someone with more metallurgical background than me.

AGBagb

But to try to answer your question, I don't think this helps us perhaps very much as far as the number of cycles goes for the new crankshaft; we would have to go past the knee at whichever height it may lie, and that would require the 740 hours or more of testing, in my opinion.

MR. GODDARD: Excuse me, Judge Brerner, I don't wish to interrupt your line of questioning but we have had several references to metallurgical testimony. The Staff requested yesterday that our metallurgist on the two crankshaft questions be empaneled with the witnesses and he has indicated to me now that he would contribute something to the answer to that last question if he were allowed to do so.

JUDGE BRENNER: The problem was at the Staff's request we have been taking several witnesses out of sequence and he might have been empaneled with these witnesses by virtue of his having answered the two questions he answered that appears in the section on crankshafts other than the shot-peening section.

However those particular answers do not very directly relate to this particular question and the Staff could have chosen to put some more testimony in the direct testimony through that witness and did not.

We took him out of sequence at the Staff's request because we didn't know or, I suppose, didn't want to

AGBagb

assume we knew how long this panel would be on and, as I recall your schedule, Dr. Bush has to leave.

MR. GODDARD: He is leaving today, that is correct, Judge Brenner.

JUDGE BRENNER: I'm not going to empanel him and then you're going to tell me he's gone after today.

MR. GODDARD: I would only state at this time that in questions asked by Mr. Ellis dealing with the Goodman diagram in C-17, questions asked by Mr. Scheidt and questions asked by the Board itself have ranged into this metallurgical area where the witnesses have indicated they are not, in their opinion, the most capable witnesses on this subject and we do have a witness who is qualified to augment their answers on these questions.

JUDGE BRENNER: Fine. You should have adjusted your request in the manner in which the witnesses were empaneled, number one, and we could have put these two witnesses on with Dr. Bush from the beginning, but you didn't make that request.

On reading the direct testimony it certainly wasn't clear that they had to be empaneled together given the way the questions and answers were divided up with sponsorship indicated and that, in my own mind at least, supported the manner you wanted to proceed in as long as we had to make adjustments to begin with.

AGBagb

I have made what have unfortunately pretty much become lectures in this case several times as to the danger of trying to be a nice guy in accomodating witnesses' schedules and then causing problems in the substance of the proceeding and now you're telling me that maybe we have done that, and if we've done it it has been the Staff's fault and I'll leave it at that.

Just to have the last word on the subject, the only metallurgical testimony that the Staff chose to put in its written direct testimony, other than shot-peening, is that very succinct question and answer on forging which induced me, at least, to ask the witness what he was trying to tell me by that and I got that; and I also asked him about his conclusion on the number of cycles even though, in order to do that, I had to realize that necessarily he was contributing to the conclusion in that regard, because you certainly didn't highlight it for us when we put him on.

You didn't interrupt my line of questioning because I wasn't going to proceed any further given the witness' answer.

I do have a question on another subject, though.

BY JUDGE BRENNER:

Q Professor Sarsten, if you'll forgive me, this may be getting back into the areas of basics -- to you, at least, not to me:

AGBagb

You refer to the resonant frequency of the crankshaft. Could you first tell me what the difference in relationship is of a resonant frequency to a natural frequency of the crankshaft?

A (Witness Sarsten) These terms are often mixed. If you want to be very precise, the natural frequency would be the mathematically-determined one while the resonant frequency of the shaft would be that frequency which gave the highest amplitudes. But these coincide within the accuracy of measurements, so there's no point in really making that distinction. In other words, they are one and the same.

I have, however, been speaking about the crankshaft speeds or engine speeds which cause one order or another to come into resonance. This means that, for example, we're speaking of the resonant frequency for the fourth order; that means that the T-sub-n values of the fourth order, that is the excitation which happened four times each engine revolution, then are in resonance with the engine's natural frequency.

Q And tell me what you mean in that context, by being in resonance with the engine's natural frequency.

A You are then exciting the crankshaft at a frequency which is the same as the engine's natural frequency, in this case, of the one node natural frequency.

AGBagb

If you go to a lower speed, then you may have a 5.5 order which oscillates 5.5 times each revolution which then coincides exactly with the natural frequency of one node vibration.

Q You referred to the fourth order in your example. Is that the order that has -- that produces resonance with the natural frequency at the closest point to 450 rpm but above 450?

A To put it one way it's the order which produces the largest vibratory stresses at 450 rpm. The actual engine speed is, if I remember correctly, well above 500. But that is an enormous peak; because this is a major order all the excitations act in phase, they're all pulling together as a team, exciting large amplitudes of vibration of the crankshaft.

BY JUDGE FERGUSON:

Q Professor Sarsten, I need a little help with a figure you referred to early this morning. It is Exhibit Number 2 attached to your testimony. I want to make sure that I have, on this figure in front of me, all of the information that you have been able to provide.

It was my understanding this morning that you did some recalculations on Shaft Number 6, is that correct?

A (Witness Sarsten) That is correct. The recalculations really encompassed all the shafts.

AGBagb

Q So you have, in fact, data that would enable you to draw a new Exhibit 2, is that correct?

A That is correct.

Q Could you say, from your understanding of what that figure might look like, whether or not all of the shafts will have stresses below the DEMA limit or will 6 still be above the DEMA limit so far as the 5 percent above the 450 rpm value is concerned?

A Shaft Number 6 will lie above the DEMA limit. It will dip slightly below at roughly 440 and lie then again slightly above the DEMA limit at the lower end of the allowable speed range -- or corrected, the speed range covered by the DEMA requirement.

Q That was at the 7051 point that you gave us this morning?

A That is correct. All the other curves would be displaced downward in the same manner.

Q Well let's focus on Shaft Number 6 again and let me make sure I understand the picture, the word picture that you have given:

On Shaft Number 6 there would be one point at the 5 percent below the 450 which would be 7051 psi, is that correct?

A That is correct. I think when you took this figure and recalculated it to take into account the slight

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deviation between calculated and measured value, you got 7090 or something, I don't have the exact figure. But that is approximately correct.

Q All right.

What I am trying to understand is what part of that curve for Shaft Number 6 lies below the DEMA limit?

We have just established that the far left-hand point at the 428 revolutions per minute value is above, slightly above.

A That's correct.

Q Now at what frequency do we get -- if we go from 428, at what revolutions do we get above the DEMA limit again?

A I don't have a plot of that curve with me but the dip below the 7000 line is very small, insignificant, I would say roughly around 440 rpm plus-minus perhaps 5 rpm or just slightly below the 7000. I could plot it out accurately, if you wish.

Q I see.

I would be helpful if you could tell me what the value at 450 is, do you know that?

A I would have to look --

Q -- the new value?

A -- in the testimony.

Q The new value, the one --

AGBagb

A -- the value in the testimony is correct. I had time to get hold of a computer and recalculate that value using the new damping.

Q Okay. That's the value in the testimony.

A That is the value in the testimony, that is correct.

Q Okay. Thank you, Professor Sarsten.

JUDGE BRENNER: I have one last quite minor question on that same Exhibit 2.

BY JUDGE BRENNER:

Q In looking at the key, Professor Sarsten, in the lower right-hand corner there, one might infer that the symbol which is the black circle with a white concentric corona, if you will, around it is the sum of 24 orders and that key figure appears at approximately 7000 psi at 450 rpm.

That is not to imply that the other ones are not the sum of the 24 orders, is it?

A (Witness Sarsten) No, that only implies that that value has been converted to the .693 measured front end amplitude. The correction is so small that the discrepancy did not -- difference did not show here, so we only had one point. There should have been a black square squarely behind the circle.

Q All right.

AGBagb

And all the other data points are in fact the sum of the 24 orders?

A That is correct. All the data points, all shafts, are the sum of 24 orders.

Q That was your testimony but I wanted to make sure I was not misunderstanding the key.

All right.

JUDGE BRENNER: That's all we have.

Redirect by the Staff?

REDIRECT EXAMINATION

BY MR. GODDARD:

Q Dr. Sarsten, in response to a question by Judge Morris, you testified that you used a dynamic magnifier of 40 to be on what you described as the safe side.

Would that chosen value of dynamic magnifier tend to underestimate or to overestimate the torsional stresses relative to actual torsional stresses in the crankshaft?

A (Witness Sarsten) They would tend to underestimate the stresses slightly.

Q Can you put a quantitative value on "slightly?"

A It is a little difficult because the effect would vary according to the engine speed. As you reach towards the lower left-hand corner of the aforementioned exhibit, you reach closer to a resonant speed of 5.5 order and the effect is larger than it is at 450 rpm. There the effect,

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I would say, is not very great. I would have to calculate it to put a number on it and that number would vary with engine speed.

MR. GODDARD: Staff has no further redirect for these witnesses.

JUDGE BRENNER: LILCO, any follow-up?

MR. ELLIS: Yes, sir.

JUDGE BRENNER: Could you give me an estimate?

MR. ELLIS: Yes, sir, I would say 10, 15 minutes.

JUDGE BRENNER: All right. Why don't you proceed?

MR. ELLIS: Thank you.

RECROSS-EXAMINATION

BY MR. ELLIS:

Q Following up that last question, Professor Sarsten, the damping factor that you ultimately chose, not the first one, but the second one that you ultimately chose, I take it you are satisfied with that damping factor or you wouldn't have chosen it, isn't that right?

A (Witness Sarsten) That is correct. I wanted, as I said, to be on the safe side. I am satisfied with it. I have no intention of making new calculations with that factor just to polish the apple.

Q All right.

Next in response to a question, I think by Judge

AGBagb

Morris, you mentioned that another method of -- I believe it was Judge Ferguson -- another method of evaluating the adequacy of the replacement crankshaft is to take the stress levels relative to the strength of the materials.

Do you recall that testimony?

A No, I don't. I would have to get it read back to get the context. I don't recall it accurately enough.

Q Well would you agree that a comparison of the endurance limits of a crankshaft with the stress that a crankshaft actually experiences is a method of assessing the adequacy of a crankshaft to perform its intended service?

A It would enter into the process of evaluating the adequacy of the crankshaft.

Q Well isn't it fair to say, Professor Sarsten, that it is a widely used method for determining the factor of safety against fatigue to machine components and other items to compare the endurance limit against the stress that is actually measured?

A That is correct.

Q And are you aware that such measurements were made in connection with the replacement crankshaft?

A I am aware that measurements were made in connection with the replacement crankshaft.

Q And do you know what the comparison was between the actual stresses that were measured, torsional stresses

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that were measured for the 13x12-inch crankshaft at Shoreham as compared to the endurance limit of the material of that crankshaft?

MR. SCHEIDT: I object to this line of questioning. I think it is far outside the questions that were asked on cross-examination by any of the parties --

MR. ELLIS: Judge Brenner --

MR. SCHEIDT: -- including the Judges.

(The Board conferring.)

JUDGE BRENNER: I will save you some trouble, Mr. Ellis, we will overrule the objection. We think it is within the realm of fair follow-up to Judge Morris' questions which we thought were material in the first instance or we wouldn't have asked them.

MR. ELLIS: May I have my question read back, please?

(Whereupon, the Reporter read from the record as requested.)

BY MR. ELLIS:

Q Do you understand the question, Professor Sarsten?

A (Witness Sarsten) I understand the question. I do not remember all these numbers, to be frank. I read that again early this morning but all these figures have drifted out of memory.

AGBagb

Q Would it refresh your recollection if I told you that the endurance limit of the replacement crankshaft was 39.2 ksi?

A Yes, taking a UTS of roughly 100 that figure would seem appropriate.

Q And would it also refresh your recollection if I told you that the stress measurements from the operation of the replacement crankshaft at Shoreham resulted in measurements of 24.6 ksi?

You may look at --

A No, that sounds like a reasonable number taking the fillets and everything into consideration, yes.

(Pause.)

Q Given that there is a measurement of the stress of the replacement crankshaft in the place of highest stress and endurance limit of the actual material, would you agree with me that that certainly gives one some confidence that the crankshaft, the replacement crankshaft is adequate for intended use at 3500 Kw?

A No, let me explain.

We are here speaking, among other things, of a slab forge crankshaft. We have metallurgical considerations and I do not feel confident to assess the fatigue strength quoted and if it is appropriate or not. It is a little outside my field of expertise.

AGBagb

Q Well then I take it that you would not consider yourself competent then to make a judgment on the basis of the actual stresses that were measured and the ultimate endurance strength of the replacement crankshaft; that is outside your area of expertise, is that correct?

A I am saying that an assessment of the fatigue limit of this material, the forging process, is outside my expertise, yes.

Q Is what you're saying then that you cannot -- Strike that.

Assuming that the endurance limit that we have talked about and the stresses that we have talked about are correct, would that then give you confidence that the replacement crankshaft can perform its intended function at 3500 Kw?

A No. Again as I have expressed in the testimony, I do not have sufficient confidence in this one calculation to use that as the sole basis of assessing the adequacy of this crankshaft in this very critical -- or what could be a critical situation.

Q Would you agree though that it is a basis for making a judgment?

A It may be some supplementary evidence but I would not use this alone as a basis.

Q I take it then you would prefer to rely on the

AGBagb

classification society rather than on the actual measured stresses and the actual endurance limit of the material, is that correct?

MR. SCHEIDT: Asked and answered two or three times.

JUDGE BRENNER: Sustained.

BY MR. ELLIS:

Q Do you know whether the method of comparing actual stresses measured against endurance limits is used on other machinery components to determine their fatigue properties?

MR. SCHEIDT: Asked and answered and beyond the scope of cross again.

MR. ELLIS: I don't think that's been asked and answered.

JUDGE BRENNER: It seems to me -- I'm sure that people with more years on the bench than myself might be able to explain it to me -- that that is an inconsistent objection. You can pick either asked and answered or you can pick....

(Laughter.)

(Pause.)

JUDGE BRENNER: Our recollection, Mr. Ellis, is that it has been asked and answered.

MR. ELLIS: I beg your pardon?

AGBagb

JUDGE BRENNER: Our recollection is that it has been asked and answered, but if you put me to the test right now and ask me what the answer is, I personally don't remember.

I'm going to allow it. I remember the question, I don't remember the answer. If Mr. Ellis needs it to follow up on something, we will give him the leeway.

Do you recall the question after all that, Professor Sarsten?

WITNESS SARSTEN: No, I would prefer to have the question reread, I'm sorry.

JUDGE BRENNER: Could you rephrase it, Mr. Ellis, or repeat it?

MR. ELLIS: Just a minute, Judge, let me rephrase it.

(Pause.)

BY MR. ELLIS:

Q Professor Sarsten, do you know whether the method of comparing actually measured stresses with the endurance limit of the material is a method used for determining the fatigue properties of machine components of various kinds?

A (Witness Sarsten) You said "determining the fatigue properties." Could you rephrase the question.

Q The adequacy of the machine components.

A That's better.

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I am aware that this method is often used on new mechanical components, yes.

Q Were you asked to review FaAA's calculations or methods of determing the actual endurance limits? Or are you competent to do that?

A As I said before, when we get into fatigue, metallurgy, I do not feel myself competent.

Q Thank you.

A And here again, also, I must add that we have the manufacturing process, the forging process, which enters into the picture, which is a substantial input.

JUDGE BRENNER: Professor Sarsten, is there any other Staff written direct testimony which I am missing in which any Staff witness testifies in answer to Mr. Ellis' question, if you know?

WITNESS SARSTEN: I do not know offhand, no.

JUDGE BRENNER: All right. I don't know of any either, but in case I was missing something I wanted to let you or Mr. Henriksen help me.

WITNESS SARSTEN: I may have misinterpreted your question.

JUDGE BRENNER: -- on crankshafts. Maybe I should have said that.

WITNESS SARSTEN: On crankshafts and the manufacturing process, Bush has --

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JUDGE BRENNER: I know. I'm talking about the analysis of the -- an analysis of the analysis performed by FaAA in terms of coming to a corclusion as to the endurance limits of the new crankshaft.

WITNESS SARSTEN: No.

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BY MR. ELLIS:

Q Professor Sarsten, you were asked some questions about the T-sub-n's and frontend amplitudes. Is the safety factor that is calculated by FaAA's as reflected in 313 depend on either the T-sub-n's or the frontend amplitude calculated by T-sub-n -- calculated by FaAA or used by FaAA?

A (Witness Sarsten) I would have to find the figure, it's figure 313?

Q Exhibit C17, figure 313.

JUDGE BRENNER: Professor Sarsten, it is the Goodman diagram that you were asked about earlier with respect to fatigue safety factors. Do you have it?

WITNESS SARSTEN: No, it is my understanding that the calculated torsional stresses do not enter into this. this is based, I believe, upon the measured values.

MR. ELLIS: You were asked some questions about table 2.5 at 2-11. Would you look at that, please?

JUDGE BRENNER: Still in Exhibit C17?

MR. ELLIS: Yes, sir. Still in Exhibit C17.

WITNESS SARSTEN: Yes.

BY MR. ELLIS:

Q I believe you told Mr. Scheidt that you thought the figures in the righthand column were based on the motile superposition model, is that correct?

A (Witness Sarsten) That is correct. They are

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calculated from the torsiograph test.

Q Well, the torsiograph test is not the motile superposition, is it?

A I realize that.

Q So would it be fair then to correct your testimony to say that the figures in the righthand column really aren't related or don't have anything to do with the motile superposition?

A The shear stress figures given you here must, if calculated from the frontend amplitude, must be based upon a torsional vibration. A half peak-to-peak figure here is given, which I assume is for the sum of orders. I must admit that these exhibits are not always clear in this respect, but this is the way I have read the table.

Q Professor Sarsten, you were asked a number of questions in which you indicated that the difference between the frontend amplitude that you used and FaAA used, was between four and five percent. Isn't it also true that the differences in your predicted summed stresses, and the FaAA summed stresses, was even smaller than four percent?

A I have not locked into the comparison; it may be.

Q Well, your figure was 7,068, is that correct?

A That is correct. That is the calculated figure, but not corrected for frontend amplitude.

Q That was your predicted figure?

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A Right.

Q And the -- do you recall the FaAA predicted figure for a sum of 24 orders?

A No.

Q If I tell you -- look at 3-15. Page 3-15 of C71.

A Yes.

Q Do you see the figures in the righthand column?

A 315 -- here. Yes.

Q Does that refresh your recollection?

A Yes, I remember the figure of 7006.

Q And wouldn't the difference between that figure and your 7068, be less than a four percent difference?

A That would be less than a four percent difference; that is true.

Q In fact, it's less than one percent; isn't it?

A Yes, that is true.

Q Do you consider that the difference of, roughly, 90 psi or 60 psi are significant, with respect to making an assessment of the adequacy of a crankshaft, when the standard of 7000 is based on a range of crankshafts?

A The difference in these calculated values is not essential. I must also point out that this is above the DEMA limit of 7000.

Q Putting the DEMA limit of 7000 to one side, are the differences significant in your opinion, with respect to

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making an assessment of the adequacy of the crankshaft?

MR. SCHEIDT: Asked and answered, Judge Brenner.

JUDGE BRENNER: We will allow him -- yes it has been, but we will allow leeway to follow up, given the last few questions to leading into it. The answers aren't always the same. I have given the County the same leeway, as I recall, among pistons, among other areas.

Do you recall the question, Mr. Sarsten?

WITNESS SARSTEN: I was asked, concerning the magnitude or difference, if it was significant or not? I would say normally it is not significant. If you were borderline it might, perhaps, tip you over the limit. But I would say, in general, it is not significant.

BY MR. ELLIS:

Q You testified, Professor Sarsten, that there was some slight uncertainty with respect to the measured values, but you couldn't quantify it. Is there also some uncertainty with respect to the predicted or calculated values that you used, that are not based on actual measurements?

A (Witness Sarsten) The uncertainty lies in the T-sub-n values. Here we have both, I assume, used exactly the same T-sub-n values. And I'm very grateful to see that the figure 7006 here, is accepted as the stress in shaft six by TDI. Several figures have been found throughout these

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calculations and I'm not quite sure which values I should refer to, to be frank. We've also had the previous table with the figure of 6600-something psi.

Q So this is the first time you've seen the 7006?

A No, it is not the first time. I've seen it previously. I've also seen it referred to in calculations apart from this table.

Q All right. When you said that you were glad to see it, the clear implication was that you hadn't seen it before. You have seen it before?

A No, I'm glad to see that it's accepted, put it that way. I'm sorry.

JUDGE BRENNER: Mr. Ellis, let's try not to repeat the question immediately after the question.

BY MR. ELLIS:

Q Is there any uncertainty in the figures that you used to predict your summation of orders, or are they precise?

A (Witness Sarsten) As explained previously, we used the same T-sub-n values, we used the same constants for the system parameters. The only deviations can come from the differences in damping, perhaps. I must add that I have seen several curves of stresses supplied by Failure Analysis Associates previously, where the figure was below the 7006 shown here. And I am sometimes at a loss to know which

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figures to use. The whole issue would have been clarified if there had been a curve of stresses in the report, such as is given by Chen, for example, and it's much easier to see there which values were calculated.

JUDGE BRENNER: Mr. Ellis, we're getting repetitive testimony now. It is not wholly your fault, because the questions are differently phrased, but the answers are coming back the same and, in some cases it is your fault. But, in any event, consider whether you've got any real follow up left to plow that will adduce any new information before you ask any more questions.

MR. ELLIS: I have just a couple more, but I want to be sure that I have an answer to that question. I want to be -- may I ask --

JUDGE BRENNER: No, don't ask that question again.

MR. ELLIS: I don't believe I have an answer to whether he agrees that there is an uncertainty or not as to those particular values.

JUDGE BRENNER: Don't ask that question again.

MR. ELLIS: May I --

JUDGE BRENNER: Or I'll rule that you're not permitted to ask it and you can take an exception. The reason being, it's been asked, perhaps in different ways, but many times, including by Judge Morris. And we've got

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that information in the record as to his view in that regard, I am confident. So proceed to your next question.

MR. ELLIS: All right, Judge Brenner. I'm not as confident that a direct answer was there. I'll proceed.

JUDGE BRENNER: Mr. Ellis, there comes a time when I get the last word.

MR. ELLIS: I know that, Judge.

JUDGE BRENNER: But it should come the first time I want to get the last word, and not the second time. And I think I've given you greater leeway in that than some other judges that I, at least, have seen.

MR. ELLIS: I appreciate that, Judge. But I'm trying to do what I can do.

JUDGE BRENNER: You've got your exception if I'm wrong, you always do. I know you want to ask it, but I'm not going to let you. So you're going to have to move on to something else.

MR. ELLIS: All right, Judge, I will.

BY MR. ELLIS:

Q Mr. Henriksen, I believe in response to a question by Mr. Scheidt, you said that Nordburg calculated the DEMA stresses at 110 percent load, was that your testimony?

A (Witness Henriksen) That's correct.

Q Did you obtain that information on the basis of a

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telephone call?

A No, that was the policy at the time that I was working at Nordburg.

Q The IEEE 387 standard that you referred to is a testing standard; isn't it?

A I beg your pardon?

Q The IEEE 387 standard or reference that you made to the 2 hours out of 24 for overload is a testing requirement; isn't it?

A Yes, but that's not the way DEMA has worded it. The reference material here, I can't quote it word for word, but I can tell you the content.

Q Is it your testimony that there is an explicit requirement in DEMA that the calculation for DEMA be done at 110 percent of the rated load?

A No, but there is explicit permission for a customer to run his engine at 10 percent overload for 2 hours in any 24 hour period.

Q You also gave some testimony, Professor Sarsten, concerning the Lloyd T-sub-n's. I believe you siad that those T-sub-n's were all right to be used in connection with the Lloyd's standards, as Lloyds interpreted it; is that correct?

A (Witness Sarsten) That is correct.

Q And then you mentioned a German writer who said

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that the Lloyd T-sub-n's were too low. Was that German writer referring specifically to the use of Lloyd's for DEMA application?

A He was referring specifically to the use of the Lloyd's data for calculations in general.

Q But he did not specifically reference DEMA, did he?

A No, he did not.

Q So you don't have any personal knowledge of whether he intended that to apply to DEMA or not, did you?

A I didn't have any personal knowledge of that; no.

MR. ELLIS: That's all we have, Judge Brenner.

JUDGE BRENNER: I don't know if there's any follow up left that we haven't uncovered yet, but I'll ask the County.

Do you have any more questions?

MR. SCHEIDT: Like the last time, Judge Brenner, I think it is three questions, approximately three.

JUDGE BRENNER: You're learning.

Go ahead.

RECROSS-EXAMINATION

BY MR. SCHEIDT:

Q Professor Sarsten, Judge Ferguson referred to a prior testimony concerning the plus or minus five percent accuracy of strain gauge tests, and I wanted to ask you

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whether that plus or minus five percent applied to a torsiograph test?

A (Witness Sarsten) I have not seen figures published, but I would believe that the front end measurements weren't the kind of instrument employed had a better accuracy than plus or minus five percent.

Q And you also testified that you believe that a 1.1 factor of safety under a certain classification society would be adequate for the stationery diesel engines -- for stationery diesel engines like the EDG's at Shoreham.

But that 1.1 does not relate to FaAA's factor of safety 1.48, does it?

A It does not, definitely. That is using this classification society's rules which has, baked in them, other factors of safety.

Q Is there any way to compare the two?

A I don't think I'm the right person to assess that. That would have to be a senior surveyor of the classification society concerned.

MR. SCHEIDT: Thank you. No further questions.

JUDGE BRENNER: Staff, we'll give you the opportunity for the last word, if you have any?

MR. GODDARD: No further questions.

JUDGE BRENNER: We have completed this panel on this subject. I won't prolong any thank you's or good bye's

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because you will be here tomorrow morning wearing different hats, or no hats, but different subjects. And we will excuse you right now. You can leave the stand if you want.

As I understand it, tomorrow morning, we will begin with the Staff's testimony on pistons, am I correct?

MR. GODDARD: That is correct, Judge Brenner.

JUDGE BRENNER: And it is the same two witnesses; am I correct?

MR. GODDARD: That is correct, also.

JUDGE BRENNER: All right.

And you will carefully, at the time we introduce the testimony, identify any and all questions that these witnesses are being sworn in to answer at that time.

And any pertinent exhibits. I guess there's only one exhibit. It would be 6, I believe.

MR. GODDARD: That's correct.

JUDGE BRENNER: All right.

If there are no miscellaneous matters, and we have none, we can adjourn at this time until 9 o'clock tomorrow morning.

If there are none, we'll go off the record.

(Whereupon, at 4:58 p.m., the hearing was adjourned, to reconvene at 9:00 a.m., Wednesday, September 26, 1984.)

CERTIFICATE OF OFFICIAL REPORTER

This is to certify that the attached proceedings before the UNITED STATES NUCLEAR REGULATORY COMMISSION in the matter of:

NAME OF PROCEEDING:

LONG ISLAND LIGHTING COMPANY

(Shoreham Nuclear Power Station)

DOCKET NO.: 50-222-OL

PLACE: HAUPPAUGE, NEW YORK

DATE: TUESDAY, SEPTEMBER 25, 1984

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(Sigt) William R. Bloom Anne G. Bloom

(TYPED) William R. Bloom/Anne G. Bloom

Official Reporter

Reporter's Affiliation