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UNITED STATES
NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF:

LONG ISLAND LIGHTING COMPANY

SHOREHAM NUCLEAR POWER STATION

DOCKET NO:

50-322-OL

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October 30, 1984

TO: All Recipients of Transcripts of Proceedings of
Docket No.: 50-322-1 (OL)
Long Island Lighting Company
(Shoreham Nuclear Power Station)

I. Enclosed are corrected transcripts in the above matter for the following days:

September 10, 1984
September 11, 1984
September 12, 1984
September 13, 1984
September 17, 1984
September 18, 1984

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II. A corrected transcript for September 19, 1984 is in the process of being prepared and should be distributed in the near future.

III. Portions of the following pages have been questioned by the Commission. The items are being checked against the original notes by the subcontractor. New pages will be distributed when the items are resolved.

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Sincerely,

Alan I. Penn
Vice President

Encl.
AIP/alr

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY & LICENSING BOARD

In the matter of: :

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

Long Island Lighting Company) :

State Office Building

Veterans Memorial Highway

Hauppauge, New York

Tuesday, September 18, 1984

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

BEFORE:

JUDGE LAWRENCE BRENNER,
Chairman, Atomic Safety & Licensing Board

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

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

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APPEARANCES:

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C O N T E N T S

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P R O C E E D I N G S

JUDGE BRENNER: We're on the record.

Good morning. As everyone can see, it's approximately 9:50. We apologize for the very late starting time. We are starting late due to the necessity to have off-the-record discussions in chambers, first among the Board and the court reporter and secondly among the Board and counsel for the parties, both discussions due to problems with the accuracy of last week's transcript and problems with the way yesterday's transcript was compiled. We are ready to begin at this point. We will have to take a break at no later than 10:35. We will take a break at that time, so keep an eye on the clock. We will then have the cross-examination, Mr. Scheidt.

MR. SCHEIDT: At this time the County proposes to cross-examine Dr. Pischinger on his section of the testimony in order to accommodate his schedule.

JUDGE BRENNER: All right.

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Whereupon,

FRANZ F. PISCHINGER,

EDWARD J. YOUNGLING

SIMON CHEN,

EUGENE MONTGOMERY,

PAUL JOHNSTON,

and

ROGER L. McCARTHY,

were called as witnesses on behalf of the Applicant and, having been previously duly sworn, were examined and testified as follows:

CROSS-EXAMINATION

BY MR. SCHEIDT:

Q. Dr. Pischinger, you reviewed the replacement crankshafts for compliance with the Kritzer, K-r-i-t-z-e-r, hyphen, Stahl, S-t-a-h-l, design criteria?

DR. PISCHINGER: Yes.

Q. Is the Kritzer-Stahl design criteria a design code?

DR. PISCHINGER: What do you mean by "design code"?

Q. Dr. Pischinger, you used the term "code" or "design code" in your deposition to describe this Kritzer-Stahl design criteria, and I refer you to

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County Exhibit 41 at page 94, if you need to refresh your recollection.

JUDGE BRENNER: Marked at a point that is so labeled at pages 6 and 11, at least of his testimony, and perhaps other places. Since we have that in the record, we can use that for reference.

DR. PISCHINGER: This Kritzer-Stahl criteria method is a method for calculating stresses in a crankshaft and compares the stresses with precalculated endurance limits or limit of the material and, by this, can calculate a factor of safety, so the way it is used in design is to give the design of the crankshaft as an input to the operating conditions of the engine as an input and to arrive at a given stress level and ratio with stress and endurance limit.

Q. Does the Kritzer-Stahl design criteria concern any other aspects of crankshaft design?

DR. PISCHINGER: I think I said geometry of the crankshaft.

Q. And with what aspects of the geometry of the crankshaft does the Kritzer-Stahl design criteria concern itself?

DR. PISCHINGER: To make it a little easier, may I refer to some written text?

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Q. Certainly. Are you referring to the design criteria themselves?

DR. PISCHINGER: Yes. It's a relative overlap of the crankshaft and the crank pin. It's a relative width of the web and the thickness of the web, the post-dimensions of the web and the radius, or if there are two, radii of the fillet. These are the dimensional properties of the crankshaft used in the Kritzer-Stahl method. I think to clarify or to elaborate a little more on this important input, there's a second criteria for influence of the dimensions used in German industry, which is according to the author of it, Lejkin, L-e-j-k-i-n, Lejkin, and he uses the same dimensional inputs and, in addition, he also takes into account if there is an oil pin.

Q. Oil hole (phonetic)?

DR. PISCHINGER: Not the oil hole: oil hole is a different pin. Sometimes a design of the crankshaft has a central hole in the crankpin or mostly the crankpin.

Q. Do the replacement crankshafts at Shoreham have such a hole?

DR. PISCHINGER: No. We used for safety also this Lejkin method to calculate stress

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concentration factors, and we found that more recent Lejkin methods give lower values, so for safety, we took the larger stress concentration factor of Stahl.

Q. Of Stahl, S-t-a-h-l?

DR. PISCHINGER: S-t-a-h-l.

Q. And Lejkin's method is not a part of the Kritzer-Stahl design criteria, is it?

DR. PISCHINGER: No, but it is often used in parallel, and the figures are not very much different, which says that both methods roughly — give similar figures — it's a little difficult. I only have got a telecopy of this, our calculation, because the requirement for this side calculation has been given to us rather late, so I have at the moment —

Q. Who has required you to make this calculation, your attorneys?

DR. PISCHINGER: Yes.

Q. And this calculation is not reflected in your testimony?

DR. PISCHINGER: It is reflected in the testimony. The stress concentration factor according to Lejkin is 1.967, and the same factor according to Stahl, S-t-a-h-l, is 2.084.

Q. The numbers are 1.967 and 2.084?

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DR. PISCHINGER: 2.084.

Q. Okay, Dr. Pischinger. Is this design criteria a design code?

JUDGE MORRIS: Excuse me, Mr. Scheidt. Perhaps I can help on this. I think he's having trouble with our use of the word "code." For example, Dr. Pischinger, the American Society of Mechanical Engineers has what they call a code for design of pressure vessels, so that code is sponsored by that professional society, and they have some authority in this country, and I think what Mr. Scheidt is searching for, and I would like to understand, is what sponsorship, for example, the Kritzer-Stahl criteria would have in Germany.

DR. PISCHINGER: This criteria, this procedure, is based on a lot of research work through German companies, but there is no formal group which, let's say, which established this as some sort of binding code for design. In this case, it's criteria which is published and used by German engine manufacturing companies.

Q. In fact, Dr. Pischinger, the Kritzer-Stahl design criteria consists of a series of magazine articles. Isn't that true?

MR. STROUPE: I'm going to object to that.

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I don't know what Mr. Scheidt means by "magazine articles," trade publications?

JUDGE BRENNER: He can ask the question. We'll find out the answer. Objection is overruled.

DR. PISCHINGER: Well, it's published in in an acknowledged German engineering journal. In my German understanding, I would not call it a magazine, which reminds me of other pictures.

Q. And these don't have any pictures, Dr. Pischinger?

DR. PISCHINGER: You do not want me to reflect on this?

Q. And these articles, if you may call them articles, are dated approximately 1958 to 1961. Isn't that true, Dr. Pischinger?

DR. PISCHINGER: Yes, this is true, but they are updated in more recent foreign publications, which the last one has been published two years ago, but the name we give to it is according to the original authors. Of course a lot of additional engineers and scientists contributed to further confirming and updating this criteria and, of course, we always use the latest version of it.

Q. Do the articles that you use in performing your calculations under the

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Kritzer-Stahl design criteria rely on any of those revisions?

DR. PISCHINGER: Yes, in some points.

Q. In what way, then, Dr. Pischinger?

DR. PISCHINGER: For instance, the calculation of the nominal stresses, which is not so much the main substance of Kritzer-Stahl, but which is also a prerequisite of using this method.

Q. And other than your calculations for nominal stresses, did you rely on any revisions to the criteria in any of your calculations?

DR. PISCHINGER: I already mentioned Lejkin, whose results have been revised, but I should not say altered, critically revised by Maas and Klier, but this criteria is based on numerous thousands of measurements on crankshafts which have been taken with a lot of effort and a lot of money behind it, so the main substance of this, results of these measurements, are still the base of using this criteria.

Q. But most, if not all of that research, occurred prior to 1961. Isn't that true, Dr. Pischinger?

MR. STROUPE: Judge Brenner, I would like to put an objection on the record. My understanding

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was that the County was contending that the criteria, German criteria used by FEV showed that the crankshafts were not adequately designed for operating an overload, but marginally for operating at full load. It seems to me what Mr. Scheidt is now doing is relating to the merits of the actual design criteria which, as I read it, is not in the contention. It's certainly not in the testimony.

JUDGE BRENNER: Mr. Scheidt?

MR. SCHEIDT: Judge Brenner, the value of this calculation depends on the worthiness of the design criteria, and he uses the design criteria to show that the replacement crankshafts are adequate. He also says this is a very conservative design criteria on page 4 of his testimony and, apparently, values this criteria as a responsible indication of adequacy for the crankshafts.

JUDGE BRENNER: Mr. Stroupe's objection is, however, that you have not put into issue the value of the criteria, but only your complaint, that the replacement crankshafts will not meet the criteria in one circumstance and will only marginally meet the criteria in the other circumstance.

Give us a moment while you confer also.

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(Board confers.)

JUDGE BRENNER: We're going to overrule the objection; however, the objection is literally correct in reading the contention, notwithstanding that it is a necessary fact of life that in order to evaluate as a Board the significance of the asserted compliances or asserted noncompliances and the degree of compliances and noncompliances of the crankshaft with respect to some of the criteria set forth in the standards listed in the contention, we need to know something about the standards being used.

As the County pointed out, the testimony itself gets into that a little bit in describing the conservative guidelines in this case, but even without that in the testimony, it would have been pertinent for the reasons I just indicated. In fact, what's in the testimony is just a recognition of that fact by the witness, a recognition which we would have shared even if it had not been in the testimony. However, in making our decision on this contention, we will look to the wording of the contention, and the focus is on what the contention asserts.

And we would want to control the degree

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to which any cross-examination will go into the standards themselves. It could quickly get out of control and start to shift. We'll control it, but we would expect you to control it and bear in mind that some of this may help us understand the picture a little better but may not be pertinent to the findings when we go back to the wording of the contention to make our findings.

Do you need the question repeated after all that?

DR. PISCHINGER: Yes, please.

JUDGE BRENNER: Mr. Scheidt, can you --

MR. SCHEIDT: I have the question in mind.

BY MR. SCHEIDT:

Q. Isn't it true, Dr. Pischinger, that most, if not all, of the research that is a part of the Kritzer-Stahl design criteria was performed prior to 1961?

DR. PISCHINGER: Yes, this is true, and they're updating activities. Now since we took that into account, it gives the feeling or gives the background that these criteria are on the conservative side, as is the case with similar rules or codes which you update. If it is allowed, I could give you -- try to give you a measure or an

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example of the conservative feature of this design criteria. Yes?

Q. Give it a shot, Dr. Pischinger.

DR. PISCHINGER: First of all, I want to point out that this design criteria takes into account much more special features of the design than the usual classification methods and so on, examples that were mentioned yesterday, but what we did in this case, again, to show the conservatism, is that we calculated by the same method, the 11-by-13 inch crankshaft, so we have two calculations, 11-by-13 inch crankshaft, and 12-by-13 inch crankshaft.

The result for the 11-by-13 inch crankshaft is that it should have failed, that means after two times ten to the sixth cycles, which is roughly about 150 hours. It is well known that the 11-by-13 inch crankshaft, in reality, failed at four times ten to the sixth cycles, two million and four million cycles, so it means that this criteria predicted only half the time for the failure by which you could calculate it, even the factor of conservatism.

We did this within the SN curve of crankshafts we have, and it came out that it was in

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the range of 22 percent. That means that this criteria has an inherint safety of about 22 percent. I could give you the --

Q. Dr. Pischinger, when you say it has an inherent safety of 22 percent, are you referring to the original versus the replacement crankshafts or does it have an inherent safety factor when you calculate endurance limits of any crankshaft?

DR. PISCHINGER: I only would say for this type of crankshaft. That means one could safely relate this also to the 12-by-13 inch crankshaft, because the differences in design are minor and the rules have been or the criteria has been applied the same way.

Q. Without getting into great detail at this point right now, Dr. Pischinger, but did you use linear cumulative damage techniques in predicting the fatigue endurance limit of the original crankshafts?

DR. PISCHINGER: No, we simply used an SN curve. That means the Miner rule, but we did not use any special formula. We relied on data on broken crankshafts of this size. There have been a lot of tests with broken crankshafts of about this size, and from all this data, the SN curve has been

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set up and we use this data to predict.

JUDGE MORRIS: Dr. Pischinger, while we're talking about SN, could you just explain for the record what SN stands for?

DR. PISCHINGER: Yes. We call it in German Wohler curve, W-o, with two dots, h-l-e-r curve, and it is a fatigue — it shows the relationship between the stress for failure and the numbers of cycle where this failure occurs, and in this case, we took a curve for a complete failure. That means crack going through.

DR. MC CARTHY: The S stands for stress and the N stands for number of cycles.

Q. Dr. Pischinger, in developing this, the SN curve that you used in your calculations, was that based solely on failures of crankshafts or is it based upon components or other objects made of the same material?

DR. PISCHINGER: This is only based on failures of crankshafts.

Q. And approximately how many crankshafts failures are incorporated into that SN curve?

DR. PISCHINGER: We used two sources, and I cannot remember at the moment the exact number of crankshafts, but it was quite an expensive and large

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experiment. It was not out of field experience testings, let's say breakage by chance, but it was an intentionally set-up test to arrive at such an SN curve, and we had two sources, used two sources. One source even was the same material as the Shoreham crankshaft.

Q. Okay, Dr. Pischinger. Can you give me an approximate number of the number of crankshafts that are incorporated in the SN curve?

DR. PISCHINGER: I would prefer to give you this information later on because it is published, and I want to reread it again before I give you a figure.

Q. Would you be capable of providing me with that figure, Dr. Pischinger?

DR. PISCHINGER: Well, I have to rely on phone calls with my people who have this literature, and this could be certainly until tomorrow.

JUDGE BRENNER: I don't know how important the particular number is to you, Mr. Scheidt. Why don't you, if you have a particular range or minimum numbers you're interested in, why don't you try that? I don't think you know whether you need a particular number at this point.

MR. SCHEIDT: Well, I assume if it's two --

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JUDGE BRENNER: Ask him a question like that.

DR. PISCHINGER: I wouldn't have mentioned the source if it had only been two. It was certainly a couple of crankshafts which has been used for this, but I could give you the figures. It's certainly enough for engineering scientists to set up such an SN curve.

Q. How many are required to set up a reliable SN curve for any component failure, if that may help you answer the question? What is a statistically reliable number?

DR. PISCHINGER: I would hesitate to answer this with a general figure because it depends on the scatter of your test results.

Q. Can you tell me, Dr. Pischinger, if there are fewer than ten crankshafts?

DR. PISCHINGER: I strictly say you will get this figure and then you can make your own judgment.

Q. You mentioned that this data came from two sources. What are the two sources from which this data was derived?

DR. PISCHINGER: I should prefer also to give you the exact source. It's published and very

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well accepted -- two different independent sources.

Q. Dr. Pischinger, you mentioned that the data from these sources was not from field experience but it is from -- is it from laboratory experience?

DR. PISCHINGER: Yes.

Q. Can you describe the tests that were performed in the laboratory on these crankshafts?

DR. PISCHINGER: It was a torsional excitation.

Q. Well, I understand the purpose of the test, but can you describe how the test is performed?

DR. PISCHINGER: The details, not at the moment. You know, if we rely on such data, we review it once and then if I keep all this in my mind. My computer wouldn't have it.

Q. Do you personally perform these calculations or does someone perform them under your direction?

DR. PISCHINGER: This was someone under my direction, and I did certainly control this, I controlled the major points to make sure there is really no mistake in it. I can take the responsibility for it.

JUDGE BRENNER: We'll take a break at

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this point. We'll make it 10:50 based on that clock. It's my desire and hope in reviewing the cross plan that the County's contention for cross-examination is based on the Pischinger, Youngling piece of testimony by the noon lunch break. We'll be back at 10:50.

(A recess is taken until 10:50 a.m.)

JUDGE BRENNER: All right. We're back on the record.

BY MR. SCHEIDT:

Q. Dr. Pischinger, isn't it true you performed a calculation under the Kritzer-Stahl design criteria to determine the accuracy of the size of the webs on the replacement crankshafts?

DR. PISCHINGER: No. The purpose of the calculation was to back me up in reviewing the FaAA crankshaft evaluation, which is given in the report.

Q. But you did perform a calculation of the webs under the Kritzer-Stahl design criteria. Isn't that true?

DR. PISCHINGER: As I said, the ratio of the web dimensions to the crank dimensions are in this criteria.

Q. And didn't your calculations show the webs were too thin under the Kritzer-Stahl design

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criteria?

DR. PISCHINGER: No, this was not a result of this criteria. If I may explain, I remember I have been asked in my deposition how would I have designed the crankshafts, and I feel that the bearing is rather lowly loaded. You could easily have applied thicker webs.

Q. Is the size of the web under the Kritzer-Stahl design criteria on the boundary?

DR. PISCHINGER: No. The Kritzer-Stahl criteria just uses the size of the web as an input to the stress concentration factors, and this ratio of the web dimensions to the crank diameter is well within the range of which has been taken into account for this Kritzer-Stahl evaluation.

Q. Dr. Pischinger, I refer you to Suffolk County Exhibit 41, which is a copy of -- portions of a copy of your deposition. On page 98 of that deposition, the first full question and answer, do you recall being asked the question, "Under the German code, do the Shoreham diesel engines satisfy the requirements of the German code?"

Do you recall that question, Dr. Pischinger?

DR. PISCHINGER: Yes.

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Q. And do you recall your answer, "It's just on the boundary. If you ask me that way, if I were to design a crankshaft in Germany for this engine, it would be a little thicker." Was that your testimony at that time?

DR. PISCHINGER: Yes. Let me read it in the whole context, please.

Q. Go right ahead.

DR. PISCHINGER: I agree. I have to admit that I mixed up a little of the questions on the so-called "code" when we named the criteria and the question of the design of how to design -- of how I would have designed the shaft. The code gives no -- or the criteria gives no advice as to how the dimensions of this web should be, but of course if you make this web thicker within this criteria, you get a little higher or lower stress concentration factor. That would have been beneficial. If I would have had to design this crankshaft, I would have done it, but this doesn't mean that the criteria dictates or gives such a limit that width dimensions are not satisfactory.

Q. So are you saying that it is your personal design practice and it has no connection with any standard or criteria --

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DR. PISCHINGER: Yes.

Q. — of any published source?

DR. PISCHINGER: Well, I wouldn't say of any. I do not know any published sources, there is so much written in paperwork, but it doesn't relate to this design criteria.

JUDGE BRENNER: Dr. Pischinger, just a moment or two ago in your oral testimony here, you said in designing the crankshaft, or words to that effect, you would have done it. Could you state precisely what you mean by you would have done it, because you had some things in mind from the deposition and from the questions and I want to make sure I understand what you mean.

DR. PISCHINGER: I didn't quite get you. Excuse me?

JUDGE BRENNER: If you had been designing the crankshaft, what would you have done with respect to the web?

DR. PISCHINGER: This is now your question to me?

JUDGE BRENNER: Well, yes, but my basis for the question was you stated a few moments ago if it had been you doing the design, you would have done it, quote, unquote, and I want to understand

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what you mean by "it."

DR. PISCHINGER: Yes. I would have made the crankshaft webs a little thicker.

JUDGE BRENNER: Can you take your analysis to the point where you could tell me how much thicker?

DR. PISCHINGER: The analysis could have given the benefit of it in calculation, and it is -- my usual design procedure is to look on the one hand at the bearing dimension, the crankshaft bearing. You have to keep the load within reasonable limits. If you make the webs too thick, which also can be, then you have to have an overloaded bearing. I did not say it is too thin here, but if I would make the web too thin, then this would give very high stress concentration values, which cannot be accepted, so it is a compromise between loading of the bearing and stress concentration, and the only thing I wanted to express, I would have made -- I would have taken another compromise.

JUDGE BRENNER: Could you be more precise as to where you would have drawn the compromise between loading on the bearing and taking into account the stresses on the web?

DR. PISCHINGER: Not at the moment now,

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because this needs some reconsidering of all influential factors.

JUDGE BRENNER: Can you arrive at an opinion in your own mind as to whether you would have to -- not have to, but as to whether, by your personal approach and desires towards design, whether the thickness that you might have had in mind for the web would have required changing the bearing?

DR. PISCHINGER: Yes.

JUDGE BRENNER: And your answer is yes, it would have required that?

DR. PISCHINGER: Yes, it would have required that.

JUDGE BRENNER: Would it have been in the range of about an additional inch of thickness, if you know?

DR. PISCHINGER: Well, I usually do this in connection with calculated figures, but my feeling, half an inch.

JUDGE BRENNER: And if you would have made a change of that approximate size, and I certainly understand your point here that you are not making a precise calculation before us, but if you had done that, just to make sure I understand

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what you said earlier, that would have required a different bearing?

DR. PISCHINGER: Yes.

JUDGE BRENNER: Mr. Scheidt, I'm sorry for the interruption. I wanted to clarify something in my own mind.

BY MR. SCHEIDT:

Q. Dr. Pischinger, you testified, didn't you, that Kritzer-Stahl's design criteria gives you figures for the relative overlap of the shaft and the crankpin, the relative width of the web, the relative thickness of the web, and the relative radius or radii of the fillet. Isn't that true?

DR. PISCHINGER: Not in that sense you are asking, because I said that the input in doing a calculation with this criteria needs these figures. It's not that it comes as an output. The only thing is, if I recalculate a design and the stress concentration factors lead to too high stresses and I have to make any change, the change could be web thickness; it could be radii; it could be all these influential factors.

Q. When you say "relative," what is it relative to?

DR. PISCHINGER: It's relative to

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crankpin diameter.

DR. MC CARTHY: These are usually expressed in geometric ratios as dimension of the parts.

DR. PISCHINGER: The reason is there are similarity rules or similarity -- laws of similarity of the elastic stress configurations so that you can do calculations for different sizes with the same figures.

Q. Are you familiar with the ABS rules that relate to the sizing of the webs and the crankpins?

DR. PISCHINGER: I'm more familiar with rules used in Europe, and they also relate to such sizes, which gives you a complete design procedure. You need not even think during design, you would just take the figures. That has been criticized a lot because it is, of course, not completely according to physical laws.

Q. I'm sure you think while you're designing, don't you?

DR. PISCHINGER: I would think so.

Q. Now, on the same page of the deposition in Exhibit 41, on page 98 of the deposition -- and I refer you to the same question that you discussed before -- the first full question on that page,

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which states, "Under the German code, do the Shoreham diesel engines satisfy the requirements of the German code?"

And the answer is: "It's just on the boundary." What do you mean by your answer, that it's just on the boundary?

DR. PISCHINGER: It means that in doing this calculation according to this criteria, the stresses which are calculated in the point of high stress in the fillet radius are just a little lower than the calculated endurance limit, and I have to add that the same rules also use calculated endurance limits. You have a given material for the crankshaft and you take into account a lot of factors, again, to calculate the endurance limit.

Q. And this is based on cyclic stresses, Dr. Pischinger?

DR. PISCHINGER: This is, of course, torsional cycle stresses.

Q. And what was the calculated endurance limit that you used in those calculations?

DR. PISCHINGER: It was — I have to excuse myself because I have all this in German dimensions, but I will give it to you. Calculated endurance limit for the 12-by-13 inch crankshaft,

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according to this method, is 175 Newtons per square millimeter.

Q. Can you convert that to —

DR. MC CARTHY: 25,375 psi.

DR. PISCHINGER: I think I left my calculator over there. Maybe anybody could get it for me.

DR. PISCHINGER: And the .11-by-13 inch crankshaft, .11-by-13 inch is 165 Newtons per square millimeter, and there are a lot of factors which are taken into account to calculate this limit. You start with the ultimate strengths, the ultimate tensile strengths, and you, again, use a lot of factors which compute the size of the component, because the ultimate tensile strengths are tested on a ten millimeter —

Q. Test sample?

A. Test sample.

Q. Specimen?

DR. PISCHINGER: Yes, and then you have the grain flow, influence of forging the degree of — forging the surface roughness and the surface treatment. All those circumstances are taken into account by factors. I did not take into account shot peening. I should have taken that into account,

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at least in connection with surface roughness, because the surface -- shot peening surface was smoother than the machine one. I couldn't feel it on the crankshaft, but to be conservative, I did not take into account this shot peening influence.

Q. Are there any factors, significant factors that are not considered by this calculation?

DR. PISCHINGER: No. To my best knowledge, all significant factors for the material were regarded.

Q. Dr. Pischinger, you testified that the result of this calculation was that the crankshafts were on the boundary of the code. Was that for full load?

DR. PISCHINGER: For full load.

Q. And that's 3500 kw?

DR. PISCHINGER: That's 3500 kw in the generator.

Q. And did you perform calculations for 3900 kw using these?

DR. PISCHINGER: Yes.

Q. And what were the results of those calculations?

DR. PISCHINGER: The result was that the strengths -- the stresses would be higher than the

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calculated endurance limit, and we tried, again, to calculate the number of hours out of the SN curve for overload, 3900 kilowatt, and the figure which you arrive at is 1200 hours of lifetime. This is a very conservative criterion, as can be shown, for instance, in this case. It's very dramatic. It can be shown by three broken crankshafts or cracked crankshafts, which it took double the time that was predicted by this method.

Q. Is using a conservative method the appropriate way to calculate the stresses?

DR. PISCHINGER: If you have no measured value and no experience, when you say crankshaft of a similar design, I think such a conservative method is important for and necessary for the design.

Q. Dr. Pischinger, you testified that the calculated endurance limit for the replacement crankshafts was 175 Newtons per square millimeter. How close was that to the limits of the criteria? What were the Newtons per square millimeter, the number for the limit of the Kritzer-Stahl crankshaft criteria?

JUDGE BRENNER: At full load?

MR. SCHEIDT: At full load.

DR. PISCHINGER: At full load, yes.

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Q. So it's just surpassed —

DR. PISCHINGER: It's near 2 percent.

DR. MC CARTHY: There may be some confusion here on the record. The calculation for the crankshaft was 172 and the Kritzer-Stahl was 175. Is that correct?

DR. PISCHINGER: Yes, the calculation was 172.

DR. MC CARTHY: For the crankshaft?

DR. PISCHINGER: For the crankshaft, the stresses.

DR. MC CARTHY: And the Kritzer-Stahl 175 —

DR. PISCHINGER: No, no. This procedure depends on no measured value, and so you calculate an endurance limit, which is, in this case, 175, and you calculate a maximum stress, which is 172, in this case, just below the endurance limit. Of course I have often been asked where the main conservatism in this criterion is, but I do not know if you want to ask that.

Q. Not at this time, Dr. Pischinger. Thank you.

DR. PISCHINGER: I could explain.

JUDGE BRENNER: I'm sure with that hint

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in the record, somebody will ask you sooner rather than later.

Q. Dr. Pischinger, have you performed calculations under any of the rules of any ship classification society to determine whether these replacement crankshafts satisfy those requirements?

DR. PISCHINGER: We did no calculations referring to ship classification codes.

Q. Have you performed any calculations under the proposed rules of CIMAC, C-I-M-A-C, for safety factors?

MR. STROUPE: Judge Brenner, I've been pretty lenient in objections, but at this point I have to object. I don't think these questions are within the contentions as admitted by the Board. We are now getting into an area where we're talking about not only contentions that are not admitted, we're talking about things that are not in Dr. Pischinger's testimony.

JUDGE BRENNER: You better be very persuasive, Mr. Scheidt, or we'll sustain the objection. What is your last material —

MR. SCHEIDT: The County has performed classifications under the various classification society rules to test this witness correctly to

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determine whether those calculations were correct and accurate and -- excuse me a minute, Judge.

JUDGE BRENNER: Why don't you tell me what CIMAC is?

MR. SCHEIDT: CIMAC is a group of international engineers who have put together a proposed -- or put together draft rules, some of which relate to a safety factor calculation. A CIMAC proposal is part of the county's contention, because it is incorporated within the IACS umbrella of the contention.

JUDGE BRENNER: That's what I thought on afterthought. That's why I asked you that question. That was my misunderstanding when I first heard CIMAC. I did not realize that, in fact, it was one of the proposals under the International Association of Classification Societies, and unless you disagree with that, Mr. Stroupe, we'll overrule the objection.

MR. STROUPE: I don't disagree that it is one of the proposals. I think my problem with the question is that it's cross-examining Dr. Pisch[illegible] on an area where he presented no testimony, and don't understand Mr. Scheidt's response that that could relate to his credibility when, in fact, it has no relevance to the German calculations that he

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did.

JUDGE BRENNER: Well, your point has some validity, Mr. Stroupe, but frankly we're interested in seeing if we can get some light shed on this, and Dr. Pischinger's presence might help. It might be he doesn't know. We'll get the answer and then move on.

BY MR. SCHEIDT:

Q. Have you performed any calculations under the CIMAC proposal, proposed rules relating to safety factors?

DR. PISCHINGER: In this case for the Shoreham diesel engines, I was aware of the fact that no rules of shipbuilding or other international associations are required. I wasn't asked and didn't do any calculations according to these rules. The question which was put to me in this connection was will the crankshaft, 12-by-13 inch, the replacement crankshaft be suited for the intended service at Shoreham. I didn't feel that it was necessary to do CIMAC calculations.

Q. So you didn't do CIMAC calculations?

DR. PISCHINGER: No.

Q. Did you do any calculations to show whether or not the replacement crankshafts complied

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with the DEMA limits for torsional stresses?

DR. PISCHINGER: No, I did not explicitly calculate it for this 3500 kilowatt, 100 percent load. The DEMA levels, as has been mentioned yesterday, it also is not completely clear if there should be used all orders, 24 orders for this calculation, or only as I know most companies do when comparing on the selected number of orders, which makes a difference. I never calculate the selected number of orders.

JUDGE BRENNER: What was your last statement, Dr. Pischinger? You never calculate using a selected number of orders?

DR. PISCHINGER: Yes.

JUDGE BRENNER: You use all the orders?

DR. PISCHINGER: All 24 orders for the Kritzer-Stahl calculations.

JUDGE BRENNER: Thank you.

Q. Your testimony is that you did perform the calculations for all 24 orders, Dr. Pischinger?

DR. PISCHINGER: Yes. You have to if you want to apply for the Stahl: you have to.

Q. I'm talking about DEMA, for compliance with DEMA. Did you sum the orders for all 24 orders to show whether or not the crankshafts complied with

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the DEMA limits?

MR. STROUPE: I'm going to object. I believe he just testified he did not do any DEMA calculations.

JUDGE BRENNER: Sustained.

MR. SCHEIDT: My understanding of his testimony, Judge Brenner, was that he did not explicitly calculate the figure for 3500 kw, 100 percent level. That's my understanding of his testimony.

JUDGE BRENNER: Correct. Now what are you asking?

MR. SCHEIDT: Did he calculate it at any load.

JUDGE BRENNER: All right. I'll allow that question. You better rephrase the question for Dr. Pischinger.

BY MR. SCHEIDT:

Q. Did you perform any calculations explicitly or implicitly to show whether or not the replacement crankshafts complied with the DEMA limits at any level or load?

MR. STROUPE: Judge Brenner, I would make my objection again that there is no testimony in the record —

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JUDGE BRENNER: It's overruled. I misunderstood the question and the dialogue, Mr. Stroupe, that I just went through -- I'm sorry, that Mr. Scheidt just went through.

MR. STROUPE: My objection was not to that.

JUDGE BRENNER: It's overruled. It's an allowable question.

MR. STROUPE: Can I state my objection to the record?

JUDGE BRENNER: You don't have to. You can state it to the Appeal Board and they'll listen to you. I should explain, in case you didn't understand, your objection is preserved without necessity to explain.

MR. STROUPE: Thank you.

DR. PISCHINGER: Could you repeat the question?

BY MR. SCHEIDT:

Q. Did you explicitly or implicitly perform any calculations to show whether or not the replacement crankshafts complied with the DEMA limits at any load?

DR. PISCHINGER: We did calculate the nominal stresses according to all 24 orders, modal

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superposition, for several loads and revolutions, but I have to say preliminary calculations, because this was not the main task, and what we got were values for the sum of all orders for different situations of this engine.

Q. Excuse me —

MR. STROUPE: Let him finish his answer, Mr. Scheidt.

MR. SCHEIDT. I'll be glad to let him finish the answer.

DR. PISCHINGER: I am personally not in a position to make this comparison with the DEMA rules, because of the uncertainty, how many orders you really should take. In this case, I think you have to rely on the American in-company experience, those people who built the rules, and since I have no concerns to the in-company experience, I could not do this calculation according to their intention of these rules.

Q. Dr. Pischinger, can you tell me what the results of your calculations are for all 24 orders for each load that you performed that calculation at under DEMA?

MR. STROUPE: I just make the same objection. He's indicated he does not feel

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competent to perform DEMA calculations for the reasons he stated on the record, and I would make the objection on that basis.

JUDGE BRENNER: We understand his caveat, and I don't think I'd agree with your description of it, precisely, but it's on the record and we can apply our judgment to the result he gives, keeping that in mind.

DR. PISCHINGER: I should mention that I usually do a three-fold check on my calculations. In this case I only could give figures which I hadn't personally had the opportunity to recheck, so -- I personally would prefer not to give these figures now.

JUDGE BRENNER: Is that something you could recheck by tomorrow? I don't know what's involved. I don't mean to ask you to do something unreasonable. Just tell me.

DR. PISCHINGER: I would feel a lot better. It's not my habit to give a one-run calculation --

JUDGE BRENNER: I just don't understand what's involved. Is it something you could check overnight and give us the check result tomorrow?

DR. PISCHINGER: I will try to do this.

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JUDGE BRENNER: If it's an unreasonable burden, tell me. I have no idea --

DR. PISCHINGER: I will help Mr. Scheidt in this matter.

JUDGE BRENNER: Why don't you give us the results you have now with the caveat and we'll give you an opportunity tomorrow to tell us if your further check leads to a change and, if so, why, and that way the County will have an answer to its question and, by the same token, will have what I consider to be a very reasonable request on your part for the opportunity for a better check.

DR. PISCHINGER: Excuse me. I have to go through my paperwork.

JUDGE BRENNER: While he does that, let me emphasize, Mr. Stroupe. I don't know what's involved. If you come back tomorrow and tell us it just wasn't feasible to check it in that time frame, we'll accept that and make some other arrangements.

MR. STROUPE: It's fine, Judge, but I don't know what's involved, either. We'll have to see from Dr. Pischinger.

DR. PISCHINGER: Well, I'll give you these preliminary figures. For 3500 kilowatt and 450 rpm, it's 47.5 Newtons per square millimeter:

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with 5 percent lower rpm, the same load, it is 43 Newtons per square millimeter; and with 5 percent overspeed, it is 51.5 Newtons per square millimeter.

Q. Can you convert those Newtons per millimeter square inch to psi?

DR. PISCHINGER: I have my calculator —

JUDGE BRENNER: Maybe we can get a very straightforward formula.

DR. JOHNSTON: I think I have the numbers.

JUDGE BRENNER: Give us the formula, also.

DR. PISCHINGER: Divide by 6.895, then you get ksi.

DR. JOHNSTON: I think you need to divide 695.

DR. PISCHINGER: Divide —

DR. JOHNSTON: To convert to ksi.

JUDGE BRENNER: And you have the result, Dr. Johnston?

DR. JOHNSTON: Yes, 95 percent speed, 6.24 ksi; 100 percent speed, 6.89 ksi; and 105 percent speed, 7.47 ksi.

Q. I'm sorry, can you repeat those figures, please?

DR. JOHNSTON: In the same order, 6.24, 6.89, 7.47.

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Q. And 6.89 relates to which calculation?

DR. JOHNSTON: 6.89 would be 100 percent load at 100 percent speed.

Q. And the DEMA limit is 7 ksi?

DR. JOHNSTON: The limit for DEMA which, of course, applies to a summation of major orders, is 7,000 psi, which is 7 ksi.

MR. SCHEIDT: Thank you.

DR. PISCHINGER: This is the modal superposition, if you wanted to ask this.

BY MR. SCHEIDT:

Q. Dr. Pischinger, are these the sums of all the 24 orders and 3500 kw?

DR. PISCHINGER: Yes. I, again, am aware of the fact that with the DEMA, the major orders should be regarded, and if you, for instance, take six of the major orders, usually, depending on the case, you can be about 10 to 15 percent lower in the calculated values, but I did not do this calculation.

Q. Dr. Pischinger, by what method did you sum the orders for these calculations that you just told us?

DR. PISCHINGER: It is a method described by Maas & Klier, again, published in the very recent textbook Engine Design and Calculation.

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Q. And what is that method? Is it a method that is similar to that used by any of the other consultants in this case for the sum of the orders?

DR. PISCHINGER: Yes. I'm quite sure that everybody has a method that has vectorial superposition modal superposition.

JUDGE BRENNER: Mr. Scheidt, with your cross plan, looking at page 69, it goes up to the top of page 70 on the subject of Dr. Pischinger's testimony.

MR. SCHEIDT: I'm sorry?

JUDGE BRENNER: Your cross plan on the subject of Dr. Pischinger's testimony starts on page 69 and actually extends to the top of page 70. Can you tell me what points on that cross plan you believe you still have to cover?

MR. SCHEIDT: Parts of Points 2 and 3, Judge Brenner, remain to be discussed, aspects of which we got into earlier this morning, Judge Brenner.

JUDGE BRENNER: You believe you've covered the other points?

MR. SCHEIDT: To the extent that I wish to cover those points, yes, Judge Brenner.

JUDGE BRENNER: How much more do you have

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on the remaining parts of Points 2 and 3? Personally I didn't think you asked some of point 4 as directly as you might.

MR. SCHEIDT: You are absolutely correct, Judge Brenner.

JUDGE BRENNER: But you do not intend to?

MR. SCHEIDT: I do not intend to ask anything about that, except to the extent that it also relates to the points in Points 2 and 3. They are all inter-related.

JUDGE BRENNER: When are you going to finish everything you have?

MR. STROUPE: I might add, this is an intriguing discussion.

JUDGE BRENNER: Every time I'm interested in a cross-examiner to get to a point, he decides he's not going to cover it. Do you think you'll finish in the next 15 minutes?

MR. SCHEIDT: If we can get Dr. Pischinger to tell us what his calculations were in other loads and get those values rather quickly, I think I could. It may be a little bit longer than 15 minutes.

JUDGE BRENNER: Let's try to come close to that. I'm not trying to criticize the means of

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the value of the information we're getting. I think it could be done slightly more efficiently and I was getting concerned if you had your eye on the cross plan, and I was rooting for you to lead up to some of the points in Point 4, as you now know. Maybe I can take care of that myself.

BY MR. SCHEIDT:

Q. Dr. Pischinger, can you tell us the results of your calculations of other loads under the DEMA limits?

DR. PISCHINGER: Again, with the same reservation, that I couldn't check or double-check this information.

Q. With that reservation, Dr. Pischinger, is there really a need for you to consult with another witness?

JUDGE BRENNER: I'm worried about the time here, gentlemen. Unless you can convince me differently, this seems to be the kind of thing Dr. Pischinger can do.

DR. PISCHINGER: Yes. Maybe the consulting was not necessary. Maybe you can repeat the question again.

Q. Can you tell me what your results are for every load that you calculated your figures for,

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including overload?

DR. PISCHINGER: If I may add, not referring to DEMA.

Q. That's the context in which we are questioning you at this time.

DR. PISCHINGER: Yes, you may put it into context, but I only can give you figures for 24 orders —

Q. That's exactly what I want you to give me the results on, Dr. Pischinger.

DR. PISCHINGER: The 3300 nominal speed, 44.7; 3300, 5 percent reduced speed, 40.5; and 3300, 5 percent overspeed, 48.5.

JUDGE BRENNER: Dr. Pischinger, what's the rpm of the crankshaft at the nominal 3300?

DR. PISCHINGER: 450 rpm, and the overspeed is 472.5.

JUDGE BRENNER: All right. That answered the question. More directly asked, you're assuming the same rpm for the nominal loads?

DR. PISCHINGER: Yes, same rpm's, and for 3200 kilowatts, nominal speed, 450 rpm speed, the nominal stress is 43.4 with 5 percent reduced rpm, 39.3, and with 5 percent increased rpm, 47.0.

Q. Did you perform these calculations at any

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other loads than 3200, 3300, 3500?

DR. PISCHINGER: No, I have no other figures.

Q. Now, did you perform these calculations only using the vectorial summation method to sum the 24 orders?

DR. PISCHINGER: Yes.

Q. And your summation method is not a square root of the sum of the squares method of summation, is it, Dr. Pischinger?

DR. PISCHINGER: No, it's as it should be, the most accurate position in a modal way.

Q. Is that what is referred to as a true sum (phonetic)?

DR. PISCHINGER: Well, you take into account for each of the harmonics the amplitude and the phase, and by taking into account amplitude and phase relationship, you can get --

JUDGE BRENNER: Phase, you mean p-h-a-s-e?

DR. PISCHINGER: Phase means angle, angle.

Q. Dr. Pischinger, performing these calculations, did you use TN values?

DR. PISCHINGER: Yes.

Q. And where did you derive your TN values?

DR. PISCHINGER: We derived our TN values

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from the measurements, which has been made in Shoreham, and the measurements have already been mentioned with the AVL quartz transducer.

Q. And did you use the same TN values that FaAA used in the modal superposition of its analysis?

DR. PISCHINGER: No, we do not have the same program, but the background certainly is the same.

Q. I'm sorry, I didn't ask you whether you used the same program. I asked you whether you used the same TN values that FaAA used in its program.

DR. PISCHINGER: Yes. In fact, we made our own evaluation. They are nearly the same. If you have — we start with the values for the cylinder pressure versus crank, and we have our own program to evaluate TN values and we have a second check for this, because there is a very well established method of calculating TN values out of boost pressure, compression ratio, peak pressure, and mean indicated pressure. You have these values.

There is a lot of experience for engines of this size that you can predict TN values, and we used both methods and we found that there was very close agreement with the predicted values and the values derived from the pressure transducer, which

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comforted us in being quite sure that we are using reasonable values, and finally we used the values as derived from measurements, but the significance of using the predictional methods is nearly -- the difference, I wanted to say, to using the predictive method is very small.

Q. Dr. Pischinger, what is the percentage disagreement between your TN values and the ones used by FaAA?

DR. PISCHINGER: I cannot tell you now. I can give you no figures. If you are interested in this --

Q. I am interested, Dr. Pischinger, and you did testify that they were in good agreement.

DR. PISCHINGER: Yes.

Q. Dr. Johnston, do you know the percentage disagreement between FaAA's TN values and the ones used by Dr. Pischinger?

DR. JOHNSTON: No, I do not. I have not reviewed his TN values.

Q. Have you reviewed his calculations at all?

DR. JOHNSTON: I have looked at the results of the calculations. I have not reviewed the calculations.

Q. Dr. Pischinger --

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DR. PISCHINGER: There is no large deviation, but to give you figures, please give us time until the afternoon, and then we can tell you.

Q. Now, Dr. Pischinger, is it your testimony that the reason why your TN values differ from those used by FaAA is because of the differences in the computer program that you have compared with FaAA's?

DR. PISCHINGER: I didn't even state that they differ — that they are different in a reasonable engineering limit, but it is — if we compared, again, we could give you something reasonable, but it is usually if such calculations are done from a pressure curve, there could be minimal differences.

Q. Dr. Pischinger, are your inputs the same as those used by FaAA?

DR. PISCHINGER: The same source, yes.

Q. So then it's your computer program that is the cause of the disagreement, whatever that percent might be, between your values and FaAA's. Isn't that true?

DR. PISCHINGER: I do not like to answer on differences which we have not now established. The only thing I could say is that there was no significant difference.

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Q. And I'm asking you, what is the reason for the difference, if you know?

DR. JOHNSTON: I think I may be able to shed some light on this. The pressure data that was taken, that Dr. Pischinger and I and FaAA have used, both came from the test conducted by FaAA in conjunction with Stone & Webster in January of 1984. The specific pressure versus time diagram that was used by FaAA was an average over a certain number of cycles. That particular average may not be the exact same average that was used by Dr. Pischinger, but basically the procedure for obtaining the data is the same. He uses the program to reduce the pressure data to Tn values as do we. The results of the calculation are likely to be different by maybe a very few percent, but certainly we would expect very small differences from this.

Q. Thank you, Dr. Johnston.

Now, Dr. Pischinger, did you also use a value for the free end amplitude in your calculations?

DR. PISCHINGER: The free end amplitude is a result of such a calculation.

Q. So you calculated a figure for the free end amplitude in your calculations?

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DR. PISCHINGER: Yes.

Q. And how did you obtain a Newton per millimeter squared value? What factor did you use to convert the free end amplitude degrees to the psi or Newton measurement?

DR. PISCHINGER: We didn't use free end amplitude for conversion at all, but the TN values calculation, which gives you the nominal stresses or the torque for the cylinders.

Q. And how did your calculation of the free end amplitude compare with that calculated by FaAA?

DR. PISCHINGER: If I remember the agreement, maybe each of us should —

Q. If you can provide me with those values, that would be very helpful.

DR. PISCHINGER: Yes, I have them with me.

Q. Do you have them with you now? Is that what you just said?

DR. PISCHINGER: Let me make sure it is the same thing, not in figure but in amplitudes. Though I can make it easier, I can't give you both values as is shown in Exhibit 17, page 3-14, Exhibit 17.

Q. That's LILCO Exhibit C-17?

DR. PISCHINGER: Yes, LILCO Exhibit C-17,

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page 3-14. There is an FaAA value which is .662, 100 percent load, and our calculation for 100 percent load is .665.

Q. And the reason for the difference between your calculated value of free end amplitude and FaAA's is the difference between your TN values. Isn't that true?

DR. JOHNSTON: I would like to point out the difference is less than half of 1 percent, and I think that that kind of difference is a difference that could be due to a number of factors, including numerical accuracy of the solution technique.

MR. SCHEIDT: I'd like to know what Dr. Pischinger's opinion is for the reason of the difference.

DR. PISCHINGER: Well, as you compare results of both of us, I think each of us should have a vote on this. I will give mine. Usually you do not argue on three thousandths --

JUDGE BRENNER: Dr. Pischinger is trying to say what I was about to say. Who cares? You could state it more relevantly.

MR. SCHEIDT: The point is they may have come to the same figures but they may have also used the same inputs.

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JUDGE BRENNER: You've asked a lot of questions and we understand a lot of what was said might be different, and I certainly agreed, until we got the results on the record, different subsidiary questions that you asked might be more or less important, and now that we've had the result, I suggest some of them become less important with the background you've established, certainly, but you've gone through it now.

MR. SCHEIDT: Judge Brenner, the results depend upon the values that use inputs, and I thought it was important to get those values on the record.

JUDGE BRENNER: That wasn't the last question you asked him. You asked him how do you explain the differences, and they told you leading up to it what might be different, and as to the precise reason for this very slight difference, you know, you have their general opinion, but it doesn't matter.

MR. SCHEIDT: Fine, Judge Brenner.

JUDGE BRENNER: If they told you about the different approaches that they might have taken for the input from the vibrational test data, but you already have that.

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MR. SCHEIDT: I have one more question and then we can break.

BY MR. SCHEIDT:

Q. Dr. Pischinger, when did you perform these calculations?

MR. STROUPE: All the calculations?

Q. The calculations that he just testified to at 3500 kw, 3200 kw, and 3300 kw.

DR. PISCHINGER: This is difficult to give you a single date for this because this procedure of calculation starting with 100 percent load and 450 rpm dates back certainly, maybe, April or May, but I'm not completely sure, and by the time you go on with your calculations, I cannot give you a figure exactly when which figure came out of the computer or when we recalculated it or revised it. The only thing I can tell you, these calculations have been intended by me as for me comforting side calculations.

I want to stress, in revising the result gained on a different figures, you always feel better if you have your own side calculations. This procedure took a certain time. In any case, the figure with different loads and rather recent figures.

Q. When did you sum all 24 orders for your

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calculation at 3200 kw?

DR. PISCHINGER: At what?

Q. 3200 kw. When did you sum all 24 orders and get the figures that you reported to us this morning?

DR. PISCHINGER: I do not even know at the moment because this is done by those people responsible for this handling this program, and I asked him to calculate a lot of different points.

Q. When did you ask him to perform those calculations?

MR. STROUPE: I think at this point I'll lodge an objection. I don't understand the importance of when these calculations were performed.

JUDGE BRENNER: I sustain your objection, Mr. Scheidt, what is the materiality of it?

MR. SCHEIDT: I think it's important to know whether the witness had these figures since April and has not disclosed them in any of the reports or in any of the documents produced to the County pursuant to discovery. I think it's significant, at least in terms of credibility, if he has had these calculations, which may conflict with those of FaAA or TDI or Stone & Webster, and those values have not been brought to light in terms of

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the analysis that has been reported.

JUDGE BRENNER: Well, he told you that he thinks he had some in the April or May time frame, and if you want to make that kind of argument in the particular context in your findings, you can do it with what we have on the record. I'm not going to sit here and listen to further detail. Now that we understand what kind of argument you want to make, I think you could make it. Whether or not it's important to make, you can have time to reflect on that between now and your findings and then we can reflect on the importance of it, too, when you raise it in a particular context, at which time we have all had time to put as many figures done by different people together for a comparative basis. Let us not forget also Dr. Pischinger is going to have the opportunity to run the check he wants to run and we'll get further word on that, also.

Have you completed your questioning of Dr. Pischinger?

MR. SCHEIDT: We can break now.

JUDGE BRENNER: That doesn't answer my question.

MR. SCHEIDT: No.

JUDGE BRENNER: This is going on too long.

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I'm not going to sit here while we go through another whole week on just cross-examination on one panel of witnesses. I don't want to jump in and criticize question by question and, in general, I have not. The cumulative result is taking too long. Again, not because we're not getting valuable information, but we're not getting it at an efficient pace. Too many details are being asked about that are not necessary to lead up to the question that could have been asked as the first question. How much more do you have?

MR. SCHEIDT: I think I may be able to do it in one question.

JUDGE BRENNER: Ask it now.

BY MR. SCHEIDT:

Q. Dr. Pischinger, were the values that you used for TN and free end amplitude for your summation of the 24 orders the same as those you used in your calculations of the fatigue endurance limit that is referred to in your testimony?

DR. PISCHINGER: The calculations of the fatigue endurance limit were -- the calculations, if I understand it right, do not need any calculation of any vibrations. The fatigue endurance limit is a material property, and this material property is

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calculated according to the specified quality of the material and, as I already explained a short time ago, from size, shape, roughness, forging, and so on.

Q. I take that to mean that you did not use the free end amplitude and you did not use the TN values in your fatigue endurance calculations. Isn't that true, Dr. Pischinger?

DR. PISCHINGER: If I am familiar with the use of this word in your language, to calculate the material property of a material in a certain context, you need not have any of this input.

Q. Perhaps I can clarify it --

DR. PISCHINGER: Maybe there's a misunderstanding.

Q. Maybe I used the wrong term. How about if I refer to it as your safety factor calculations?

DR. PISCHINGER: That sounds better.

Q. Thank you.

DR. PISCHINGER: Yes. For the safety factor calculations, the calculation, let's say, of the stresses, I used the same TN values.

Q. And you used the same free end amplitude values?

DR. PISCHINGER: Yes.

Q. They're both the same --

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DR. PISCHINGER: Yes, the free end amplitude values are just a figure you get as an output.

MR. SCHEIDT: Thank you, Dr. Pischinger. That's the end of my questioning on his testimony, Judge Brenner.

JUDGE BRENNER: Mr. Scheidt, after lunch you will be returning to the earlier portion of your cross plan, and right now I cannot remember where you left off. Can you help me?

MR. SCHEIDT: Page 65, Judge Brenner, Point D-3.

JUDGE BRENNER: And the portion of the cross plan dealing with crankshafts started on page 64, so yesterday you went from -- you essentially did 64 and 65?

MR. SCHEIDT: Twenty-four pages of testimony, Judge Brenner, yes.

JUDGE BRENNER: I hope you're assuming you will complete your cross-examination of this panel today. Whether you are or not up until this point, you should assume in your preparation during the lunch break that that may be all the time you have, so prioritize what you want to ask. If you have not completed by the end of the day, we'll make

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a judgment, but the judgment may be that's all the time you're going to get for this panel on cross-examination. We'll have a better basis by the end of the day to make that decision.

Let's break until 1:45.

(Whereupon, at 12:25, the hearing was adjourned, to reconvene at 1:45 p.m., this same day.)

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AFTERNOON SESSION

JUDGE BRENNER: Good afternoon. We're back on the record. The County may continue its cross-examination. There are a couple of preliminary matters.

MR. STROUPE: Judge, I have been informed by Dr. McCarthy that he will have to leave tomorrow at around twelve o'clock. He has to appear in Detroit as a witness early Thursday morning. I apologize for that but it's an obligation he could not get out of. It's been existing for some time.

JUDGE BRENNER: If that's the case, it would have been better for all of us to have heard about it earlier than right now.

MR. STROUPE: The reason is we thought we were going to be able to delay it past Thursday. Basically, as it turned out, the scheduling did not work out that way. We thought we would be able to have him here the entire week.

The second matter is I believe, Mr. Scheidt, Dr. Pischinger was now able to obtain during lunch the data on the number of crankshafts that you asked him to look into.

JUDGE BRENNER: Before we jump to that, I want to come back to the subject of scheduling at

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the end of the day today. The parties were supposed to work things out and we have heard no report. We certainly expected to hear it by now, and I have some questions as to what's been worked out and what subjects will be taken up after we finish crankshafts, and we can have some questions as to the remaining order within crankshafts.

My question is: Are we going to go to the LILCO testimony on the heads or on the blocks after crankshafts, and some of that may involve Dr. Pischinger's schedule, which may cause a reason to change what we had originally set as the schedule. I would certainly be pleased if the schedule could be worked out so Dr. Pischinger could be here for some of his testimony on cylinder heads, if I remember correctly.

I assume the parties have talked about all this by now. If not, you better do it over the next break. I had directed the staff last week to discuss the matter with the other parties, and we'll take it all up near the end of the day today. As to Dr. McCarthy, we have no objection, subject to the fact that if something comes up and he's not here to answer a question, that will be the state of the record.

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MR. STROUPE: We understand, Judge Brenner.

JUDGE BRENNER: Did you want to get that information from Dr. Pischinger before moving on to your next subject?

BY MR. SCHEIDT:

Q. Dr. Pischinger, how many crankshafts were encompassed within the SN curve that you described this morning?

DR. PISCHINGER: Eight measurements, the scatter not being very significant, so I think this shows — well, the reliability of this SN curve, I just only want to point out that this SN curve is used for relating the endurance limit to the stresses versus failure, and it is, of course, not the absolute value of this curve used, just to make clear what use has been made of this SN curve.

Q. Dr. Pischinger, were there eight crankshafts or eight measurements from a fewer number of crankshafts?

DR. PISCHINGER: No. There was intentionally on a twisting test bench one crankshaft with eight cranks used, and this is intentionally done that way so you always have the same materials and properties. That's the best way

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you can do it.

Q. So only one crankshaft was actually measured in eight different locations. Is that true?

DR. PISCHINGER: Broken one crank after the other, eight cranks. It's equivalent to eight crankshafts, but if you would have taken eight different crankshafts, you would, in addition, have had some large scatter of material.

Q. How wide was the scatter, Dr. Pischinger?

DR. PISCHINGER: The maximum, 10 percent.

Q. And what size crankshaft was this?

DR. PISCHINGER: 245 millimeters, which is very close to ten inch.

Q. And ten inches refers to what part of the crankshaft, dimension?

DR. PISCHINGER: This is in diameter.

Q. And is it an eight cylinder crankshaft?

DR. PISCHINGER: Yes.

Q. And what was the forging method that was used on this crankshaft?

DR. PISCHINGER: I didn't ask on the telephone on this detail, but the crankshaft was a material rather similar to the LILCO crankshaft, tensile strengths of 650 Newtons per square millimeter.

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Q. Can you convert those to pounds per square inch, please?

DR. PISCHINGER: Yes. I think it's about 95. Yes. It's about 95 ksi.

Q. Isn't the type of forging a significant factor in an endurance limit for a crankshaft?

DR. PISCHINGER: Certainly, yes, but in establishing SN relationship, it's of not so much importance.

Q. Why is that, Dr. Pischinger?

DR. PISCHINGER: Well, there's an SN relationship, principal relationship, between the point where the material is getting to be distracted and the time, the number of cycles it takes to get to this point. If you have a better forging, of course it takes a longer time, but also the endurance level is higher, so if you take the inter-relationship of these figures, there is usually no change, but I can, of course, if it's comforting to you, I can also ask on the telephone on the type of forging.

Q. That would be very good, Dr. Pischinger. I'd appreciate if you would provide us with that information, and you also testified that you could provide us with the two sources. Have you been able

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to obtain that information, Dr. Pischinger?

DR. PISCHINGER: Yes. One source which I referred to is worked on in MAN Co. and -- shall I give you the German?

Q. If you can translate it, that would help a lot more, Dr. Pischinger.

DR. PISCHINGER: The title translated is Contribution to the Question of Endurance of Crankshafts of Large Diesel Engines.

Q. Do you know when this was published?

DR. PISCHINGER: It is in MTZ -- this is the main engine journal in Germany, and MTZ No. 511. I do not know at the moment the exact date.

Q. MTZ No. 5.11?

DR. PISCHINGER: 511.

Q. And what was the other source you referred to, Dr. Pischinger: do you have that information?

DR. PISCHINGER: Yes. The other source was named the Torsional Vibrations in Piston Engines, and it is -- I'll say it in German, Konstruktionsbucher, Design Manuals, Karl Springer, 1952.

Q. Thank you, Dr. Pischinger. Dr. Chen, isn't it true that the DEMA recommendations require

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a consideration of the torsional stresses at 5 percent overspeed and 5 percent under speed?

DR. CHEN: Let me read it from --

Q. Exhibit C-14.

DR. CHEN: In the case of constant speed units, such as generator sets, power generator, the objective is to insure that no harmful torsional vibration, vibratory stresses, occur within 5 percent above and below the rated speed.

Q. And what is the limit at those over and underspeeds for some of the orders under the DEMA recommendations?

DR. CHEN: I think that we are to read the rest of it. Then we will talk about the limits. So far we talk about speed range and no harmful vibratory stresses. "For crankshafts, connecting rods, flange or coupling components made of conventional material, torsional vibratory conditions shall generally be considered safe when they induce a superimposed stress of less than 5,000 psi created by a single order of vibration or a superimposed stress of less than 7,000 psi created by a summation of the major orders of vibration, which might come into phase periodically." This would explain the limits at the rated speed.

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Then the other question you asked, before and after, 5 percent above or 5 percent after. The rules are not explicit. Whether it's dangerous or not, one can — an engineer can make some judgment about that.

The second thing is major orders. Major orders, the way the group was set up, those orders, which resonance torsionals come within the rate of speed range, you can sometimes say they are the torsionals which caused resonance, let's say within a certain speed range of the rated speed, and the way we look at it is those large amplitudes caused by the harmonics, and if you look at rated speed, larger amplitudes, sometimes we use four, sometimes we use two, sometimes we use six orders. We select six large orders and calculate the combined effect of those six orders we select and calculate a summation of stress.

Q. Dr. Chen, don't you interpret the DEMA recommendations to apply a 7,000 psi limit at 5 percent overspeed and 5 percent underspeed? Dr. Chen, can I have your interpretation of that?

DR. CHEN: I'm just trying to refer to my report to show you what I have in my report, sir.

Q. C-18, I believe, Dr. Chen.

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DR. CHEN: So if you refer to C-18 on page 3, on page 3, I mention allowable speed range. I calculate single order and sum of orders at rated speed, as well as 5 percent overspeed and 5 percent underspeed, 95 percent speed, so if I cover that range, I find the single order stress and sum of order stress less than the imposed DEMA allowables.

Q. So you do interpret the DEMA requirements to consider underspeed and overspeed at 5 percent and the limits of the recommendations of the stresses that you sum should be less than 7,000 psi. Isn't that true?

DR. CHEN: I did the calculations to show that I'm conservative, but the rules have never been explicit to say whether, let's say, a few percent over the limits are dangerous or not, are harmful or not. That's left to the judgment of the individual engineers.

Q. But the recommendations say that if you are under 7,000 psi, you will generally be considered safe. Isn't that true, Dr. Chen?

DR. CHEN: But as I say —

Q. Isn't that true?

DR. CHEN: Under 7,000 is certainly

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considered safe, but if you have a few percent over 7,000, it can also be considered safe, depending on quite a few factors, such as if you're using conventional material, whether you're using any surface enhancement, you have different forgings, tensile strengths, so it has other considerations, and I think I can testify for that.

Q. Thank you, Dr. Chen.

Dr. Pischinger, you performed calculations at 5 percent overspeed at 3500 kw and 3300 kw, didn't you, Dr. Pischinger?

DR. PISCHINGER: We talked about this.

Q. And those are sums of 24 orders. Isn't that true, Dr. Pischinger?

DR. PISCHINGER: Yes.

Q. And the values that you got for 3500 and 3300 exceeded 7,000. Isn't that true?

DR. PISCHINGER: Yes, if we do no selection of major orders, as has just been stated by Dr. Chen.

Q. And Dr. Johnston, your calculations at 95 percent rate of speed and 105 percent rate of speed were 7,000, plus or minus 3 percent. Isn't that true?

DR. JOHNSTON: My calculations at 5

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percent overspeed and 5 percent underspeed, when all 24 orders are summed, rather than taking the major orders, do show some numbers that are within plus, minus 3 percent of the 7,000 limit, some of those numbers going over 7,000, some being under 7,000. Again, when 24 numbers are summed, that is correct.

Q. Thank you, Dr. Johnston.

Stone & Webster measured the angular displacement of the free end of the crankshaft and obtained a value of .63 degrees — 693 degrees, excuse me, for the measurement of the vectorial summation of the free end amplitude. Isn't that right?

DR. JOHNSTON: Yes, that's correct.

Q. And where is that information contained in Exhibit C-17?

DR. JOHNSTON: That information is contained in the third column of page 3 dash 14 of Exhibit C-17.

Q. Those values are also contained in table 2.5 of Exhibit C-17?

DR. JOHNSTON: That is correct.

Q. And the figures in the first column under 3500 kw, which is the second column in the table, are actual measurements, isn't that true, from the

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Stone & Webster test?

DR. JOHNSTON: That is correct.

Q. And the second column under 3500 kw is a calculated value of nominal shear stress. Isn't that true, Dr. Johnston?

DR. JOHNSTON: Yes, that is correct.

Q. So the half peak to peak summation value of 6626 psi is not an actual measurement, is it, Dr. Johnston, but it's a calculation?

DR. JOHNSTON: It is a calculation as, indeed, are the measurements of what I've been terming measurements in the previous column. The measurements, of course, are not made in degrees, they're typically made in millivolts or some other such number from the torsiograph transducer. There are various conversion factors to convert those numbers to, for example, degrees or radians and also, indeed, to stresses.

Q. But in converting those values, the accuracy of the numbers is not changed in any significant way, is it, Dr. Johnston?

DR. JOHNSTON: I don't think there's any significant error introduced by the conversion.

Q. In order to convert the amplitude of free end rotation degrees into nominal shear stresses,

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each of those measurements must be multiplied by a factor of 9562 psi in order to get the nominal shear stress values. Isn't that true?

DR. JOHNSTON: That is correct.

Q. And the 9562 figure is derived from TDI's torsional critical speed analysis, which we discussed yesterday. Isn't that true, Dr. Johnston?

DR. JOHNSTON: That particular number may be derived from both TDI's torsional analysis and also from FaAA's torsional analysis. The particular number shown here is, indeed, the number that's quoted in the TDI torsional analysis. The number computed by Failure Analysis Associates does not disagree with this number and, in fact, would agree essentially, precisely, probably to the last digit of this particular number.

I should point out that this particular number does not require -- this 9562, does not require any information such as T sub N or pressure loading in order to calculate. This number is a stress that you get on the shaft by applying a displacement, rotational displacement at the free end of the shaft, assuming that the shape of the shaft is in the first mode of vibration, so it does not depend upon the T sub N values that we discussed

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yesterday being different between the TDI analysis and the Failure Analysis Associates analysis.

Q. But the 9562 figure is based on the assumption that the crankshaft only vibrates in the first mode. Isn't that true?

DR. JOHNSTON: It is customary in reducing torsiograph test data to assume a single mode of response, and that is, indeed, what is assumed here. It is assumed as a first mode of response. The same type of approach may be used in many of the common textbooks, and also, for example, by the American Bureau of Shipping.

Q. But that figure and the resulting amplitudes of nominal shear stress will be different and they will be higher -- let me start all over again.

The 9562 figure is based upon the assumption that the crankshaft only vibrates in the first mode. That number will be different if you take into account the fact that the crankshaft vibrates in all modes. Isn't that true, Dr. Johnston?

DR. CHEN: May I say something?

Q. Dr. Johnston can answer the question.

DR. JOHNSTON: That number, as it's been

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stated, was calculated using the first mode of response. It would be possible to calculate a similar number using the second or third or any other mode of response; however, it is quite clear that this crankshaft would vibrate primarily in the first mode with regard to the stress at the first node point that is usually considered and, indeed, this particular calculation was performed in this manner because it represents a customary way of reducing torsiograph test data.

However, I would like to point out that this particular method of reducing torsiograph data, the principle of first mode of response is common; however, the principal of using a half peak to peak is, in fact, a very conservative approach for reducing torsiograph data because much data in the past has been reduced based on the square root of the sum of the squares of individual orders, which, for this particular shaft, would produce a value in the range of 4,000 and some psi as opposed to 6,626.

MR. YOUNGLING: Drs. Chen and Pischinger would also like to comment on your question.

JUDGE BRENNER: Don't take too long.

MR. SCHEIDT: I would like to follow up with Dr. Johnston and they can put on their comments.

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BY MR. SCHEIDT:

Q. Dr. Johnston, wasn't the use of the SRSS method by TDI in evaluating the stresses in the original crankshafts a contributory factor to the failure to predict that the original crankshafts were inadequate?

DR. JOHNSTON: I believe that the original crankshafts, while they did fail, they also clearly did not meet DEMA. Whether you consider the fact that they didn't meet DEMA as the reason they failed or whether you consider some other measurement or some other analysis or technique that may have been employed by TDI at the time, that is, perhaps, a matter of conjecture. The point is that the original crankshafts did not meet DEMA and they did, indeed, fail.

Q. And isn't it true, Dr. Johnston, that if you used the SRSS method, you will vastly undercalculate the state of nominal shear stress in the crankshaft?

DR. JOHNSTON: I agree the SRSS method underpredicts the nominal stress in a crankshaft and that the half peak-to-peak method is a more accurate representation. The reason that I infer that it is a conservative representation is because of the fact

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that the limits are set based upon the experience gained from diesel engine manufacturers who are used to using the square root of sum of squares technique.

Q. Dr. Chen, do you have something to add?

DR. CHEN: I believe if you use the first mode figures suggested, 9650 psi on the peak-to-peak figures, you are overly conservative. In other words, you're overestimating stress.

Q. Do you mean half peak to peak or peak to peak?

DR. CHEN: Well, the way it was done --

Q. On this table, 2.5?

DR. CHEN: On these calculations. I would further say that I have made calculations on the failed crankshaft using several different methods and find none of those methods that I used would pass DEMA. The figures come out actually just using four orders, sum of orders. The stress level is -- it's over 9,000 psi versus a limit which we consider 7,000, which is adequate, so it has -- in other words, it has a stress level much higher than is considered safe by DEMA, both on the sum of order basis and the single order basis.

And the torsiograph data, the torsiograph data comparison also exceeds the DEMA limit by a

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large margin, so you can say that if we use the same methods and compare the two shafts, our safety factor is in the order of 1.4, 1.5, because the other shaft has torsional fatigue cracks around 4 million cycles.

Q. Dr. Chen, I think we're deviating somewhat from the original line of questioning. We will get to the factor of safety calculations that were performed by FaAA.

DR. CHEN: I'm just trying to respond to your question about what SRSS methods contribute to understatement of stress. My answer is no, it's not the SRSS methods, it's other factors. The whole crankshaft, the design and the T sub N, used contributes to it.

Q. Then the SRSS method and TN values contribute to the accuracy of your calculations. Isn't that true, Dr. Chen?

DR. CHEN: I say the largest factor is not SRSS.

Q. What is the largest factor?

DR. CHEN: Larger factor has an 11-inch crank pin.

Q. Fine, Dr. Chen.

Dr. Pischinger, did you have something to

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add?

DR. PISCHINGER: No.

Q. Dr. Chen, in Exhibit C-18 on page 10, you indicate that you chose to first sum the six orders that are indicated, and those orders -- I'll wait for you to get to the page, C-18 on page 10. Those orders are .5, 1.5, 2.5, 4.0, 4.5, and 5.5. Dr. Chen, you chose those values based upon your engineering judgment as to which were the major orders. Isn't that true?

DR. CHEN: No, sir. It's based on calculating all the way up to tenth order, tenth order and its half orders on the TORVAP-R software. In other words, we're using the Holzer forced vibration classical methods to find out the section that we're considering, what are the largest orders, and then we pick. We select the six largest orders at that point and summarize it.

Q. And these six orders are not the same as those indicated in table 2.5 of Exhibit C-17, are they, and to clarify this, Dr. Chen, you chose, or your computer program chose .5 as one of the first six major orders, and the table 2.5 indicates that instead of .5, 3.5 was chosen as a major order.

DR. CHEN: Well, the TORVAP-R at that

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time when we evaluated it, the results of the tenth order and the amplitudes between the two orders you mentioned are very close, so it's somewhat arbitrary to pick a half order over the three-and-a-half, but you can also see that we follow it up with six more orders, so in that case, we do include three-and-a-half orders.

Q. Is there a significant difference between the twelfth order that you chose and the thirteenth order that you chose -- or that you did not choose, excuse me?

DR. CHEN: Pardon me?

Q. I'll repeat it, Dr. Chen. When you put together, when you summed the twelve orders with your computer program, was there a significant difference between the twelfth order that you decided to include in your program and the thirteenth order which you determined not to include in your program?

DR. CHEN: May I ask you, are you saying why we didn't pick up the thirteenth order?

Q. No, Dr. Chen. Let me try to ask this question a little bit more clearly. You just testified that the difference in amplitudes between .5 order and 3.5 order were so close that it was, I

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believe you said, arbitrary as to which one was chosen. You could pick either one and it wouldn't make that much difference. Is that the meaning of your testimony?

DR. CHEN: I believe that's right, because at that point, it doesn't make that much difference.

Q. Now, is the difference in amplitude between the -- not the twelfth order, but the twelfth value that you chose, is the difference between that value significantly different from the thirteenth highest order that you decided not to include in your program?

DR. CHEN: I believe what you're trying to say, why I didn't include a thirteenth largest order in my table?

Q. No, Dr. Chen, I'm just trying to find out if there was a significant difference between the twelfth order and the thirteenth order, whether there was a significant difference in amplitude between those orders that you could use your judgment and exclude the thirteenth time.

DR. CHEN: Using my judgment, I picked the six largest orders and then the next largest six orders based on the computer results. I didn't

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choose randomly or arbitrarily. I can add that even the next six largest orders, those figures are rather small at the free end.

DR. MC CARTHY: If you refer to table 3-3 on page 3-14 --

Q. Which exhibit, Dr. McCarthy?

DR. MC CARTHY: This is Exhibit C-17. We can put this discussion in perspective by noting that the first order of response is .325 and that the difference, the twelfth order of response, which is shown there, 7.0, is .002, and No. 13, which is the second order, is.001, which is one-third of 1 percent, but there's a 50 percent difference between the twelfth and thirteenth in magnitude of these.

Q. Dr. McCarthy, you're referring to Stone & Webster's test data. I was asking Dr. Chen about his calculated amplitudes.

JUDGE BRENNER: Actually I was going to suggest you take a look at table 3.3 myself, Mr. Scheidt, because I don't want to repeat some of what we already have from yesterday, and some of your leading questions to Dr. Chen were why he used a half order instead of the three-and-a-half order, and if you look at table 3.3, it has the data for the FaAA analysis as well as the Stone & Webster

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analysis, and you can see the differences for the top six orders and why the sequence is different and what the difference would have been going to the seventh order in each case — the seventh largest order, I don't mean No. 7 order — and we went through a lot of this yesterday, and I know you want to get somewhere else with Dr. Chen. I think you can do it more quickly.

Dr. Chen, looking at page 10 of your report, which is Exhibit C-18, one of the numbers is obliterated in my copy. The second sentence under the table at the very end, it states, "S sub 12 is the highest at shaft section 6" — is that next number 7?

DR. CHEN: Yes, Judge.

JUDGE BRENNER: And is that the end of the sentence?

DR. CHEN: Yes, sir.

JUDGE BRENNER: Thank you.

BY MR. SCHEIDT:

Q. Dr. Chen, is there a table of amplitudes that you calculated that will show what your amplitude was for the twelfth largest order and for the thirteenth largest order?

DR. CHEN: Yes. I was going to say that

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if you look at page 11, section 5, comparison of free end amplitude.

Q. Exhibit C-18, Dr. Chen?

DR. CHEN: C-18, yes. If you look at the table, I have compared all these orders, and if you look at TORVAP-C calculations, that was the calculation we made here in this report, and so I think you would agree with me I picked the six largest and the next six largest from that, and shown here is the sixteenth order. All together we have shown sixteen harmonics.

Q. I see eleven, Dr. Chen.

DR. CHEN: Yes, well, eleven, eleven harmonics. I do have calculations on all — actually I believe twenty of them. We print out only those which are larger than .01, and it's my firm belief that anything less than .01 in 1969, early 1970's, we were not really able to measure them accurate enough to consider anything less than .01. I would say less than .02, we cannot measure that.

Q. Thank you, Dr. Chen.

Dr. Johnston, the nominal shear stress values calculated from the Stone & Webster torsiograph test of 6626, is that value based on the

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assumption that the crankshaft is a long, circular cylinder?

DR. JOHNSTON: No.

Q. Dr. Johnston, isn't your testimony that FaAA's dynamic torsional analysis is a more accurate prediction of the state of shear stress in the crankshafts than either TDI's torsional critical speed analysis or the values obtained from the Stone & Webster torsiograph test?

DR. JOHNSTON: I believe that the accuracy of the torsiograph tests on the actual crankshaft at Shoreham is extremely accurate and also of about the same accuracy as the calculations performed by Failure Analysis Associates. I believe that both of those calculations would be considered more accurate in terms of calculating a nominal stress than the calculations made by TDI for a couple of reasons:

One being that the Failure Analysis calculation assumed 24 orders while the calculation of TDI was performed to make a single order comparison with DEMA, and also because of the fact that during the time when the torsiograph test was being conducted on Shoreham engines, we also had the opportunity to measure pressures to obtain the

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pressure versus time curve, which allowed us to develop more accurate loading functions, known as T subscript N.

Q. Dr. Johnston, is it your testimony that the measurements taken by Stone & Webster are accurate?

DR. JOHNSTON: Yes, it is.

Q. And is that what you testified to in your last response as being accurate or do you mean the calculated value of nominal shear stress is accurate?

DR. JOHNSTON: I mean that the measurements are accurate.

Q. The measurements by the torsiograph test. Correct?

DR. JOHNSTON: That is correct. The calculation of nominal stress from those torsiograph measurements, as I have already stated, was calculated using an assumed first mode of response, which was done for the reasons that were previously stated: that is, to be in accordance with common practice for the reduction of torsiograph test data. In order to calculate a more accurate measure of nominal stresses, I believe that the modal superposition technique is better, and that is the reason why it was used as an input to the fatigue

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endurance limit calculation to establish a safety margin to compute a safety margin on the crankshaft.

Q. Your testimony is that the nominal shear stress values calculated by FaAA's dynamic torsional model are more accurate than the values that are contained in the table derived from Stone & Webster's measurements of the free end amplitudes?

DR. JOHNSTON: Nominal stresses are really hypothetical things that don't really exist. The computation of them depends upon what you wish to do with them. If we wish to calculate a safety margin or a true stress rather than a nominal stress, then we would use a modal superposition technique. If we wish to use the data to make a comparison with, for example, a DEMA limit, then we would use a standard technique of reducing the torsiograph test data, and that technique is the technique of assuming a single mode response of the crankshaft.

Q. And that technique is less accurate than your dynamic torsional technique. Isn't that true?

DR. JOHNSTON: I really don't think it's a question of accuracy. It's a matter that if you want to make a comparison to an allowable that has been established over years of experience by using certain techniques, then you perform that

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calculation in that manner so that it makes a comparison of a sort of apples-to-apples situation. It's not a matter of accuracy, it's a matter of using the technique that has been used to establish those particular allowables. I think one of the reasons why many different societies have different allowables is simply because they're used to using different techniques, and this, I think, is just another example of that.

Q. And isn't the most accurate technique in determining nominal shear stress the most appropriate one, Dr. Johnston?

DR. JOHNSTON: For an input to a fatigue analysis, I would certainly say that it was.

Q. But not for consideration of DEMA?

MR. STROUPE: Can he be permitted to finish the answer before Mr. Scheidt interrupts him?

JUDGE BRENNER: Yes, Mr. Scheidt.

DR. JOHNSTON: For the calculation of a fatigue limit where we are interested in the true stress, indeed, we would use the most accurate available technique to calculate stresses and endurance limits; however, as I've stated before, and I'll state again, if we wish to make a comparison to a limit that has been established over

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years of experience based on certain reduction techniques, then I believe that that is the appropriate technique to use.

Q. Dr. Chen, in your calculations, you used TN values and you used calculations of free end amplitude. Isn't that right?

DR. CHEN: T sub N value, I use a common domain reference.

Q. And that reference is Lloyd's Register of Shipping TN values?

DR. CHEN: Yes. At the beginning of this job, I looked over the figures from TDI and looked over the figures from FaAA, and the latest figure that Dr. Johnston is using was not available, and I felt as an independent review, I should use a T sub N figure which is commonly considered acceptable for this type of calculation, such as for Lloyd's and for ABS, and also I could have used Porter. I could have used Ker Wilson. Those figures are somewhat lower, and Lloyd's happens to be the highest reference, a considerably reliable reference.

Q. And another reason that you used Lloyd's TN values is because you did not have available to you a reliable indicator diagram, isn't that true, Dr. Chen, for these engines?

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DR. CHEN: The major reason, as an independent review, I should not rely on any -- information which is done by -- not by me, and so I do not have access to other information. I look over that information and my figures look right and I use it, and those figures are higher than the Porter reference, which is used by ABS, for example.

Q. And aren't the Lloyd's TN values less conservative than those used by FaAA in its calculations?

DR. CHEN: Monday morning quarterback. Looking at it, their figures are higher, but at that time we really have no verification whether those figures are accepted as reliable or not, and this is the truth.

Q. Do you have an opinion, Dr. Chen, as to the reliability of the TN values used by FaAA in their calculations?

MR. STROUPE: I'm going to object to this questioning, playing one expert off the other. I don't believe there's any testimony anywhere in the record where Dr. Chen says there is something right or wrong with FaAA's analysis.

JUDGE BRENNER: Well, in his report on page 13, he presents the table of comparisons made

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from the report. In addition, I don't want to get into great detail in everything that's in his report. One thing, I'm probably not competent to discuss it on my own in advance of testimony, but the second thing is we warned that thick reports would not be relied on for controversial information, if that's the only place the information is presented.

I may remind LILCO that it had some objections to some reports, and the shoe is on the other foot, and some of its own exhibits, too. Some of these reports have been moved into evidence that fall into that label, in my opinion, so if we're going to learn anything about this comparison, we're only going to learn about it through an examination. Getting back to your first and more fundamental point, it does not appear material, at least at this stage. Maybe some of the more current questioning, which would cause you to renew your objection, but for now we will overrule it.

MR. SCHEIDT: I have completely forgotten my question, so could you please read the question back.

(Pending question read by the reporter.)

DR. CHEN: There are two situations here. You asked me whether those figures are more reliable.

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I look at those figures and in comparing them with Lloyd's, I would say at least they are more conservative than Lloyd's, but whether those figures -- I talked to Dr. Johnston, and I really believe that he and his people are professionals and these figures, to me, are as reliable as you can get. I was not able to have that information when I first made the calculation.

Q. So is it your opinion that those TN values are reliable TN values?

DR. CHEN: I have not checked the details about the software program and the pressure time diagram, but I believe those figures look very reasonable in comparing with the Lloyd's figures and in comparing with other T sub N figures in the text.

Q. So you haven't done an extensive analysis of their TN values, but your general feeling is that they're okay?

DR. CHEN: I think, based on my experience and talking to Professor Johnston, I have full confidence on his TN values.

Q. Dr. Chen, if you used FAA's TN values in your calculations -- and I understand that you cannot do that because your computer program uses Lloyd's TN values -- but if you were able to input

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FaAA's TN values in your computer program, isn't it true that your calculated values would be higher?

DR. CHEN: You say that I was not able to use the T sub N figures Dr. Johnston has. This is not true.

Q. I'm sorry. I misunderstood.

DR. CHEN: I used the TN Figures because I believe that is a common domain of T sub N figures that I have, frankly, no objection to. If you look at some of the orders, if we use Dr. Johnston's figures, my stress level would be proportional to the ratio of TN that we use, directly proportional.

Q. So for the summation of orders under your calculations, if the TN values were, for example, 5 percent higher used by FaAA, then if you input those TN values into your calculations, your stress values that you calculated would be approximately 5 percent higher. Isn't that true, Dr. Chen?

DR. CHEN: For that particular order, yes.

Q. And Dr. Chen, you also calculated a value of free end amplitude in your calculations. Isn't that true, Dr. Chen?

DR. CHEN: That is proportional to stress, so yes, free end amplitude, I dio calculate.

Q. And your vectorial summation of free-end

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amplitude was .59. Isn't that true, Dr. Chen?

DR. CHEN: Yes. I think if you refer to page 11, the true sum, which is the vectorial sum of those orders, all the orders I considered, is .59.

Q. And isn't the vectorial sum on the Stone & Webster torsiograph test .693?

DR. CHEN: Yes, I believe that's the figure in that reference.

Q. So your free end amplitude calculated values are approximately 15 percent lower than those measured by the Stone & Webster torsiograph tests. Isn't that true, Dr. Chen?

DR. CHEN: Yes, because several things are involved here. One is the T sub N figures that you just mentioned. If I would use the failure analysis T sub N figures, our answer would be closer. The second thing is if I use the 24, I think our figures would be closer, but that's not the point. The point is, you can also use SRSS methods or some other less accurate methods. What we say here is it's my experience and my judgment that if we add up six orders, that would be sufficient for the purpose of making DEMA calculations. As I mentioned before, if I only use four orders, the 11-inch crank would have failed to meet the DEMA criteria of 2,000 psi

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by four orders.

Q. Well, Dr. Chen, if you used the value obtained from the Stone & Webster torsiograph test, the vectorial summation value, and you used that in your calculations, you would have obtained a higher calculated value of nominal shear stress. Isn't that true, Dr. Chen?

DR. CHEN: You asked me whether I used Stone & Webster .693 figures to make my calculations. I have not made those calculations, and I think if you want to talk about that calculation, actually Dr. Johnston made those calculations.

Q. Dr. Chen, first let me finish up with you. If you used the Stone & Webster free end amplitude measurement of .693 in your calculations, wouldn't your calculated stress values be higher than you obtained using your figure?

DR. CHEN: Well, if you would read page 11, I say my psi figures or stress levels are related to the .59 figures. If my answer -- if you have a higher amplitude, naturally you will have higher nominal stress. I don't think --

DR. JOHNSTON: I think there's a little bit of confusion. The free end amplitude is not an input to Dr. Chen's calculation, so it's not a

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question of if he had used it. He doesn't use any value of free end amplitude. It's not an input to his calculations.

Q. Dr. Chen, if you had used higher TN values than you did use, you would have gotten closer agreement with Stone & Webster's actual measurement of free end amplitude. Isn't that correct?

DR. CHEN: I think I testified to that before.

Q. Okay. Thank you, Dr. Chen.

Dr. Chen, the value obtained by Stone & Webster is an actual measurement of the free-end amplitude, is it not?

DR. CHEN: This figure is in the reference as an independent. As an independent reviewer, I have to say it's in the exhibit. I was not there to make that test.

MR. YOUNGLING: Perhaps Dr. Johnston can comment on that.

Q. It's an actual measurement, isn't it, Dr. Johnston, a vectorial summation of all the measurements?

DR. JOHNSTON: Yes. The measurement is just -- is made with a torsiograph transducer, and

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then there is a constant, which that is multiplied by -- the output of that is multiplied by --

Q. I'm just talking about the measurements.

DR. JOHNSTON: Well, like I said before, the measurements really come out in the form of millivolts, and then there is a conversion factor to obtain the response as a measure in degrees, and that was conducted by Stone & Webster in conjunction with Failure Analysis in January of this year. While Dr. Chen indicated he was not present at the time, I was there at that time and did witness this measurement.

Q. So, Dr. Chen, since your calculated value is less than the actual measurement of that value, doesn't that suggest to you that your value may be incorrect?

DR. CHEN: I don't believe so. The figures have to be compared on an apple-to-apple basis. My calculation here is not designed to make an accurate prediction about stresses. It's to calculate nominal torsional stress as defined in the DEMA book, major orders, and I have used the six largest orders using very well accepted computer software to do that.

I would say it's very important to

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compare on an apple-to-apple basis figures which are not included here, but the actual sum of orders of amplitude of the 11-inch crank is in the order of .9 or more. That's if you have an amplitude of that magnitude. Then I would say you have a little bit of a problem, but our figures on the six-order basis still are considerably lower than the .9 figures, which was an 11-inch crank.

Q. Dr. Chen, if you summed all 24 orders, wouldn't your calculated values be less than those values obtained by using a free-end amplitude of .693, as measured by Stone & Webster?

DR. CHEN: Using what program, sir?

Q. Using your program, Dr. Chen.

DR. CHEN: If I used the same input, I would get the same output, because the other calculations are very comparable.

Q. That wasn't my question. If you used Stone & Webster's torsiograph measurement of .693 and you used your calculated value and summed all 24 orders under your program, you would come up with a lower figure. Isn't that true, Dr. Chen?

MR. STROUPE: I'm going to object because I believe Dr. Chen has previously testified that Stone & Webster's result is not input.

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JUDGE BRENNER: I'm at the portion of the question -- did you refer to the amplitude in your question? If so, the objection is correct.

MR. SCHEIDT: Yes, I did, Judge Brenner.

Q. Dr. Chen, I refer to you page 30 of your testimony, Question 46. Dr. Chen, isn't it true that the vast majority of crankshafts that fail do not fail primarily in torsional stress but rather from a combination of stresses?

DR. CHEN: I have not changed my judgment on this. I think on page 30 I have testified that in many years of experience as designers and developers of diesel engines, I do not know of any situation in which a crankshaft met DEMA recommendations and failed primarily from torsional fatigue. I have not experienced any case which met DEMA and failed primarily due to torsionals. That's what I said here.

Q. Isn't it true though, Dr. Chen, that the vast majority of crankshafts that fail do not fail primarily from torsional stress but from a combination of stresses?

DR. CHEN: I believe you have to tell me exactly what cases so that I can make a judgment. I have failed crankshaft torsionals in my laboratories

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many times, pure torsional, but if you go back, you'll find out that either a damper failed -- if I have damper failures, it would be a torsional fatigue for sure, but that's because of failure for the damper. Also I have experienced torsional failures, classical torsional failures because that particular shaft did not meet DEMA criteria.

In other words, if I meet DEMA criteria, my experience is good, and if I do not meet DEMA criteria because of failures of other situations, then my experience is bad, so because of this experience and its judgment, I give good confidence on the criteria, and this is my experience and this is my judgment, and it is the truth.

Q. Dr. Chen, can you tell me, either yes or no, whether it is true that the vast majority of crankshafts that fail do not fail primarily from torsional stress, but rather from a combination of stresses. Can you tell me, yes or no?

DR. MC CARTHY: For whatever it's worth, the vast majority of crankshafts --

JUDGE BRENNER: Wait a minute. He's asking Dr. Chen. We'll let you add after, Dr. McCarthy, if you still want to answer.

JUDGE BRENNER: Wait a minute. I want to

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get Dr. Chen's answer.

DR. CHEN: I believe your question is do the majority of the crankshafts fail because of torsional stress?

JUDGE BRENNER: You better restate the question.

Q. For the fourth time, isn't it true, Dr. Chen, the vast majority of crankshafts that fail do not fail primarily from torsional stress but rather from a combination of stresses?

DR. CHEN: Yes. I believe in many instances, the failures that I know of are because of misalignment, in the marine applications, the foundation is not rigid enough, and many of the crankshafts failed because of lack of proper lubrication. When you have problems like that, you fail the bearing and then you have failed your crankshaft, so there are other reasons which affect the operation of a crankshaft, whether it's safe or not.

DR. MC CARTHY: Dr. Chen is correct. The bearing failures lead.

JUDGE BRENNER: I didn't hear you.

DR. MC CARTHY: If you look at the cross section --

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JUDGE BRENNER: I didn't hear you.

DR. MC CARTHY: Bearing failures lead the crankshaft failure causes.

Q. Dr. Johnston, in your dynamic torsional analysis — or I should say the dynamic torsional analysis performed by FaAA, the results of which are included in Exhibit C-17. FaAA calculated the harmonic loading as an input into the analysis. Isn't that correct, Dr. Johnston?

DR. JOHNSTON: FaAA calculated what you referred to as harmonic loading or the loading as the function of order often known as T subscript N based on the pressure measurements on the EDG 103.

Q. And the results of those gas pressure measurements are contained in the digitalized data contained in LILCO Exhibit P-35?

DR. JOHNSTON: I believe that is correct.

Q. And those measurements were taken from cylinders No. 5 and No. 7. Isn't that correct?

DR. JOHNSTON: That particular measurement was taken from a transducer in the air start valve of cylinder No. 7.

Q. And why was the air start valve in cylinder No. 7 chosen for this pressure measurement?

DR. JOHNSTON: We were placing strain

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gauges on crankpins No. 5 and 7 and we wanted to take a pressure measurement on one of those two corresponding cylinders. The reason why No. 7 was chosen over No. 5 is because of the fact that typically indicated diagrams are more accurate the closer the cylinder is to the location where the top dead center marker is measured. Now, the top dead center marker was measured at the flywheel, so the nearest cylinder for which we had a pin strain gauged was No. 7.

Q. And if you had strain gauged at crankpin No. 8, you would have chosen that cylinder to measure the cylinder pressure. Isn't that true?

DR. JOHNSTON: That is correct.

Q. So there was nothing magic about the selection of cylinders, it was just closer to the flywheel, isn't that true, and it was being strain guaged?

MR. STROUPE: I'm going to object to the use of the word "magic."

JUDGE BRENNER: If you tell me more, I'm going to overrule the objection.

MR. STROUPE: I would like to make a general objection that I think this particular testimony was gone into very, very detailed in the

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piston testimony, and I thought the record was pretty well full of how those measurements were made.

JUDGE BRENNER: He's focusing on a particular context, and at least, so far, I don't think he is unnecessasily replowing old ground, so we'll overrule it on that basis. Go ahead. Do you need the question again?

DR. JOHNSTON: Please.

Q. Dr. Johnston, this cylinder was not chosen for pressure measurements because of any prediction that the pressure measurements would be the highest in the cylinder that was there?

DR. JOHNSTON: The engines are typically balanced so that the cylinder pressures are approximately equal throughout all of them. We neither sought to find the highest nor the lowest pressure measurement, but instead we chose a pressure measurement on cylinder 7 for the reasons stated previously because of the fact that we had gauges on pin No. 5 and 7, and we believe we could get a more accurate indicator diagram by having the pressure measurement on cylinder 7 rather than cylinder 5.

Q. Isn't it true, Dr. Johnston, that those pressure measurements could be as much as 10 percent

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too low?

DR. JOHNSTON: A primary concern in calculating --

Q. Can I have a yes-or-no answer first and then your explanation?

JUDGE BRENNER: Try to give him a yes-or-no answer first.

DR. JOHNSTON: No. The type of pressure measurement that we're interested in for a torsional analysis is not a peak pressure. We are interested in an entire pressure curve, but even more to the point, we are interested in a typical pressure curve because of the fact that vibrations do not respond to one individual individual peak of pressure, but rather an accumulation of a series of loadings.

That's what causes vibrations or causes vibrations to build above a static level. That's the whole reason we're doing a dynamic rather than static analysis. For that reason we're interested -- rather than a very, very peak pressure that could be measured by another instrument, we're interested in a pressure that represents an average, so in cylinder No. 7, what we have done is we've taken the measurement over many, many cycles and then performed an average in order to calculate an

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appropriate pressure curve.

In addition, having used that pressure curve, we can calculate the inputs to our modal superposition analysis, and the result of that shows that the predicted amplitude of vibration of the shaft is, in fact, in extremely good agreement with that measured by the torsiograph, as shown in table 3.3 of Exhibit C-17.

Q. Dr. Johnston, isn't that agreement or lack of agreement approximately 15 percent between your calculated value of the free-end amplitude and Stone & Webster's measured value of the free end amplitude?

DR. JOHNSTON: Not by my mathematics.

Q. Well, what is your mathematical calculation of the difference?

DR. JOHNSTON: Between 4 and 5 percent.

JUDGE BRENNER: Just to make sure I follow this -- and then I want to take a break, and I hope this is a convenient point for you, Mr. Scheidt -- in your own mind, Dr. Johnston, the two figures you're comparing are Stone & Webster's figure of .693. Is that right?

DR. JOHNSTON: That's correct, with a failure analysis figure of .662.

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JUDGE BRENNER: Mr. Scheidt, I'm not sure exactly where you are on the cross plan because you've shifted order slightly within it, some of the paragraphs overlap, so when we come back after the break, the first thing I'd ask you to do is orient me as to your cross plan and what you have left within it.

I want the parties to use the break to discuss the matters alluded to. I don't know if the parties had discussed that matter already or not. I didn't ask. Judging by the blank faces I was looking at as I discussed it, they did not and, of course, you better be more aggressive about discussing procedural matters that could be of some importance, more to the parties than to us, in fact, and not let that slide as long as it has. Let's give you an extra five minutes to have your discussion and we'll come back at 3:45.

(Whereupon a recess was taken.)

JUDGE BRENNER: Back on the record. Mr. Scheidt, you were going to orient me on your cross plan.

MR. SCHEIDT: I'm at page 67, .E1, the third sentence.

JUDGE BRENNER: It's 3-V.

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BY MR. SCHEIDT:

Q. Dr. Johnston, shouldn't the torque -- produced by the pressure readings that we were referring to -- let me start over.

Shouldn't the mean value of the torque created by the gas pressures we were discussing be the torque required to produce 3500 kw divided by the mechanical efficiency?

DR. JOHNSTON: In calculating the loading functions, T sub N loading functions for the modal superposition analysis, one of the results of that calculation is a zero or T sub N, which can be converted to a measure of the output power. When we perform that calculation, we obtained 3500 kw output power for the full load case.

As Mr. Scheidt indicated, you would normally expect that to be 3500 kw divided by the mechanical efficiency; however, the difference between those two numbers does not have any effect on the accuracy of the analysis, as is clearly demonstrated by the excellent agreement of the predicted response using that pressure curve and the measured response which is, again, shown in Exhibit C-17, table 3.3.

I'd just like to point out here that the

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amplitudes for the individual orders under the column labeled FaAA Analysis are directly proportional to the T sub N loading coefficients, and the output under the SWEC, the Stone & Webster Engineering test, are completely independent of this pressure measurement, but rather are measured by a torsiograph transducer and, as you will see, the significant or major orders show excellent agreement and the vectorial summation shows an agreement of between 4 and 5 percent which, for this type of experiment and analysis, would show a very good agreement.

Q. Dr. Johnston, isn't it true that if you had obtained higher cylinder pressure measurements, the agreement between your calculated value for free-end amplitude and the measured value by Stone & Webster would be even better?

DR. JOHNSTON: No, that is not true, Mr. Scheidt. If we had obtained a pressure curve which had produced more mean torque than 3500 kw — for example, if it had produced 3500 kw divided by the mechanical efficiency, then we would have applied frictional forces to reduce the total amount of output torque to that of 3500 kw, and we would not necessarily expect the result to be in better

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agreement with the SWEC test. It might have been better. It might have been worse. It's not at all clear as to which way it would have gone; however, it is still, I will state, still quite clear that the agreement here of about between 4 and 5 percent is considered by, I believe, the vast majority of reasonable engineers as excellent agreement.

Q. Dr. Johnston, you obtained the mechanical efficiency of 1.0 or 100 percent. The expected mechanical efficiency for this engine is 88 percent. Isn't that true?

DR. JOHNSTON: Yes.

Q. And isn't it true that on Exhibit C-17, page 3-3, which is the FaAA report on crankshafts, that you explained that the difference between the mechanical efficiency that was obtained of 100 percent and the 88 percent that was expected is probably explained by either the pressure measurements being too low or the TDC, which is top dead center, being shifted?

DR. JOHNSTON: That is correct.

Q. So either the pressure measurements are too low or top dead center is shifted. Isn't that correct?

DR. JOHNSTON: That is correct, but I'll

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repeat again that the effect of that we have demonstrated as being insignificant and the T sub N values that were calculated by this pressure curve have also been reviewed, I believe, by Dr. Pischinger, and I think that he would like to comment on what he believes to be the accuracy or inaccuracy of these values.

DR. PISCHINGER: Well, out of experience, these measurements with this quartz transducer in scale of pressure is very reliable. It is an usual problem with such measurements to get a very precise reading of the top dead center, so it can happen that the indication of top dead center can be a little shifted, and because of this, we did this shifting -- in my side calculations, we did this shifting to such an amount, which is only a very small amount needed, that indicated the mean effective pressure corresponding with a reasonable mechanical efficiency, and we, out of these pressure traces, we calculated, again, the TN values and we calculated the torsional response and, for instance, as an indication, the free-end amplitude was nearly the same as was calculated by FaAA, within very small limits.

Q. In fact, Dr. Pischinger, it was higher,

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wasn't it, the calculated value of free-end amplitude?

DR. PISCHINGER: Yes, but this was --

DR. JOHNSTON: This was a value that was higher by less than one half of one percent, a value that we talked about this morning.

Q. Dr. Pischinger, how did you fix your baseline when you were doing your test for pressure measurements?

DR. PISCHINGER: The baseline is fixed by -- with a four-stroke engine by using the boost pressure, as was done in this case.

Q. Okay, Dr. Johnston. When you obtained a value of mechanical efficiency of 100 percent rather than 88 percent, doesn't that give you an indication that the top dead center marker or the pressure may be off by the order of 10 percent?

DR. JOHNSTON: As you referred to in my report, it does indicate that the pressure measurements or the top dead center are off by of the order of -- have a combined order, but if you add that extra 10 percent in, you then proceed to subtract it back out again by taking account of the frictional forces in the engine, and so that the net result would be something very similar to what we

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obtained, even though we had a mechanical —
apparent mechanical efficiency of 100 percent.

Again, it just comes back, really, to the bottom line of a comparison between the predictions made with this particular pressure curve and the measurements made with the torsiograph test, so I would keep referring to that same table, 3.3, in Exhibit C-17. In addition, Dr. Pischinger, I believe, has just indicated that he provided — he input a certain shift of top dead center to take care of this problem and then performed the calculations in that manner and came up with a result that was in agreement with Failure Analysis to within less than one half of one percent.

Q. Dr. Johnston, are you saying that the effects of the pressure measurements being too low or the top dead center being shifted should be canceled out by the frictional losses in the system?

DR. JOHNSTON: What I'm saying is that the result of these uncertainties is that you obtain an analysis which is in very close agreement with the test measurements. The exact manner in which you would subtract frictional forces would have a slightly different influence than that of shifting top dead center; however, the result of all of this,

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which is what's important, we're interested in calculating stresses, and the result of calculation of stresses appears to be unaffected by the fact that we compute a mechanical efficiency of 100 percent.

Q. Dr. Johnston, isn't it expected that the frictional losses in the system are going to be of the magnitude of approximately 1 or 2 percent?

DR. JOHNSTON: I don't believe that that is correct. Dr. McCarthy is going to comment further on that.

Q. May I first ask, has a calculation or a measurement of what the frictional loss should be, has that been made?

DR. JOHNSTON: We neither calculated what the expected frictional forces would be nor did we, in fact, calculate the value of 88 percent for mechanical efficiency. That particular value, it could possibly be higher, possibly as high as 95 percent, but that value also was not calculated. We did not attempt to calculate either the, in a sense, the real mechanical efficiency of the engine or the real frictional forces within the engine, since they were not needed and were not necessary for an analysis that has been shown to closely correlate

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with the experimentally measured amplitudes of vibration of the free end, but as far as the expected levels of frictional forces, I would like Dr. McCarthy to be allowed to state his comments on the subject.

DR. MC CARTHY: And I will appreciate any input from Dr. Pischinger after I complete, but a mechanical efficiency that resulted in frictional forces of only 1 or 2 percent would be phenomenal. It would be revolutionary. There's no such engine in existence. I am not personally familiar with any engine in this size range that's 90 percent efficient, but I would invite Dr. Pischinger to comment.

Q. May I just follow up on that? Are you equating frictional losses with mechanical efficiency?

DR. MC CARTHY: After you are working with indicated gas pressure, there just remains frictional losses in the mechanical system and, indeed, losses remain in the oil fluid shear, which is still in the fluid, so all your losses, once you start working with indicated gas pressure in the cylinder, that's all there is between there and the drive shaft is some form of friction.

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JUDGE BRENNER: Dr. Pischinger wanted to --

MR. SCHEIDT: Or at least Dr. McCarthy indicated that.

JUDGE BRENNER: I'm writing down the name of the engine that has only a 2 percent friction loss. I'm going to go out and buy one. Go ahead.

DR. PISCHINGER: It's certainly true that all we are striving for is such an engine, but we will certainly not have such an engine. The frictional losses of 10 percent are already very good values of such an engine, very small friction losses.

Q. Dr. Johnston, in Exhibit C-17 on page 3-3, first full paragraph, third sentence, it refers to an expected 88 percent mechanical efficiency figure. Where was that figure derived from? Isn't that the mechanical efficiency value that TDI gives?

DR. JOHNSTON: That value is the value that has been provided by TDI. Again, I would like to stress that it's not a value that has been needed or used in the performance of this calculation.

Q. Dr. Johnston, you obtained a mechanical efficiency of 100 percent. Doesn't that tell you something is wrong in your assumptions that you're using?

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DR. JOHNSTON: I think I've already indicated that, that I expected that there was a difference and that that difference was due to some combination of pressure measurements and errors in locating the top dead center marker. I think we've been through what the effects of that are and the fact that the effects of that are not significant: in fact, that the difference is within 5 percent or between 4 and 5 percent of the measured values.

I agree that there is, you know, some value that is not the same as the 88 percent. Of course, I also don't really know that that 88 percent is necessarily the value for the Shoreham engine. That particular value may, in fact, be larger if the engine does not drive itself, very many of the pumps that are used for the engine.

Q. So you don't know what the actual mechanical efficiency is and you didn't know when you wrote this report what the frictional losses were and you didn't know what the explanation of this mechanical efficiency was? You just assumed that it was either top dead center being shifted or the pressure measurements were too low and you didn't check those?

MR. STROUPE: I'm going to object to the

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conclusion because I do think it wrongly characterizes what the witness just testified to.

JUDGE BRENNER: We'll sustain that objection. As you know, I allow leeway on experts to explain answers, but that gets too compound. If you want to go on to another point, go ahead. We have the record on what was just very recently testified to and there's no need to repeat it in a compound question like that. Each of the parties later can argue as to what the testimony was.

Q. Dr. Chen, are frictional losses normally neglected or not considered by diesel engine operators on calculating stresses on an engine?

DR. CHEN: Frictional losses in the context we're discussing today are mostly fluid loss caused by bearings, the pumps, and some heat transfer, which is not accounted, and it has very little to do with the stress. Let me explain that. The stress of the engines, whether it's pistons or blocks or crankshaft, is not a function of mechanical efficiency. It is a function of gas pressure, inertia, dynamics, vibrations, in that order.

If Dr. Johnston would have asked me last spring, he does not have good mechanical efficiency

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figures and he would not want to depend 100 percent on the figures TDI gives him, I would say my lower limit of this engine would be 85 percent, the highest possible you can get is 90 percent, and I will give you the figures. 87-and-a-half. He used 88. I think it's a good guess. It's about as good as you can get, but the stress itself has nothing to do with the assumption of whether it is 85 percent or 90 percent. It depends quite a bit on the pressure and the temperature you are operating at.

Q. And Dr. Chen, if the pressure readings you get give you a mechanical efficiency of 100 percent, then doesn't that tell you that the cylinder pressure readings may be incorrectly low?

DR. CHEN: I have other references to show that the pressure measured is the average of the maximum pressure where he is operating at, so it is not low and it's not high. It just happens to be in the middle.

Q. Dr. Chen, we've been talking about average peak firing pressures. Do you know how frequently the maximum peak firing pressure occurs in this engine?

DR. CHEN: It occurs every time you inject some fuel in there, which each cylinder is

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720 degrees: peak firing pressure is every two revolutions.

Q. And how many cycles is that, Dr. Chen? How often, Dr. Chen, does the peak firing pressure occur: is it every cycle?

DR. CHEN: Every two revolutions.

Q. Which is two cycles, Dr. Chen?

DR. CHEN: Every two revolutions.

Q. And how many revolutions will this engine run in a minute?

DR. CHEN: 450 rpm.

Q. So we have 225 times in a minute when the peak firing pressure occurs in the cylinder. Isn't that correct, Dr. Chen?

DR. CHEN: If every time is injecting, yes, no miss firing, that's good mathematics.

Q. And doesn't that impose a significant stress in the cylinder in that short time period?

DR. CHEN: Let's understand what you're trying to get. I really don't understand what you're driving at, sir.

Q. Dr. Pischinger, you mentioned that in addition to the values shown on the graph contained in LILCO Exhibit P-35 that you had to add 30 psi to the figures that were shown in that graph. Isn't

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that true?

DR. PISCHINGER: Well, at the moment I cannot recall if this graph already has 30 psi. I cannot say at the moment. I would have to check.

DR. JOHNSTON: Could we be given a copy of Exhibit P-35? I don't think we were prepared for piston exhibits in this cross examination.

JUDGE BRENNER: I certainly don't have my copy in front of me, either. If you're going to ask the witnesses about it, they should be given an opportunity to get a copy. If that's the only question you have on it, we've got the record from what Dr. Pischinger said with respect to it.

MR. SCHEIDT: Judge Brenner, maybe we can assume the figures in that chart do not include the 30 psi and we can go from there.

MR. STROUPE: I object to that. Of course we can't assume it.

JUDGE BRENNER: Wait a minute. We did establish a record on it. I just don't remember myself what the answer was. That's my problem.

MR. STROUPE: I understand, but I don't think it's safe to make an assumption without looking at the document.

MR. SCHEIDT: May I approach the witnesss.

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Judge Brenner? I have copies of the exhibit.

JUDGE BRENNER: Yes. Give me a moment to get mine because I think I'm adding over with respect to the 30 psi to the time I came in. If you have a transcript reference, that would help.

MR. SCHEIDT: Judge Brenner, the transcript reference is page 22535.

JUDGE BRENNER: All right. As you know, we've gone into the transcript for other purposes. Do you have a copy that you can direct the witness' attention to? You can read it into the record. My recollection is Dr. Pischinger did testify you have to add the 30 psi, but I don't want to go from my recollection.

MR. SCHEIDT: The portion of the testimony appearing on 22535 from Dr. McCarthy states that, "The bottom pressure is 523. The one over at the right-hand side through the mean line there is 1574. Now, all of these pressures, the 1638, the 1523, and the 1574, one has to add the turbocharge boost, which is approximately 30 psi."

JUDGE BRENNER: And now you want to ask a question about that. Why don't you proceed to the question?

BY MR. SCHEIDT:

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Q. Dr. Pischinger, do you have a copy of that exhibit there?

MR. STROUPE: Mr. Scheidt, may I have a copy, since I was not part of the piston --

MR. SCHEIDT: May I approach the witnesses, Judge Brenner?

JUDGE BRENNER: Yes.

Dr. McCarthy, it's the tabulation as well as the graph that form the Exhibit P-35.

DR. MC CARTHY: Perhaps there's a slight confusion. The digitalized tabular summary does have the 30 psi lower pressure added. The chart, the graph that looks like an electrocardiogram, you have to add 30 psi to those values.

Q. And why is it necessary to add the 30 psi to those values?

DR. MC CARTHY: Because in the middle of the hearings, you requested backup data, and we sent it out by telecopy, and had it been prepared as a presentation exhibit, we would have had it at the offset.

Q. Why is it necessary to add the turbocharge boost pressure?

DR. MC CARTHY: Because the pressure in the manifold has a zero set point. We know the

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amplifier is zero — we know the chamber pressure is zero at the boost pressure with the turbocharger, so that's the steady state baseline pressure of the cylinder and that starts 30 psi above atmosphere.

MR. SCHEIDT: I have no further questions on that exhibit, Judge Brenner.

JUDGE BRENNER: I hope you're not losing sight of your main points in the cross plan by some of these side trips you're making.

MR. SCHEIDT: I hope not also, Judge Brenner.

JUDGE BRENNER: Some of the differences that you're inquiring into may not be proportional to the amount of time being spent on the differences.

Q. Dr. Johnston, in your dynamic torsional model of the replacement crankshafts, your calculated values for nominal shear stress show for the space between cylinder No. 5 and 6 that the sum of all 24 orders is 7,006. Isn't that correct?

DR. JOHNSTON: Yes.

Q. In fact, the actual maximum stresses in that area may be higher. Isn't that true, Dr. Johnston?

DR. JOHNSTON: If you're referring to the effect of the stress concentration factors induced

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by the fillets, yes, indeed, the actual true stresses would be considerably higher, and those would be the stresses that have been calculated by the finite element model, and those would also be the stresses that were measured by the full scale dynamic strain gauge test on the EDG 103, and those would have been the values, then, that would have been used to compare with an endurance limit to calculate the margin of safety for the crankshaft.

Q. And this dynamic torsional model is based on the assumption that the crankshaft is a long, circular cylinder. Isn't that true, Dr. Johnston?

DR. JOHNSTON: That is not actually correct. The model for the modal superposition assumes a system of lump masses on torsional -- in a sense, torsional beams, but those beams have equivalent stiffnesses which are calculated based on the actual measurements of the pin, the main journal, and the web. The calculation of the nominal stresses shown here from the torsion that are computed from the modal superposition model are done for a pin that has a twelve-inch diameter using the shear stress equal to the torque times the radius divided by the polar moment of inertia.

Q. But this model, the dynamic torsional

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model does not take into consideration the stress concentration factors that are present in the crankshaft, isn't that true, Dr. Johnston?

DR. JOHNSTON: That is correct.

Q. You performed calculations of the stresses that would be present in crankpins No. 5 and crankpin No. 7. Isn't that correct, Dr. Johnston.

DR. JOHNSTON: Yes.

Q. And you modeled two cases for each of those crankpins. Isn't that true, Dr. Johnston?

DR. JOHNSTON: Two different sets of boundary conditions were used in the torsional analysis of the crankshaft using the finite element model.

Q. Should actual measurements in that area, strain gage measurements in that area fall between the results calculated by the finite element model?

MR. STROUPE: May I have the question read back. I didn't catch the last part of it.

(Pending question read by the reporter.)

BY MR. SCHEIDT:

Q. Perhaps, Dr. Johnston, if I clarify the question, you can answer more easily. For a particular crankpin, should the experimental -- or

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should I say strain gauge measurements fall between the results calculated from the two boundary conditions?

DR. JOHNSTON: For the determination of the stresses in the crankpin fillet area due to torsional stresses alone, you would expect the two boundary conditions to bracket the stresses that were obtained by measurement. If you look on Exhibit C-17, table 3.7, and table 3.6, show the results for -- I gave them in reverse order -- for crankpin 7 and crankpin No. 5, you will find that the results for crankpin No. 5 do, indeed, show a bracketing of the measured results by the two finite element models. That would be expected and was found because of the fact that the stresses on crankpin No. 5 are essentially exclusively due to torsion.

If you look at the same comparison on crankpin No. 7, you will find that the range of principal stress is, again, bracketed by the two boundary conditions, although the range of equivalent stress falls outside of that bracket by what looks to me to be about one-and-a-half percent, a pretty small indication. This would be due to the fact that on crankpin No. 7, there is a small effect

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of bending, which would mean that these two particular boundary conditions would not cover that specific case and additional analyses using boundary conditions suitable for bending analysis would be needed to include the bracket; however, the discrepancy is so small that it was considered that it would complicate the presentation to provide all of those additional cases.

Furthermore, I would like to point out the thrust and the reason for the finite element calculations here. The analysis that is done in Section 3 of this report, Exhibit C-17, was aimed at calculating a margin, calculating the margin of safety for the replacement crankshafts. That margin of safety is dependent only directly on the measured stresses in the 13-by-12 inch crankshaft to calculate the stress and the measured stresses in the 13-by-11 inch crankshaft to determine the allowable limit. The finite element results were, however, performed -- calculations were, however, performed in order to demonstrate the location where the strain gauges should be placed on the replacement crankshaft.

The gauges were to be placed in the locations of maximum stress that would be indicated

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both around the circumference of the pin and within the fillet, as indicated in figures 3-8 through 3-11 of the same exhibit. It is worth noting that while the individual stresses -- distribution of principal stresses varies by a considerable amount between the two bounding finite element load cases, the location of the maximum stress is determined to be the same under both conditions, and it is only the location of the maximum stress that was used as input to the strain gage test to be sure that the strain gauges were, in fact, located in the places of maximum stress.

Q. Dr. Johnston, with respect to crankpin No. 7, you mention that you believe that the reason the measured value exceeded the predicted value was due to bending. Did you perform any investigation or calculation or analysis to determine whether, in fact, the additional stress was due to bending?

DR. JOHNSTON: Yes. Calculations were performed to compute the bending stresses, maximum bending stresses in the crankshaft.

Q. In crankpin No. 7, Dr. Johnston?

DR. JOHNSTON: In all crankpins, and -- excuse me, I need you to find the location in the report to refer you to. I refer to page 3-7 of the

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same exhibit, C-17. The maximum stress in any crankpin due to bending was computed to be 15.5 ksi, which is physically in a different location than the location of maximum stress due to torsion, because of the fact the location for maximum bending is essentially at the bottom of the crankpin when the pin is at top dead center, and the location of maximum torsional stress occurs some 45 or 50 degrees around the crankpin away from that.

In addition, this particular stress occurs at a different point in time than the maximum torsional stresses. The net result is that the maximum stress that occurs on this crankshaft, which is, after all, the stress that we were most interested in in determining the factor of safety for the crankshaft, occurs on pin No. 5 and is shown in table 3.6 to be at a range of 49.3 ksi.

On pin No. 7, there is a small overlap in time between the occurrence of the bending stress and the occurrence of a secondary peak of torsional stress, which causes the range of equivalent stress to be 44.5 ksi. That is the number in the bottom, right-hand corner of table 3.7, that causes that particular number to fall outside of the range of the two numbers above it, but again, I'd like to

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point out that this number is only slightly outside of this range and is, in addition, significantly lower than the maximum stress, which is shown on the previous page.

Q. Dr. McCarthy, in your references in Exhibit C-26, you referred -- the documents contained in Exhibit C-26 refer to various safety factors. How were these categories of numerical values derived?

DR. MC CARTHY: You mean how have the safety factors reflected in these various references been derived?

Q. Exactly.

DR. MC CARTHY: Basically over the years, engineering has progressed and we have a better understanding of materials and loads and ways of calculating same and, of course, more powerful tools like computers. The result is that there have been general guidelines set down in various standard references and also collected in other literature that set forth what have been found to be acceptable margins in design for various applications under various circumstances. There are obviously a body of very specific literature that also deals with very specific products.

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Q. Well, Dr. McCarthy, are those values obtained from field failures, from laboratory experiments, or other sources?

DR. MC CARTHY: Basically through a large body of experience and, of course, part of all experience in engineering is designs that didn't work. Most of the values that I have set forth in that appendix and in my testimony are values that are taken out of design texts that are very widely used, Shigley being the most widely used in this country, Machineries Handbook, a reference I cited, the particular volume which I cited was the 18th edition. I have the first edition of the Machinery Encyclopedia presented in 1910 on my bookshelf as well. This particular reference reflects a huge amount of past design experience and learning from designs that worked effectively and designs that didn't work effectively.

Q. In the time period between 1910 and the current edition, have those values changed at all?

DR. MC CARTHY: Oh, yes. In the old days, in the older design references, it's not uncommon to see factors of safety like twenty or something cited because people didn't understand stress concentrations, materials. In fact, very often

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you'll see just a single factor of safety designated to take care of fatigue loading and the factor of safety will be stated on the ultimate strength, so you'll see design tests saying for something that's cyclically loaded, use a factor of safety of 10 to 20 on the ultimate strength, when what they were going to do was figure out a way to get people down to the endurance limit by use of a single parameter, because at the present time of endurance limit was not well understood.

Q. Do you know when these figures were last revised in Machineries Handbook?

DR. MC CARTHY: Well, the 13th edition, the second printing was 1969. I don't know when these particular values were published; however, with each succeeding publication of an engineering handbook, the values invariably go down, not up. In other words, acceptable factors of safety reduce.

Q. But you don't know whether these have gone down or not, do you?

DR. MC CARTHY: If there has been a subsequent edition, I assure you, they've gone down.

Q. Now, in fact, in your third article, Mechanical Design and Systems Handbook, those values have remained the same, at least since 1964. Isn't

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that true, Dr. McCarthy?

DR. MC CARTHY: Remained the same at least — I do not have multiple editions of Mechanical Designs and Systems Handbook and I don't recollect the printing date of this edition.

Q. But you don't know when the last time these were revised either, do you, Dr. McCarthy?

DR. MC CARTHY: No. These are, if anything, too conservative because they're a little dated, but this is a very widely accepted text.

Q. Dr. McCarthy, in note 2 of that article in Exhibit C-26, it states that: "For castings, forgings, et cetera, factors of safety here used do not usually vary appreciably from those presented above." Now, do you know under what circumstances this reference suggests that forgings may vary appreciably from the factors of safety cited in the article?

DR. MC CARTHY: I do not recollect a discussion of forgings in this article. I know generally under what conditions, castings especially and forgings sometimes, have to be used by larger factors of safety.

Q. Do you know whether these factors of safety that are cited in here are derived from

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experience with failures of crankshafts?

DR. MC CARTHY: I do not know. I do not know what specific body of failures went into the author's mind for these specific recommendations. They certainly, in my opinion, would be more than applicable to crankshafts.

Q. Do you know whether the other articles that you have referred to in Exhibit C-26 encompass failures of crankshafts?

DR. MC CARTHY: I have only personal knowledge relative to the Shigley article because I did my undergraduate work at the University of Michigan in the Rheology and Fracture Lab, and Dr. Shigley is a professor on the faculty at the University of Michigan, and the University of Michigan is heavily associated with the automotive business, and automotive type-fatigue calculations were, including crankshafts, were a significant part of the type of research that we used to do and undoubtedly form a part of his body of recommendations.

JUDGE BRENNER: You're on the last point in your cross plan with respect to this panel of witnesses. Correct? It's almost quarter to five. I want to leave sometime to discuss scheduling --

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MR. SCHEIDT: That's why I moved to this subject, Judge Brenner, in the fear you might say that you would cut me off at five o'clock.

JUDGE BRENNER: There was nothing to figure. I told you we would, subject to it being demonstrated that you would need more time.

MR. SCHEIDT: May I respond to that?

JUDGE BRENNER: Are you about finished, in any event?

MR. SCHEIDT: No, I have more than the remaining time until five o'clock on this subject, if I'm allowed to pursue it as fully as I care to.

JUDGE BRENNER: How much do you have?

MR. SCHEIDT: I would predict about an hour, Judge Brenner, and I might point out we did lose a half hour this morning and we lost a couple of more, five or ten minutes, this afternoon.

JUDGE BRENNER: I guess I don't recall where you lost a half hour subsequent to the time I told you that we were expecting to finish by the end of the day. Give us some time.

(The judges confer off the record.)

JUDGE BRENNER: We, of course, have reviewed the principal points in the cross plan as recently as the time I gave you the estimate that we

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would expect you to finish by the end of the day. Why don't you stop your cross-examination now for purposes of being able to discuss scheduling? It appears to us that you've been able to cover your main points and, in fact, you've spent some time going over things that were out of proportion. I recognize some of that is hindsight, but not all of it. Some of it got more repetitive than necessary.

I can't put a stop watch on it, but we think the time we gave was adequate. We're not going to rob you of the 15 minutes remaining. We'll give you the 15 minutes at the outset tomorrow morning, and that will be your time limit. You'll have the advantage that you would not otherwise have had being able to compose your thoughts so that you can be more efficient. After the 15 minutes, we'll put into the record what you wanted to cover but couldn't so you can have your record on it, if you feel it's necessary. Then we'll go to the Staff's questions of this panel.

How much does the Staff have?

MR. GODDARD: Not more than one half a day. We would hope to finish by noon, possibly early afternoon.

JUDGE BRENNER: All right. We can let

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the witnesses go at this point and we can discuss scheduling. They're excused until nine o'clock tomorrow morning. What time did Dr. McCarthy have to leave?

MR. STROUPE: Around twelve o'clock. Is that correct?

DR. MC CARTHY: That's the current plan, but I'll be going away to a trial and if more time stretches on, I will stay as long as possible.

JUDGE BRENNER: I will ask the Staff to ask his questions of Dr. McCarthy first. You can see the area of his prime concentration does fit within the area of the testimony, and if we have any questions, we'll ask them also, I think. He has limited time. We can accommodate him. I hope not to be here again this late before the time the witness has to go. However, circumstances here are such that we don't have to inquire into the priority of being in Detroit as opposed to Hauppauge. I will not ask for evaluation of how they compare. I'm ready to hear.

MR. GODDARD: Judge Brenner, I think I should begin by stating the problem the Staff has experienced with the nonavailability of Dr. Bush as our primary witness with regard to the metallurgy of

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the blocks and shot peening, plus one individual question on crankshafts generally. Dr. Bush is going to be in Europe because of a prior commitment for the period of 9 to 23, October, inclusive.

If the Board believes that this hearing will still be in session, it would be quite convenient for Dr. Bush to return and be available to testify from Wednesday, October 24th, as long as as is necessary, until the NRC Staff panel on blocks completes its testimony. I don't know whether the Board has plans at this time of wrapping up this entire hearing prior to that date. In the event --

JUDGE BRENNER: Mr. Ellis has from time to time, and you can report this to him, I have hopes.

MR. GODDARD: I understand. In the event this is not compatible with the Board's plans for this hearing, Dr. Bush is available, I'm afraid, only on Monday and Tuesday of next week, that being the 24th and 25th of September.

JUDGE BRENNER: Didn't you tell us he was available sometime this week?

MR. GODDARD: And Thursday this week. That is correct. I anticipate the way the schedule is set in this proceeding, it would be only a half a

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day this week, but he would be available.

Dr. Sarsten, the Staff's primary witness on the subject of the crankshafts — who, I might add, testifies on no other subject — is available continuously through October 5th, which is a Friday; however, he will not be available at any time thereafter, as he is returning to his teaching position at Norway Institute of Technology in Fraundheim (phonetic), Norway.

The parties have discussed the potential scheduling of both the Staff's panel on crankshafts to include shot peening and the Staff's panel on blocks, and I think I can state that they have agreed that we could take them out of turn; however, it would create considerable discontinuity in this proceeding. If the Board anticipates this hearing will proceed into late October and possibly the first week of November, the Staff would prefer — and I don't feel either party would object — to the Staff putting on its panel on the blocks beginning on Wednesday, October 24th.

JUDGE BRENNER: You've got inconsistent witness problems. One of them is here now, gone tomorrow, one of them is gone now, here tomorrow. I'm exaggerating, but —

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MR. GODDARD: Hard cases make bad scheduling.

MR. DYNNER: Judge Brenner, I can try to give you a quick picture of the county's position on the scheduling. First of all, I want to report to the Board a late breaking development. Prior to the start of this hearing, the County made a proposal to settle the issue of the cylinder heads. This afternoon at the last break, I was handed a letter from Mr. Ellis representing LILCO.

This letter indicates that the parties appear to be close to the resolution of that issue for submittal to the Board. Obviously this is a matter that I want to have additional discussions on with the Staff as well as getting back to Mr. Ellis on some points where we still have some differences, but I can say that it appears very possible that the issue of the cylinder heads will be settled.

For that reason, it seemed to the County that the appropriate way to proceed would be to conclude with the cylinder -- I'm sorry, conclude with the crankshafts on the shot peening panel following the panel that is currently before us and then go ahead with the Professor Sarsten out of turn in order to be sure that he has an opportunity to

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testify before he goes back to Norway on the crankshafts, which, as Mr. Goddard had said, is the principal area that he is testifying on.

JUDGE BRENNER: You're anticipating me. I was going to suggest that, too, with the footnote we could take Dr. Bush on shot peening before Professor Sarsten.

MR. DYNNER: Then it seems to us following Professor Sarsten's testimony on the crankshafts, we could go ahead, again, picking up the County's cross-examination of the LILCO panel and proceed to begin the cylinder block component. That may well put Mr. Bush for the 24th in at least a reasonable position insofar as the cross-examination of the County's panel would, of course, follow the County's cross-examination of LILCO's panel on the blocks.

I'm stating this not having come to any agreement with the other parties because Mr. Goddard at our last break did not have a complete report on Dr. Bush's availability until just before we started speaking when it became apparent that Dr. Bush would be available on the 24th on.

JUDGE BRENNER: Can we put Dr. Bush on the subject of shot peening on the stand at the same

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time that LILCO witnesses are on that subject?

MR. GODDARD: The Staff sees no reason why not at this time.

MR. STROUPE: LILCO's only problem with the proposal Mr. Dynner has made, as I've indicated to him, is that we had, perhaps incorrectly, assumed that the crankshaft issue would most possibly be going through Thursday of this week until 12:45.

JUDGE BRENNER: Including shot peening?

MR. STROUPE: No. My witnesses on shot peening may well not be available until Monday. We have sort of a different problem there because rather than consultants, we have two outside people who are with Metal Improvements who actually performed the shot peening at Shoreham, and I really don't have a whole lot of control over either one of those gentlemen.

JUDGE BRENNER: Where are they located physically?

MR. STROUPE: One in Chicago and the other one is in New Jersey.

JUDGE BRENNER: As I said before in this case, it's not going to pay --

MR. STROUPE: I understand that, but we are certainly willing to allow the Staff with Mr.

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Bush on the blocks and shot peening, and I think we're agreeable to having Mr. Sarsten taken out of turn. Again, our only concern is that we're able to get our witnesses here on the shot peening when they're needed.

JUDGE BRENNER: I believe that we should be able to start shot peening no later than the beginning of Thursday. I may prove wrong, but I believe that right now.

MR. STROUPE: I must confess I based my estimate on the fact two-and-a-half days were spent last week on pistons, which I did not feel to be as complicated an issue as the crankshafts, so I used the wrong assumption.

JUDGE BRENNER: You want to support Mr. Sheidt's request for more time?

MR. STROUPE: That was not my intent.

MR. DYNNER: This is a precedent. It should be recorded for posterity.

JUDGE BRENNER: I'll give you my view that we were very liberal in the time we allowed for cross-examination by the County last week -- we were somewhat liberal.

MR. GODDARD: Judge Brenner, as opposed to putting on Dr. Bush with the LILCO panel in

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regard to shot peening, the Staff would have no objection to making Dr. Bush available on that subject by himself on Thursday. That might give us a chance to utilize that time productively.

JUDGE BRENNER: It would be, I think, more efficient to put them on together. For one thing, sometimes it's useful to put certain questions to non-LILCO witnesses, including Staff and County witnesses, based on some of the testimony we get from LILCO witnesses, and by putting them on together, I will not be deprived of that opportunity, and if I had my druthers and we put them on and you wanted them on separately, I'd put Dr. Bush on second, rather than first, unless that runs a risk for the following week, although I think we could finish within his schedule.

I thought rather than get to the point where people started feeling too pressured at the end, we could put them on together. Why don't you put -- "you" being LILCO. Find out what the situation is with your shot peening witnesses. I recognize you raise it now as a potential problem, so I won't tell you tomorrow if you say something today. You've achieved that. See if you can put them on standby with the possibility that they might

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well have to be here at the beginning of Thursday and, given their geography, I think that would be time enough to update them around midday tomorrow, and we can see what that situation is. We'll find some way to take Dr. Bush on shot peening, so you better have him on standby to be here whenever we get to it.

MR. GODDARD: Yes, Judge Brenner. He arrives tonight and he will be available through the 25th -- tomorrow night. He arrives tomorrow night. I stand corrected.

JUDGE BRENNER: That takes care of shot peening. Subject to our having to make some other adjustment for LILCO witnesses, which if we have to, we could make, but I think what would be more efficient in terms of finishing --

MR. STROUPE: I agree fully with that. It's just a question of scheduling. I will still, I think, probably be able to reach, at least the witness in Chicago maybe now with the time difference.

JUDGE BRENNER: I also understand why you want to take up the County's cross-examination of LILCO witnesses on blocks ahead of the County's cross-examination of LILCO witnesses on cylinder

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heads for the reasons indicated, and another reason would be that if cylinder heads are not settled, as I recall, Dr. Pischinger is one of the witnesses on cylinder heads, and this would give him time to return to Germany, with the possibility of coming back here for heads.

MR. STROUPE: He is a witness on cylinder heads if, in fact, that is not settled, but of course LILCO does have the desires we've expressed, both to Mr. Dynner and Mr. Goddard, if at all possible to take the cylinder blocks last because, as everyone knows, there are some ongoing analyses that have yet to be completed.

JUDGE BRENNER: I thought one of the reasons for putting that ahead of blocks was to see if we could get to it while Dr. Pischinger is here. Now that that's not possible, it might make sense to switch it around. I don't know what is ongoing on blocks.

MR. STROUPE: Well, there are some additional analyses being done and, as I think was indicated, maybe at the outset of the hearing or at least during one of the Board conference calls that we had, there is the possibility of supplemental testimony being requested.

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JUDGE BRENNER: Mr. Dynner said something about it, oddly enough, not LILCO, and I said I don't know anything about it, and that was all I heard. That was the end of the conversation. I'll repeat, I don't know anything about it. If you want to make some motions, we'll consider them. You've seen the footnote on one of our previous orders regarding Staff testimony.

Well, I'd like to know sooner rather than later whether we're going to have the cross-examination of LILCO witnesses on heads ahead of blocks or whether we'll take the blocks ahead of the cylinder heads, and we'll make a decision, if we have to, but see if you can work it out and let us know tomorrow sometime, sometime tomorrow.

MR. DYNNER: If I could just make one comment, we're going to proceed as quickly as we can to try and see whether we can get the cylinder head issue resolved. As you well know, that sometimes takes some time because our client is not an individual, but we have to go through some layers of bureaucracy to do that, and while we will be able to give you a very good idea and give LILCO a very good idea, once we have our discussions with them and even before we go through the layers of the

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bureaucracy, I doubt very much whether that can be tomorrow, Judge Brenner, and our obvious desire is that we not spend valuable time starting the litigation of an issue that we believe may well be resolved, simply to defer an issue that may or may not have supplementary testimony that we don't know anything about, either.

JUDGE BRENNER: Let me put it this way. I understand why you might not get your client here by tomorrow, but we've been through this before. I'm hoping that you, yourself, have a reasonable feel for your recommendation as counsel by tomorrow, and we can make some judgments on that.

MR. DYNNER: We will do the best we can.

JUDGE BRENNER: Thursday morning at the latest, let's put it that way. I won't describe the nature of the review by your client.

After we finish crankshafts, including shot peening, we could take Professor Sarsten on crankshafts. I assume that if we get to him next week, he will be here?

MR. GODDARD: Yes, sir.

JUDGE BRENNER: Of course, you can judge as things get close as to whether it looks like we're going to get to him or not, and we'll take him

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the week of October 1st. We're not going to run on October 5th, so I think we should be able to complete it earlier than October 5th.

The Staff testimony is not cleanly divided up on some subjects, and tell me a little more later, not now, as to who you would be putting up for crankshafts, whether you want to try to make some division with just Professor Sarsten or other witnesses up with him. Talk to the parties about that first after you have had a chance to consider and then let us know.

MR. GODDARD: Yes, sir.

JUDGE BRENNER: This week: let us know this week. That takes care of the short range problems. I don't think I'm going to be able to solve your problem. It's your problem, not our problem, with respect to Dr. Bush on the blocks. I do not want you to assume that we will still be in hearing on October 24th and thereafter. We might be, and certainly if it's just by a day or so, I'm sure we can make some accommodation, but I don't want to hold the hearing open for some lengthier period of time just to take one witness. There are a lot of people involved and very complex schedules, our schedules as well as the parties'.

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MR. GODDARD: The Staff understands that, Judge Brenner. Dr. Bush was a late addition to the panel in our PNL witnesses --

JUDGE BRENNER: You told me that in the context of your nonapology the other day. You pointed it out, but at the time you added him as a witness, you knew the schedule of the proceeding, so I comment on some of the cross-examination of the materiality of which came first. I don't know why he has to be in Europe. I assume it's important, to him, at least, and you may have to get him to make a closer judgment. Why does he have to be in Europe for that lengthy a period of time without the possibility of parole for time to testify here?

MR. GODDARD: He is involved with an organization which is doing some planning for coming here with regard to metallurgical programs, and he is an officer of the organization, or at least primarily a consultant to it. His presence there is, in his opinion, required. He is involved in the planning, and this is a commitment that did exist prior to his becoming a witness for the Staff in this proceeding, and we appreciate the problems this may cause and we hope it will work itself out.

JUDGE BRENNER: I don't know if it will

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work itself out, and the reason I say that is I don't know that the proceeding necessarily will last that long, not that your witnesses don't have scheduling problems, but if it works out, we're going to be here longer than I had hoped. We may be, and you'll see as things unfold, we'll have time to adjust, but as we get close to the beginning of the time of his departure to Europe, as we approach October 9th, you'll have a better feel for the situation, as will we, and we can discuss it again then, and it may be that you can find out whether he has to be there each and every day in Europe, that is, or whether there is some block of time by which, this being an organization, he can become involved a little later or finish a little earlier and concentrate his efforts on one end or the other end, and if he is unable to or unwilling to do that, you may need another witness.

MR. GODDARD: The Staff is aware of that possibility and has taken some steps in that regard. The primary problem at this point in time within the context of this proceeding is it's just too early to tell.

JUDGE BRENNER: It's to early to tell but it's not too early for you to have backups well in

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hand, and if you're going to do that, you need to do it sooner so the other parties know what other witness or witnesses you might have in mind, if there are such other witnesses, their qualifications, and then if you want to take some prehearing steps with regard to those witnesses. You can't wait until the last minute and say, Here's witness B instead of witness A.

MR. GODDARD: Your comments are understood by the Staff.

JUDGE BRENNER: But you'll know more and we'll know more. I recognize, Mr. Goddard, you're the messenger in this regard. So the parties will give us information on whether we'll take cylinder heads up ahead of cylinder blocks and that will depend on the settlement discussions before we get that point; however, we will finish with crankshafts and precisely how we will finish in terms of the shot peening witnesses, we will know more about tomorrow.

The preference would be to put Dr. Bush on the panel with LILCO witnesses, recognizing, as we have, what we've done prior to this time in this proceeding. They're testifying on behalf of different parties, of course. Would Dr. Bush be the

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only Staff witness on the stand for shot peening?

MR. GODDARD: That is correct, Judge Brenner.

JUDGE BRENNER: If there's nothing further, I think we've solved all the problems except Dr. Bush on blocks, and we'll see how that works out, but the Staff in the meantime is going to prepare for the eventuality that may not work out.

MR. GODDARD: We are prepared for it, Judge Brenner.

JUDGE BRENNER: Prepare, including the disclosure to everybody.

MR. GODDARD: We will disclose — as a matter of fact, the Staff's backup witness is a Mr. John Tobin, who is present at this time, and we will make his qualifications available to the parties this week.

JUDGE BRENNER: I missed his name. Could you spell it?

MR. GODDARD: John Tobin, T-o-b-i-n.

JUDGE BRENNER: We can adjourn at this time and we'll resume at nine o'clock tomorrow morning. Mr. Scheidt will complete his cross-examination of the first 15 minutes and we'll go to the Staff.

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(Whereupon, at 5:10 p.m., the hearing was adjourned, to reconvene at 9:00 a.m., September 19, 1984.)

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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:

SHOREHAM NUCLEAR POWER STATION

Long Island Lighting Company

DOCKET NO.: 50-322-OL

PLACE: Hauppauge, New York

DATE: September 18, 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)

(TYPED) JUDY L. FLOWER

Official Reporter

Reporter's Affiliation