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UNITED STATES
NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF:

LONG ISLAND LIGHTING COMPANY
SHOREHAM NUCLEAR POWER STATION

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY & 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

Wednesday, September 19, 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

APPEARANCES:

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C O N T E N T S

P R O C E E D I N G S

JUDGE BRENNER: Good morning.

MR. STROUPE: Judge Brenner, just as a preliminary matter, let me make two representations to the Court. One, Mr. McCarthy has worked his schedule out so that he will not have to leave at noon today. He'll be available, I believe, for the entire day, if need be.

Two, I have been able to get in touch with the shot peening panel and we are all set to begin shot peening tomorrow morning.

JUDGE BRENNER: All right. Very good.

I don't want to get back into the schedule again now, but when the Staff discussed the availability of its witnesses and we talked about being able to make an accommodation for the witness Sarsten, it was on the crankshafts.

Professor Sarsten also appears as a witness on the cylinder heads and on one other subject -- statistics.

Obviously, I guess he won't be here on that subject and is there any discussion from the Staff on this schedule?

MR. GODDARD: I'm afraid you are correct, Judge Brenner.

JUDGE BRENNER: I think he's the sole witness and there will not be any evidence then on that. My recollection from the testimony is that there may be no such occurrence.

MR. GODDARD: We do not -- on a review of it yesterday we did not find any and we are considering how we will handle that at this time.

JUDGE BRENNER: In addition, we said we'd take Mr. Bush on shot peening out of sequence.

You neglected to note that Mr. Bush also is the sole sponsor of two answers within the other section on crankshafts relating to something involving forging of the crankshafts.

MR. GODDARD: That is correct. We would make him available next week on those two limited questions also with the Board's permission.

JUDGE BRENNER: Yes. Well, you should be pointing these things out for us. I certainly don't have to.

MR. GODDARD: I believe I did point out one of them on the record yesterday. I didn't know there were two questions dealing with the forging.

JUDGE BRENNER: If I'm correct, there are two current sequences.

We can continue with the County's

cross-examination. It's 9:05, with your cross-examination to conclude at 9:20.

Whereupon,

ROGER L. McCARTHY,

FRANZ F. PISCHINGER,

PAUL JOHNSTON,

SIMON CHEN,

EUGENE MONTGOMERY

and

EDWARD J. YOUNGLING

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

CROSS-EXAMINATION

BY MR. SCHEIDT:

Q. This is to the entire panel. Other than the analyses referred to in the FaAA reports, LILCO exhibits and in your testimony, have you performed or are you performing any other analyses to evaluate the adequacy of the replacement crankshafts?

Q. Dr. Chen, can you start first?

MR. STROUPE: I thought it was directed to the entire panel. Maybe they should have an opportunity to discuss it.

JUDGE BRENNER: Yes. I thought you did direct it to the entire panel.

MR. SCHEIDT: The question is directed to the entire panel. If any of them are performing such analyses, they can so indicate.

JUDGE BRENNER: Do you want to ask each one of them individually or do you want the entire panel to discuss it and answer it?

Q. I'll start with Dr. Chen.

Are you performing or have you performed any other analyses other than those indicated in your report that is an exhibit to this testimony and any other analyses that may be reflected in your written testimony concerning the adequacies of the

replacement crankshafts?

Dr. Chen, if you can't answer it immediately, perhaps there's another witness who can.

DR. CHEN: I'm ready to.

MR. SCHEIDT:

Q. Thank you, Dr. Chen.

JUDGE BRENNER: Dr. Chen, before you even start, you're going to have to move your hand.

DR. CHEN: Yes.

When we run this TORVAP calculation, TORVAP R and TORVAP C, single orders, we did run tests concurrently with 11-inch crankshafts.

Q. I'm only concerned with replacement crankshafts, analyses of replacement crankshafts?

DR. CHEN: No, I have no other written reports.

Q. Any other analyses, whether written reports or --

DR. CHEN: Certainly, I make analysis to see the adequacy of 12 inch crank based on some of the experience we have with 11 inch, I have made some comparison.

Q. And what were the results of those comparisons?

DR. CHEN: On 11-inch that single order

stress is in the order of the 6200 psi which is over the DEMA limits and at that time I did not use six orders or 12 orders but based on four orders I collected the sum of the orders stress of the 11-inch is 9,000 pounds, way over the DEMA limit.

Q. Other than those analyses, have you performed any other additional analyses of the replacement crankshafts?

DR. CHEN: I did a lot of thinking, a lot of comparison, but nothing in a computer form, sir.

Q. Dr. Pischinger, have you performed any additional analyses?

DR. PISCHINGER: The analysis -- additional analysis done by me is -- with its results shown in the handwritten files you have. What --

Q. The calculation you're referring to?

DR. PISCHINGER: Yes, the calculation.

Q. And those calculation are your calculation on the endurance limit on the replacement crankshaft?

DR. PISCHINGER: Yes. Using the Kritzer-Stahl and we went several times as to these calculation. There has been further refinement to it and you asked what has been done since the

testimony was written.

Q. And in addition to your fatigue endurance calculation, have you performed any other analyses to evaluate the adequacy of the replacement crankshafts?

DR. PISCHINGER: No. Only refining and -- with the knowledge what the results has been proven.

Q. Dr. Johnston, have you performed any additional analyses of the adequacy of the replacement crankshafts?

DR. JOHNSTON: Yes, Failure Analysis Associates has performed calculation to determine the influence of the oil holds on the adequacy of the crankshaft.

We have calculated the stresses near the oil hold locations, determined that the stresses are lower than the stresses in the areas of the fillets, and, thus, have reached a conclusion that for the in-line eight engines, DSR-48 engines, the 13 by 12 crankshafts do not have a problem with respect to the oil holds.

In addition, we have also performed calculation on the question of misalignment.

There are specifications for acceptability during the alignment check that are

specified by Trans-America DeLaval.

We have reviewed these specifications to determine what the stresses would be if the misalignment was at the extreme limits of the allowables and have determined that the stresses under those conditions are very low and do not affect the adequacy of the crankshaft.

Q. Dr. Johnston, are you or FaAA currently performing any analyses or planning to perform any additional analyses to evaluate the adequacy of the replacement crankshafts?

DR. JOHNSTON: No.

Q. Thank you.

Dr. Pischinger, you testified that it was very difficult to measure strain from an operating piston.

Isn't it also very difficult to measure strain from an operating crankshaft?

DR. PISCHINGER: It's much less difficult because it's a rotating part. The piston is connected to this rotating part via connecting rod, and if you want to transmit any signals, you either have to do it by tender and wire or by any very complicated connection which -- this is much easier for crankshaft. It's a proven way to get the

signals from the crankshaft wire rotating equipment. I think to a degree it's a minor problem with measurements in crankshaft.

Q. It's not anywhere as difficult as pistons; is that correct?

DR. PISCHINGER: State of the art.

Q. Is it a proven technique?

DR. PISCHINGER: I wouldn't say this.

Q. Drs. Johnston and McCarthy, isn't it true that the total time strain gage on EDG 101 with the original crankshafts especially at a hundred percent load had to be minimized due to the distressed state of the crankshaft wire?

Do you know or do you not know?

DR. MC CARTHY: The discussion we're having basically centered around minimized that we got all the data we needed.

We weren't interested in running the test any longer than we had to to get the data that we required, so --

Q. Dr. McCarthy, do you have the October 31st Failure Analysis report on the failure investigation of the original crankshafts?

DR. MC CARTHY: I think so. Hold on.

Q. While you get that, may I ask Dr.

Johnston another question?

In fact, Dr. Johnston, the strain gage test on EDG 101 with the original crankshafts measured strain only in crank pins number 5 and number 7; isn't that true

DR. JOHNSTON: That is actually not correct.

The strains were also measured on the crankshafts beyond cylinder number eight, near to the fly wheel to determine the torque at that particular location.

Actually on crank pins strain gages were placed on crank pins number 5 and 7.

Q. In fact, signal problems occurred with strain gages on the number 7 crank pin so that the primary data obtained in use was taken from the crank pin number 5; isn't that true?

Dr. McCarthy, in reference to that report, if you'd look at page 4-2.

DR. MC CARTHY: I have 4-2.

Q. Thank you.

Doesn't that state that the total time that the strain gage test was performed on EDG 101 especially at a hundred percent load had to be minimized due to the distressed state of the

crankshaft?

Dr. McCarthy, doesn't that report state that fact?

DR. MC CARTHY: Yes, indeed.

The report states that we excavated the shaft, removed the cracked material and reduced the cross sections substantially. The report does state as you indicate.

Q. Thank you.

In fact, signal problems occurred with crank pin, the strain gage measurements on crank pin number 7 so that the primary data was obtained from crank pin number 5; isn't that true?

DR. JOHNSTON: The strain gage rosette consists of three separate gages which would have existed both on crank pin number 5 and on crank pin number 7.

If all three gages on one opinion are not performing properly, then it is not possible to get a complete reduction of data from that crank pin.

That was the case in crank pin number 7.

In crank pin number 5, we were able to obtain complete data.

I'd like to add --

Q. Dr. Johnston, I'm sorry --

MR. STROUPE: Could he finish his answer, Judge Brenner?

DR. JOHNSTON: I'd like to add that typically in running a test, the engine is brought to the load of interest and maintained there for approximately ten minutes to assure a form of equilibrium and then data is taken for approximately some small number of minutes, about two minutes is about all that is required.

That is our normal procedure that we will move to a load level of interest stabilized for approximately ten minutes, and then take data.

That procedure is also commonly used in taking torsiograph test data.

One of the reasons why you do not need a particularly long time to stablize when taking measurements on a crankshaft is because of the fact that the torsional vibration condition stabilizes very rapidly.

It's not dependent on temperature transients and other such phenomena he that might be take a long time to stablize.

Q. Dr. McCarthy, isn't it true that the strain gage measurements that are used in making your calculation of safety factors are based on

strain gage measurements taken on one EDG, namely, 101, with the original crankshaft and one EDG 103 with the replacement crankshafts; isn't that true?

DR. MC CARTHY: I'm going to defer to Dr. Johnston in answer to that question.

DR. JOHNSON: The strain gage test is done in close correlation with the finite element analysis.

The finite element analysis shows you the location to place the strain gage in order to obtain the maximum stresses.

Thus, it is not necessary to place gages at other locations that are not -- do not represent the peak strain locations.

In addition, the actual values of the stresses obtained by the strain gages are bound at crank pin number 5, as we've discussed yesterday, by the two finite element cases.

JUDGE BRENNER: Mr. Scheidt, the original time we set this morning is up.

If you could make efficient use of about 15 more minutes, we'll give it to you.

Q. Thank you, Judge.

JUDGE BRENNER: I don't know where these questions were over the last two days but I can

think of a lot of questions that you could have substituted these for including your opening discovery-type questions this morning, but we'd be interested in the questions that you've asked in the last ten minutes, so see if you can get what you want to get in the next 15 minutes.

BY MR. SCHEIDT:

Q. Dr. Johnston, your finite element analyses predicted maximum strains in crank pins number 5 and 7 for both the original and replacement crankshafts; isn't that true?

DR. JOHNSTON: Could I have the question again, please?

Q. Your finite element analysis predicted with both the original and replacement crankshafts that the crank pins with the maximum stresses were crank pin number 5 and crank pin number 7; isn't that true?

DR. JOHNSTON: The crank pin with the maximum stress is predicted and measured to be crank pin number 5.

Crank pin number 7 also has high stresses, not as high as crank pin number 5.

I just would like to clarify, though, that the finite element analysis uses as input to

that the calculation done in the modal superposition analysis.

Q. Thank you.

And all of your strain gage measurements on crank pins were taken from only crank pin number 5 and crank pin number 7; isn't that true?.

DR. MC CARTHY: Sure.

We don't particularly want to put gages on crank pins that are not highly stressed.

The purpose was to determine the most highly stressed values -- values of the most highly stressed crank pins, and those were the crank pins that were strain gaged.

Q. Isn't it true, Dr. Johnston, that EDG 103 cracked at crank pin number 6, and only at number 6?

DR. JOHNSTON: It is correct that the original crankshaft in EDG 103 cracked at crank pin number 6, as I see here looking at the LILCO deficiency report on that particular matter.

I would like to clarify this position.

The modal superposition modal which calculates the maximum stress in crank pin number 5, as we mentioned yesterday in response to a question by Judge Brenner, the maximum stress occurs between the center of crank pin number 5 and the center of

crank pin number 6.

DR. JOHNSTON: Thus, the prediction is that the stresses on the modal end of crank pin number 5 are the same as those on the governor end of crank pin number 6.

This is confirmed by not only Failure Analysis' analysis, also by Dr. Chen's analysis, by Dr. Pischinger's analysis, indeed by Dr. Sarsten's analysis of the Staff.

Thus since the stresses are believed to be of the same order on the modal end of crank pin number 5 and on the governor end of crank pin number 6, and we did indeed have cracks in both of those locations on different engines, it was perfectly reasonable to put the gages on one or other of those two locations.

The gages were indeed placed on the modal end of crank pin number 5.

Q. But your testimony is that you did not strain gage that location at which EDG 103 cracked on crank pin number 6?

DR. JOHNSTON: It is essentially the same stress location. We measured the stresses that you would obtain at that location. We did not place a gage there as I just explained because of the fact

that it is stressed in a similar manner to that on the modal end of crank pin number 5 where we did indeed place a strain gage rosette.

Q. But you did not have strain gage measurements from that specific location on crank pin number 6 to confirm or verify your predictions or calculations, do you, Dr. Johnston?

MR. STROUPE: Objection. He just said that was his answer.

Q. Yes or no, Dr. Johnston?

JUDGE BRENNER: Let's get a yes or no.

DR. JOHNSON: We did not and we did not need to, as our analysis is, in fact, apparently universally agreed to by both the NRC Staff and all of the experts on this panel.

Q. The NRC Staff will speak for itself, I'm sure, Dr. Johnston.

Dr. McCarthy, I want to refer you to your answer in question 58. The last sentence states that it was determined -- in part -- that it was determined that the endurance limit for the original crankshafts was 36.5 ksi.

Page 37, last sentence of answer 58.

DR.MC CARTHY: I am not an answerer of question 58.

Q. I'm sorry, then Dr. Johnston, and I want you to compare the figure in that sentence with the figure in Exhibit 317 at page 310 which states that the endurance for tne original crankshafts is 32.4 ksi. Is there a discrepancy between those two figures?

DR. JOHNSTON: No. There is not a discrepancy between those two figure. The 36.5 figure of endurance limit corresponds to an endurance limit with zero mean stress.

The 32.4 ksi refers to an endurance limit with a mean stress ratio -- a ratio of mean stress to alternating stress of that in the original crankshaft, so there is no discrepancy.

Q. Thank you.

And, Mr. Montgomery, isn't it true that the ABS calculated factors of safety are significantly lower than those calculated by FaAA -- than that calculated by FaAA?

Mr. Montgomery, do you know, yes or no?

MR. MONTGOMERY: The calculations performed by ABS which were provided to us as an integral attachment to their deposition shows that they performed six different calculation for a combined factor of safety; all of which I might note

are greater than one.

The mechanism that they used to arrive at these factors of safety --

JUDGE BRENNER: Mr. Montgomery, you're not answering the question.

He didn't ask you how they arrived at it. He asked you whether they calculated different factors of safety.

MR. MONTGOMERY: Than FaAA, and I need to describe --

JUDGE BRENNER: Answer it first, then describe it.

MR. MONTGOMERY: Different than the factor of safeties which were arrived at by FaAA.

Q. The question is aren't those values significantly lower than the value of factor of safety obtained by FaAA for the replacement crankshafts?

MR. MONTGOMERY: Absolutely not. In fact, some of them are higher than the factor of safety submitted by FaAA.

Q. Could he finish his answer?

JUDGE BRENNER: Now, let him give the explanation.

MR. MONTGOMERY: As I started to say

earlier, the ABS review has performed these calculations for combined factor of safety under six separate techniques.

The calculation utilized the proposed CIMAC rules for determination both of fatigue endurance strength as well as stress in the crankshaft which required the combination or superposition of bending and torsional stresses.

These factors of safety, therefore, would reflect a conservative code technique for determining compliance with a CIMAC stated allowable safety factor of 1.15, but, in fact, they went further and prescribed a desired minimum of 1.34 as their benchmark and made these various comparisons against that.

The spectrum again of factors of safety ranged from a minimum of 1.0.

MR. YOUNGLING: Up to and including a 1.568.

The FaAA factor of safety as stated in their report is 1.48; therefore, ABS factors of safety do, in fact, exceed the factor of safety determined by FaAA.

Q. Only when you consider the effects of shot peening, isn't that true, only when the ABS

attributes 20 percent increase to the fatigue endurance from shot peening, isn't that true, that's the only time that the FaAA calculations is lower than the ABS calculations; isn't that true, Mr. Montgomery?

I might add that FaAA's calculations did not include any effect from shot peening.

MR. STROUPE: I believe Mr. Scheidt has asked three questions in that same --

JUDGE BRENNER: Up until his last comment which we'll let the witnesses disregard unless we put Mr. Scheidt on the stand. Although he had several clauses in the question, it was really the same question, in my opinion.

Q. Mr. Montgomery, yes or no.

JUDGE BRENNER: Well, now you're being pushy.

I let you get away with the phraseology of the question, if you're going to insist on the answer yes or no. I would prefer you rephrase it.

Q. I'll rephrase the question if that will speed things up.

Aren't the values calculated by ABS in excess of the values calculated by FaAA only when ABS attributes a 20 percent increase to the fatigue

endurance limit on shot peening?

MR. MONTGOMERY: The ABS calculated factor of safety based upon stresses determined under CIMAC rules when adjusted would show a factor of safety of 1.565 with the effect of shot peening, and 1.3 or 1.2 without the effect of shot peening.

These marginal combined factors of safety, when bench marked against their desired minimums was determined assuming a superposition of maximum bending and torsional stresses.

The benefit that we have from the FaAA analysis, as Dr. Johnston had described earlier, was through the finite element and experimental techniques employed, we were able to determine both spatial as well as time differentiation between the locations of bending and torsional peak stresses; therefore, the determination of total stress state as calculated by FaAA would be representative of a more accurate stress state, whereas ABS performed their calculation under the proposed code rules which typically are utilized in the absence of a crankshaft. It's done for design purposes.

Q. Isn't it true --

DR. PAUL JOHNSTON: I would like to --

JUDGE BRENNER: Don't ask another

question. Are you still answering that one?

DR. JOHNSTON: Yes.

I would like to add that the allowable endurance limits specified under the CIMAC rules represent a very conservative allowable limit, whereas in this particular case we have -- we are in a really rather extraordinary position of having very good data on the endurance limit from the three full scale tests to failure of the original crankshafts.

In addition, I might add that ABS having considered this range of six factors of safety, all of which were greater than one, did, indeed, conclude that the crankshaft was adequate.

JUDGE BRENNER: Mr. Scheidt, I have relied upon you to keep an eye on the clock and you didn't do that, so I'll have to do it for you. We can see it's the second 15 minutes now and we'll go to the Staff.

If you want to put some offer of proof in on things you haven't gotten to, you can do it now or later.

MR. SCHEIDT: Judge Brenner, I don't anticipate making an offer of proof but I'd like to take the time and determine that for sure.

JUDGE BRENNER: All right. My experience has been, and one reason why I've become impatient with some of the cross-examination when we go over two days, is it takes too long to zero in on what is truly important, and then only when we say the end is in sight do you begin to priortize things.

I don't mean you, I mean all cross-examiners, and we're very liberal on the follow-up questions after redirect and we may become less liberal as to that -- so, but my experience has been by the time you go through that process everything gets asked and about the second time it's in a more focused context.

I'll stress some industries and I'll repeat it, when you're in your final moments as you were this morning, you open up by asking with a general discovery question of are there any other analyses.

You had the whole discovery time to do that and if you had something particular in mind, you should have asked a particular question.

But, as I said, we're certainly interested in some of the questions after that, but that's why we gave you the additional time this morning.

I'm asking all questioners to become more efficient and putting a little more -- put a little more self-discipline on yourselves from beginning and not wait until we're telling you the ax is about to fall before you do that.

We don't expect this pattern over two days of cross-examination or approximately two days of cross-examination of a panel on a subject to become a rule, and the cross-examiners for LILCO had better keep that in mind, too, when the County panel is up there and the same goes for the Staff.

All right, we'll go to the Staff's questions at this point.

BY MR. GODDARD:

Q. Dr. Pischinger, in the calculations of forced torsional vibration, the use of how many orders would be considered standard European industrial practice today?

DR. PISCHINGER: For the purpose of determining stresses in crankshafts, especially to refine methods, 24 orders is usually taken into account, that means up to the twelfth order starting with the .5.

Q. Can you estimate approximately how long the use of 24 orders in those calculation has been

standard in European industry practice?

MR. STROUPE: Judge Brenner, I'm going to object to this line of questioning. I must say I don't understand the relevance as it relates to the contention.

JUDGE BRENNER: I can see the relevance. The objection is overruled.

DR. PISCHINGER: To give a precise answer is not possible for me, because there are so many companies working, but, as I remember, it's mainly connected with the introduction of powerful digital computers, which took place in the -- well, mid-sixties, beginning of sixties to mid-sixties.

Q. Thank you.

You, in fact, you used 24 orders in the calculations of your adequate -- your calculation to determine the adequacy of the crankshaft under the Kritzer-Stahl method; is that correct?

DR. PISCHINGER: That is correct.

Q. In your calculation, what forging process for the Shoreham crankshafts did you use?

DR. PISCHINGER: For calculating the endurance limit, it was assumed, slab and twist, I think this is the translation of Frieform Geschmiert. And which is not so good as a so-called pressed

forging which is used for small crankshaft, and which is -- which is of the medium way you can do it.

Q. Which is the medium way you can --

DR. PISCHINGER: This is -- I think it's called slab and twist, yes.

I personally had a questioning with Krupp who manufactured this crankshaft and we used their procedure as an input.

Q. And it is your opinion that the Frieform method is the same as what is referred to as the slab and twist method?

JUDGE BRENNER: Yes. Can I ask a clarification question at this point?

MR. GODDARD: Certainly.

JUDGE BRENNER: You said that Krupp manufactured this crankshaft.

DR. PISCHINGER: Yes.

JUDGE BRENNER: Did you mean all three or one of the --

DR. PISCHINGER: All three of the replacement crankshafts?

JUDGE BRENNER: All three of replacement crankshafts.

DR. PISCHINGER: Yes. All three of the replacement crankshafts.

Q. What ultimate tensile strength did you assume in your calculation with regard to these crankshafts, Dr. Pischinger?

DR. PISCHINGER: We used conservative value of 700 units per square millimeters sorry. It is easy to convert.

This is one hundred -- about 102 ksi.

Q. Thank you.

Mr. Youngling, do you have the figures as to the actual measured UTS of the material in the crankshaft available ordered by Shoreham station from Krupp?

MR. YOUNGLING: Yes, we do. Mr. Montgomery has that.

MR. MONTGOMERY: Can you provide that figure for the UTS.

MR. MONTGOMERY: I direct your attention to Exhibit C-12 and you'll find therein the three American Bureau of Shipping reports on castings and forgings uniquely identified by their manufacturers' number 181965, 181943 and 181942 and the ultimate tensile strengths recorded, I believe, in Newtons per square millimeters. Newtons are shown to range from 695 for 181965, minimum of 702 for 181943 and a minimum of 695 for 181942.

Q. Dr. Pischinger, 695 Newtons per millimeter square would compute out to 100,777 psi; is that correct, 100.8?

DR. PISCHINGER: Yes.

Q. For two of those crankshafts then, the ksi would be slightly below your assumption using your calculation of 103; is that correct?

DR. PISCHINGER: Yes. This is -- but is no significant value in my opinion.

Q. Approximately two percent below; is that correct?

DR. JOHNSTON: It's less than one percent. Five parts out of 700.

Dr. Pischinger used 700. The minimum shown is 695, so it's about .8 of a percent.

DR. PISCHINGER: Yes. I went through these figures and, of course, I asked Krupp and Krupp -- they recommended to me to take 700.

Q. Mr. Montgomery, Dr. Pischinger was correct when he described the slab and twist method as the method of forging used; is that correct?

MR. MONTGOMERY: I can't confirm that point at the moment.

The crankshaft right now is in the process of manufacture to be forged with a specified

heat treatment but I'm sure that piece of information could be confirmed.

Q. Thank you.

MR. YOUNGLING: Perhaps I can help. The method is slab and twist.

Q. Thank you, Mr. Youngling.

Dr. Pischinger, is it typical European industry practice today to manufacture crankshafts for medium speed diesel engines of this size by use of the slab and twist method and for material of approximately this ultimate tensile strength?

DR. PISCHINGER: Yes.

Q. If you were designing a crankshaft of this size for an engine of this type and application, is this the forging method and material property which you would specify?

DR. PISCHINGER: This is a general question. Yes.

Q. Dr. Pischinger, are you familiar with revisions made by European classification societies, their standards for crankshaft design over, let's say, the last 20 years?

MR. STROUPE: Judge Brenner, I think at this point I'm going to lodge an objection to --

JUDGE BRENNER: All right. It's

sustained. Why don't you zero in more efficiently and directly to where you want to go.

Q. Dr. Pischinger, are you familiar with any trends in the standards for crankshaft design used by European classification societies with regard to the degree of conservatism in allowable stresses for crankshafts?

MR. STROUPE: Same objection.

JUDGE BRENNER: That one is a little better. I'll allow it. But you could have zeroed in more specifically than that.

I'm concerned about efficiency in general.

And you're liable to get a very long answer which might not contain what you're looking for and then you'll have to ask the question again you should have asked but if you want to stay with that question, I'll allow it.

Q. Thank you.

Can you answer the question as asked, Dr. Pischinger?

DR. PISCHINGER: Yes. To my knowledge, the trend of the European classification societies is to make increasingly better use of the most sophisticated knowledge of how to really calculate a crankshaft according to mechanics, and they are

today willing to give exceptional allowbles if a company can prove by enough evidence that the crankshaft, according to the state of the art of mechanical engineering science is reliable.

Q. Then, in your opinion, they are becoming less conservative or more conservative in their standards for analysis of crankshaft qualification?

DR. PISCHINGER: These allowances show -- because allowances are only necessary if a crankshaft would not comply with their rules, with their overall rules, so they are going to be less conservative -- which I do not want to be interpreted as a loss of safety. They make better -- they are willing to make better knowledge of today's technology.

Q. In your experience, are the allowable stress levels for crankshafts decreasing or increasing in the standards of these societies?

MR. STROUPE: Judge Brenner, I'll again make the same objection.

When he says these societies. I don't know what societies he's talking about, whether they're the ones that will be admitted in the contention or not.

JUDGE BRENNER: I'll sustain the

objection for that reason, and also because on what is now the second round of cross-examination, although certainly a first round by the Staff, I want to zero in better.

For example, the previous question and answer was generally interesting, but we can't use it as a finding that I can see.

I don't have any quantification at all to apply.

If the number goes from 1.4, the margin of safety goes from 1.4 to 1.1 because there are better analyses methods supposedly, how can I evaluate based on that type of general question and answer whether their reduction in the allowable margin of safety was justified especially if you're talking abstractly.

It's not going to help us.

Q. Thank you, Judge Brenner. I'll try to make these questions more to the point and shorter and we can get on to Mr. Stroupe's redirect probably this morning.

JUDGE BRENNER: I'm not criticizing the time the Staff is taking at all. It's obviously been very little time.

MR. GODDARD: I understand. We will

limit our questioning in accordance with your guidelines.

Q. Dr. Chen, do you interpret DEMA recommendations regarding maximum torsional allowable stresses to apply to the 110 percent overload as specified in the DEMA rules?

MR. SCHEIDT: Judge Brenner, can we ascertain what Dr. Chen was just reading from?

MR. STROUPE: He's obviously looking at DEMA, I believe.

JUDGE BRENNER: Wait a minute. Please don't talk to each other automatically unless it becomes an obviously minor point that you can sense that I won't mind.

Hold it, dr. Chen.

JUDGE BRENNER: If you want to ask him what he was reading from later, why don't you do it. I'm not that interested now. It may be after the answer is given and it will be important to you either -- if it is still important.

They're obviously reading from a lot of things continuously as they're up there answering a lot of questions. That's why I don't want to stop each time to find out what they're reading from.

Go ahead, Dr. Chen.

DR. CHEN: I'm trying to be exact.

The DEMA says it's to insure that no harmful torsional vibratory stress occur within five percent above and below the rate of speed.

It does not address to the overload condition.

In other words, the DEMA feels that if you pass the 5,000, 7,000 allowables, the rate of speed is conservative enough so that you can run two hours out of 24 at overload situation -- overload situation specified is 110 percent load without any problems.

Q. Do you know the reason for the limitation of the ten percent overload to two hours out of 24 in the DEMA standard?

DR. CHEN: This is -- this limitation is put on somewhat different from most of the marine codes, which is specified in maximum continuous reading.

And you can also refer to ISO codes which shows what is 100 percent rating and the DEMA code is somewhat unique, he mentioned about two hours at 24, as a limit how long you can run at the overload conditions.

And the member companies will try to

analyze and develop their engines according to that criteria.

Q. I believe my question; however, Dr. Chen, was whether you knew the purpose for limiting the overload operation of an engine to two hours out of 24 at a ten percent overload.

Is that to protect the engine?

DR. CHEN: I believe when we say that, if you will have more than two hours or 24, the repair maintenance costs or operating costs could be higher. The maintenance intervals have to be increased, something in that order.

Q. Thank you.

Dr. Pischinger, yesterday you testified to preliminary calculation which you performed comparing the maximum torsional stresses, I believe you used the units of measurement, Newtons over millimeters square for these crankshafts at 35 and 3300 rpm using rated speed plus five or minus five percent speed; is that correct?

JUDGE BRENNER: Did you say 3500 and 3300?

MR. GODDARD: Yes, I did.

JUDGE BRENNER: 3200 also.

MR. GODDARD: 3200 also. My concern is with the 35 -- 3300 calculation.

DR. PISCHINGER: Yes, I --

MR. GODDARD: Thank you, Judge Brenner.

DR. MC CARTHY: I think the question used rpm and you meant kilowatts.

MR. GODDARD: 3500 and 3300 kw at 450 rpm. That's correct, Dr. McCarthy. Thank you.

DR. PISCHINGER: Yes. Yesterday I gave preliminary values on the 3500 and 3300.

Q. Were you able to confirm those figures? I believe you were going to do a check on those overnight.

Have they been performed?

DR. PISCHINGER: I tried to do a check on the values at nominal speed, but, unfortunately, not yet at the values at over speed and lower speed.

Q. At the time that you performed those calculations do you remember when that was that you did, in fact, perform these calculations?

DR. PISCHINGER: Well, the lower load and lower -- higher rpm calculation are very recent. I think last week.

Q. At the time that you performed those calculations and recognizing that they were preliminary, it was apparent that the five percent overload calculation for both 3500 -- over speed

calculation for both 3500 and 3300 rpm exceeded the DEMA limits; is that correct?

DR. PISCHINGER: No. I think this is not correct, because the DEMA specifies the use of the summation of the major orders of vibration.

If you take it verbally as it is written, you have to do as you are advised. That's usually the reason of the code. You can argue if this is a good habit or not, but it's a code. The ABS even goes further.

They only sum up too critical as far as I went through the paperwork, so I think if you use a limit of the code, you have to apply the code mechanism of the code.

Well, to me it's similar --

JUDGE BRENNER: Dr. Pischinger, I wonder if I could interrupt, if you'll forgive me. This sounds very familiar, Mr. Goddard. I think I heard it somewhere.

MR. GODDARD: I don't think the question sounded familiar but the answer sounded familiar.

JUDGE BRENNER: The question sounded familiar, too.

Q. Dr. Pischinger, you testified yesterday that these calculations were intended by you on this

as comforting calculation; is that correct?

DR. PISCHINGER: Yes. I started these calculations, were given me -- would give me some additional feeling in going through the FaAA work.

Q. Were they intended in any way to support your conclusions reached in the calculation done under the Kritzer-Stahl criteria?

DR. PISCHINGER: Maybe there was now a misunderstanding.

What calculation did you mean now? At reduced loads or increased speeds or the calculation according to Kritzer-Stahl?

Q. I'm referring to the calculation which you did at 3300 and 3200 kw, 450 rpm at rated speed plus or minus five percent.

DR. PISCHINGER: To be correct in this connection, I had some discussion with Professor Sarsten, and I wanted to compare values. I think he did similar calculations.

MR. GODDARD: If I may have a minute.

Q. Dr. Pischinger, what is the factor of safety you arrived at under the Kritzer-Stahl criteria?

DR. PISCHINGER: This answer should be a little explanatory, I think.

I did the torsional calculations according to the Kritzer-Stahl criteria calculating, as I said yesterday, endurance from -- of the material, endurance limits, fatigue endurance limit and the maximum stresses.

The figure I arrived at was a little bit -- a factor of 1.02, that is a little, for one hundred present load, nominal. It is a little below -- well, it's about 1.02, and I compared, in addition, the lifetime as I pointed out yesterday of the 11 by 13 inch crankshaft, and found that the lifetime, cycles at full load, cycles at full load were about half of the real lifetime at the cracked crankshaft.

The other crankshafts having already cracks or it could have been expected they had only a little longer lifetime.

From this you can calculate further factor of safety, and this was done very carefully, because this is very important, and I found additional factor of safety in these predictions of 22.7.

This is a figure which came out of this comparison percent, so if you add this -- these both safety factors, you will take both into account, you can say a safety factor of about 24 percent.

Q. Dr. Pischinger, can you explain how you arrived at that 22.7 percent figure?

DR. PISCHINGER: Yes.

I used S-N curve, conservative S-N curve determined with failed crank, on the torsional vibration, and used this S-N curve in -- as it is done in the answer of the Miner's Rule with relative values, that means I brought it relative values, maximum strength. The ratio maximum strengths to endurance limit versus the cycles.

And if you go with the figures I got for the 11 by 13 inch crankshafts into this relation, you find a certain lifetime which are about two million cycles.

The real lifetime -- you have one point in this S-N curve. The real lifetime, -- at the Shoreham plant is the shortest lifetime of the three was four million cycles.

Then you can go with four million cycles in the same relationship and you find that the ratio of maximum stress to endurance limit should have been 22.7 percent lower, and by this you can say that either the predicted maximum stresses should have been lower or the endurance limit should have been higher.

I hope I am still answering your question.

Q. I think so, Dr. Pischinger.

DR. PISCHINGER: Yes. The endurance limit should have been higher.

Of course, I tried to answer these questions and I think I can answer these questions which of both is the case.

The Kritzer-Stahl under tortion is usually giving you very good prediction because it is based on a huge amount of measurements, and there is a further confirmation, of course, which is not needed for this method that I used, but it is very interesting.

If I compare the maximum stresses, the maximum stresses in the fillet predicted by Kritzer-Stahl with the measured values on both crankshafts, as it is shown in the FaAA report, there is very close correspondence, so close that I really was surprised myself that measurements on the crankshaft are predicted so close by this method, and so I had a further confirmation and I think the main point is now the endurance limit of this crankshaft, and it is known to me that the method in predicting the endurance limits by using all these factors for materials influences which I mentioned

yesterday give usually a conservative figure.

Though this figure is a lot lower than the endurance limits used by FaAA, the difference is in this figure, of course, and the endurance limit of this crankshaft must be higher than I calculated. Otherwise, it couldn't be explained that even the old crankshaft which material was a little inferior failed at about half of -- failed at about double the predicted time by this method.

Q. Dr. Pischinger, how did you arrive at the four million cycle lifetime for the failed crankshaft in EDG 103?

DR. PISCHINGER: This was a figure calculated out of the -- this was a figure given to me by -- supplied to me by FaAA and maybe they could comment on this.

It was, I think, taken out of the engines log book and taken into account, its load and overload cycles.

This, of course, is very important for my conclusion.

Q. Thank you.

Dr. Pischinger, were those figures based upon the time when the crankshaft actually severed and engine 103 was shut down?

DR. PISCHINGER: This was based on the time when the engine -- when the crankshaft severed.

Q. In your opinion, Dr. Pischinger, is failure of a crankshaft something that occurs at the time that a crankshaft is cracked due to stresses or must the crankshaft actually be operated until such point as it severs?

DR. PISCHINGER: This is -- well, this is really an interesting question.

There are two -- you can define two moments, one moment where the first crack appears, and the other moment when the crankshaft crack separates, cracks into two pieces, and I have to point out that the S-N curve I used was related to the time when the crankshaft separated into two pieces.

Though, of course, you can -- you can plot different curves, but this is, I think -- this curve which is in this case has to be applied.

Q. Well, then if you were to define failures as the time when a crack initiated in that crankshaft, the failure would be substantially less than the 4,000 cycle lifetime you just described; is that correct, Dr. Pischinger?

DR. PISCHINGER: This is correct, but my

calculation took into account the actual cracking of the crankshaft.

It is not essential for these calculations when the crack initiated.

By the way, it's very difficult to define the time of the varied initiation of the crack because the beginning is so small.

In these tests, I mentioned the proceeding of the cracks through the crankshaft, when designing the S-N curves, the proceeding of the cracks was watched, but it was only taking time to the complete crack.

DR. MC CARTHY: I might just add to that the time it takes a crack, once it reaches any size in the crankshaft it's not substantial.

In other words, it's a very short part of the remaining lifetime of the crank from the time a crack reaches measurable size until the time it severs the crankshaft.

Q. Dr. Pischinger, in contemporary European industry practice, what would be an acceptable range for the factor of safety in the design of a crankshaft for a medium speed diesel engine of the size that you're discussing here?

MR. STROUPE: I will make the same

objection on the record that I made some time ago.

JUDGE BRENNER: Well, if you're not going to be more specific, I will overrule the objection

MR. STROUPE: I will be more specific.

I don't understand the relevance of that question. I don't understand how it relates specifically to the contingent as it is admitted when it's not directed to a particular classification society or code that we're concerned with.

MR. GODDARD: I'm not looking for a factor of safety under any particular code.

Dr. Pischinger is familiar with the European manufacture and design of crankshafts.

He is purported to be an expert in this field, and I'm asking him what is the acceptable range for margins of safety for -- factors of safety for crankshaft design in Europe.

JUDGE BRENNER: I understand.

MR. GODDARD: I didn't mean to encompass all societies.

JUDGE BRENNER: All right. We're overruling the objection. There may be some confusion in your mind, Mr. Stroupe. Some of the prior objections of yours that were granted today on

Mr. Goddard's questions were not because the questions were irrelevant but because they were too broad to assist us in evaluating the merits.

I recognize why you wanted to get into the area. My encouragement was for him to get more specifically into the area, and this question is acceptable under that standard. And we'll allow it.

I don't want to give a long discussion here, but suffice it to say for the sake of argument, if you will, that we perceive from the way the testimony by LILCO was structured is that we should not use these other classification society bench marks or standards or guidelines, but, rather, take a look at the type of analyses that was done with the result, therefore, including the finite element analysis, et cetera, and the results of those analyses are expressed as factors of safety, among other means, and this question is certainly pertinent to assisting us in evaluating those results and that approach if, in fact, were correct that LILCO is going to argue in part, at least, that we should take that approach in evaluating the merits, so we'll overrule the objection.

Q. Do you remember the question, Dr. Pischinger?

DR. PISCHINGER: Yes.

As you probably will expect, the answer covers a broad range of safety factors.

To my knowledge, the lowest figures are 15 percent and it's ranging up to 30 and above.

And what is the reason for this, which is also expressed -- not only expresses my own knowledge, but which is also expressed in the relevant literature, it depends upon how much information -- how much background was put into the calculations used to assess the -- or to compute the strengths and the stresses in the crankshaft.

And if there have been measurements or if there are previous crankshafts you can rely upon but if it's a complete unique design or if it's a little upgrading of an engine which you know very well and have measured a lot, so it is one of the very well known experts in this field, Dr. Maas (phonetic) really says one should not worry so much on the safety factors but more on the background of calculation in connection with safety factors, but to my knowledge, it's ranging from 15 percent to 30 percent, the usual today's design practice.

Q. Thank you.

Dr. Pischinger, what credit did you take

in those calculations that you performed for the shot peening of the Shoreham crankshafts?

DR. PISCHINGER: None.

Q. If you were designing a crankshaft for a stationary diesel application, and your computed factor of safety is 1.02, would you take any steps to upgrade either the material or the method of forging -- or the dimensions of critical components of that crankshaft?

DR. PISCHINGER: If I have no other information available, that means simple calculations of a given design, I certainly would take measures. It depends on the circumstances.

One possibility is upgrading the material, of course, or change -- or alter the design.

Q. Thank you, Dr. Pischinger.

The Staff has no further questions for this panel.

JUDGE BRENNER: I was going to suggest we take the mid-morning break at this time if you wanted to use it to confer, but if you're complete --

MR. GODDARD: We're satisfied, thank you.

JUDGE BRENNER: We'll take a break at this point.

In any event, we will come back at 10:45.

(Recess)

JUDGE BRENNER: We're back on the record.

We're going to go to the redirect and pick the Board questions up later in the sequence either after the redirect or after the recross.

From time to time in this case, we have varied that, and I'm never sure which sequence works out better or even if there is a difference, and I don't know which sequence the parties prefer, so we'll try it the other way this time and maybe at some point we'll solicit your advice as to whether you have any strong preferences.

MR. STROUPE: We certainly don't have any and I think I can finish the redirect in fifteen or twenty minutes.

JUDGE BRENNER: We do have Board questions then?

MR. STROUPE: Yes, I do understand.

REDIRECT EXAMINATION

BY MR. STROUPE:

Q. Dr. Chen, do you recall testifying on Monday about the DEMA rules not being explicit enough to be used as a crankshaft criteria?

DR. CHEN: Yes, I have said that.

Q. Did you mean to say by that statement the

DEMA rules cannot be used to design a crankshaft?

DR. CHEN: Yes. I have said that, too.

Q. If you have an existing crankshaft, can you apply the DEMA rules to determine whether it is reliable?

DR. CHEN: Yes. That's what that allowable was designed for, based on their experience.

Q. Do you consider the DEMA rules obsolete?

DR. CHEN: If I have said obsolete, I don't mean that. I mean it's old rules that was established in the 1950's, 1960's and didn't change even in the 1970's, so they're conservative rules, old rules.

Q. Is it your testimony in response to the questioning by Mr. Sheidt, to your knowledge the DEMA rules with regard to crankshafts had not been revised since approximately 1972?

DR. CHEN: The portion on torsionals have not been revised since 1972.

Q. In spite of the fact there have been no revisions to the portion of DEMA relating to torsionals since 1972, do you consider DEMA to be a valid and reliable method of evaluating torsional stresses on crankshafts?

DR. CHEN: Yes. I believe that. And I think I made that statement before, and I -- I agree with you.

Q. Dr. Chen, could you take a moment to explain to the Board and to me the methodology or how you went about applying the DEMA rules to the replacement crankshafts?

DR. CHEN: I calculated the major orders of stress based on the TORVAP C which is a modal superposition method, and determined the stresses at all shaft sections and compared that to the allowables, both single order basis and on the sum of order basis I compared the figures with the 11-inch crankshaft also.

MR. SCHEIDT: We're just going into a re-summary of direct testimony.

I don't see the purpose that this testimony is advancing

JUDGE BRENNER: I don't agree with your characterization fully.

I think the questioning is still within a fair range of redirect.

We gave you a lot of leeway on cross and I think given that, the redirect is fair.

The nature of redirect is such that we're

going to hear the same subjects that we heard on the cross. And we'll draw the line, of course, in not allowing total repetition, but I don't think we've approached that at this point. Certainly not in any of the questions so far, Mr. Stroupe.

Q. Dr. Chen, can you explain or state how you selected the major orders for purposes of making the DEMA calculations?

DR. CHEN: Since the rule says major orders and not all orders, I selected the six largest orders and I'd like to refresh the audience here, the judge, one more page in Exhibit 18. I think -- I think we treated that one a little better.

Q. C-18?

DR. CHEN: C-18 and page 16.

The graph in that page shows graphically what I mean by major orders.

Since this engine is rated a 450 rpm, I consider the largest orders around that rate of speed. Some of the printing is not very clear.

If you see the two -- the largest one is the one that goes all the way to the peak is the force order and then the right of it peaks around 525 is the four-and-a-half order and that's also a large one, and the five-and-a-half peaks are 420 and

just left of the 100 percent speed and the other largest one six-and-a-half and the others, you can see it's quite a bit a ways from the speed we're talking about and they are very insignificant.

Q. Would it be correct that you did not consider the other orders as major orders?

DR. CHEN: I calculate them at the rate of speed, I selected six largest orders. Those are the majors I mentioned, then I added the six largest ones.

Q. Dr. Chen, is there an historical reason as to why DEMA requires that major orders be assumed for determining torsional stresses?

DR. CHEN: It would take a lot of time to talk about historical reasons. You have to go back to the SAE, the engineering Board and all that, but let me be brief that in the time of the 1950's, 1960s when these allowables were established as reliable figures, they were using only Holzer vibration type of calculations, and at that time it is not practical or feasible to calculate many, many more orders for any reason -- any degree of accuracy.

They were using tables, using hand calculators, and so they are not trying to simulate the actual dynamic vibration. They were using the --

using the major orders and see how it works and established a limit based on major orders and not all the orders.

Q. Dr. Chen, is it your testimony -- strike that. I'll start over again.

Is it customary and accepted practice of diesel engine manufacturers in the United States in making calculations to see if their crankshafts meet DEMA allowables to utilize four to six orders to sum?

DR. CHEN: Yes. The major orders are picked by looking at a graph on page 16 and usually only a few of them.

Sometimes only two or three of them are significant around the rate of speed that we're talking about, so four or six are chosen based on engineering judgment and based on their experience using that code of --

Q. Is it your testimony, Dr. Chen, that the replacement crankshafts comply with the DEMA allowables at 3500 kw?

DR. CHEN: Yes. I used, I believe, advanced methods. Modal superposition and using session by session and find the sum of six orders as well -- single order stress way did he below the DEMA allowables, and certainly based on that

calculation based on the same calculations using the same number of orders and same Ts of N, same number orders and find that 11-inch crank failed and exceeds the DEMA limits by as much as 40, 50, 60 percent.

Q. Dr. Chen, do you have an opinion as to whether the three replacement crankshafts at Shoreham are safe and reliable for their intended function?

DR. CHEN: Yes. I believe based on my calculations and based on reviewing all the data they are safe and adequate for the intended service.

JUDGE BRENNER: What do you have in mind as the intended service when you give a broad conclusionary statement like that?

DR. CHEN: Your Honor, when you design a crankshaft, you have to consider whether the generators, consider the rate of speed and consider the rpm work you're working with, and you also have to look at the past experience.

JUDGE BRENNER: I was hoping you would fill in some numbers for me.

Q. Dr. Chen, do you have the John Kaymmer affidavit available?

JUDGE BRENNER: Wait a minute. Let me

stay with this.

When you gave your conclusion, what intended service for these diesel machines did you have in mind? Did you have particular loads in mind or --

DR. CHEN: Yes.

The DEMA stipulates ratings, a speed and the application to go with their ratings.

I based on the ratings 3500 kw rate of speed -- rated power level 3500 kw power level and 450 rpm and used as a modal

JUDGE BRENNER: Did you have in mind a possible overload use at 3900 kw on the -- kw on the modal, of course?

DR. CHEN: Modal load.

JUDGE BRENNER: I have to watch horsepower versus piston --

DR. CHEN: I understand, Your Honor.

This is the reason I have conducted some calculations at overload conditions and see whether there is any danger at all, and I find that even you're running a 3900 kw you will be safe and adequate, but I have not predicted the hours how long you can run continuously at that rate of speed, no, sir.

JUDGE BRENNER: When you use words like "dange
I don't know what you have in mind. Are you thinking of consequences flowing or not flowing from the diesel not operating reliably or are you restricting your conclusions solely to whether or not there will be some defect in the crankshaft that would appear at the intended use of service, both normal and overload conditions as we've just defined it in our dialogue?

DR. CHEN: In all these calculations, we have to assume everything else the same, no lubrication problems, no other problems, and the engine will not suffer any torsional -- excessive torsional amplitudes of vibrations which causes torsional cracks or other consequences of the torsional vibration.

JUDGE BRENNER: I didn't mean to interrupt for that long, Mr. Stroupe, but some of these broad conclusionary things, I've had this conversation before with other attorneys, both for LILCO and other parties, are not going to help us. We're way past the point of the types of findings of decisions 15 years ago that the witness admits everything is okay, therefore, we find everything is okay.

We need the facts and we understand the conclusion in his testimony and then we'll put it together. But you're not going to get anywhere citing the finding on page so and so Dr. Chen says they'll be all right.

Q. Dr. Pischinger --

JUDGE BRENNER: Let me add, you won't get anywhere unless the bases for that conclusion is already in the record, and that's what we're interested in.

BY MR. STROUPE:

Q. Dr. Pischinger, these calculations that you testified yesterday about and you testified this morning in response to Mr. Goddard's questions about, specifically, at the 3500 kw loading, the 3300 kw loading and the 3200 kw loading, at both underspeed and overspeed, were those calculations done to determine if the replacement crankshafts comply with DEMA?

DR. PISCHINGER: No. These calculations have been just done to arrive at the -- sum of the 24 orders and the nominal stresses there and I didn't intend to compare it with DEMA.

JUDGE BRENNER: Does that one sound familiar to you, Mr. Stroupe?

MR. STROUPE: Well, I think -- in my mind at least there was some confusion about what the state of the record was for that particular aspect.

JUDGE BRENNER: All right. We'll give you some leeway.

MR. STROUPE: There may be some confusion in my mind automatically any way, but I was certainly confused there.

JUDGE BRENNER: Me, too.

Q. Dr. Pischinger, do you recall testifying, I believe, yesterday, that if you had designed the crankshafts -- replacement crankshafts at Shoreham that you might have made the webs approximately one half inch thicker?

DR. PISCHINGER: Yes, I did.

Q. Does that fact have any effect upon your stated opinion that the crankshafts are adequate for the intended service at 3500 kw and 3900 kw?

DR. PISCHINGER: No. I think I explained that in designing a crankshaft in a general sense, one tries tc compromise between web thickness and bearing load, and my feeling is that with -- for this engine, you could have found a better compromise which at least you could have used in the future to further operating the engine to higher

BMEP. This would have been reason enough for me to make this different design, but this has nothing to do with my assessment of the crankshaft by the Kritzer-Stahl criteria and calculations of safety factor.

I did it overnight. I even could tell you how much this improvement of thickness would have contributed. It would have contributed by about three percent to the endurance level.

Q. Dr. Pischinger, do you recall stating in your deposition testimony that the replacement crankshafts at Shoreham were just on the boundary of the Kritzer-Stahl criteria at full load?

DR. PISCHINGER: Could you repeat that? I had a problem with hearing.

Q. Yes. Do you recall stating in your deposition testimony that the replacement crankshafts at Shoreham were just on the boundary of the Kritzer-Stahl criteria or code at full load?

DR. PISCHINGER: Yes.

I made this statement. I mentioned also in this deposition that this criteria are conservative as already mentioned.

I did some further refinement work to this calculations in the meantime, and I also --

which is most important, applied this method to the 13 by 11 crankshaft which put me into a position to give a factor of safety which is inherent in applying this method to these crankshafts, and thereby I can now say that there is a factor of safety at full load of about 24 percent.

Q. Dr. Pischinger, based on your diesel expertise and experience, do you have an opinion as to whether the various analyses, calculations, experimental testing done by LILCO, FaAA, Stone & Webster and yourself, for that matter, is a reliable method of determining whether these three replacement crankshafts are safe for their intended function at 3500 kw and 3900 kw?

DR. PISCHINGER: I think that -- or I -- I believe my opinion is that all the data put together and having the experience with three failed crankshafts and having strain gage measurements on these crankshafts measured -- at least the 12 inch crankshaft at two places and the 11-inch crankshaft although with most of the strain gages operating, this is a very, very good input in connection with the work done at FaAA, finite element work, trying to do an independent assessment of the stresses in the crankshaft, and by comparing all this data and

comparing with my data, I am really confident that this crankshaft is good for this service.

Q. Thank you, Dr. Pischinger.

Dr. McCarthy, you testified in response to questioning by Mr. Scheidt in reference to a factor of safety, did you not?

DR. MC CARTHY: Yes. I recollect that.

Q. Can you tell this Board and me why you have confidence in this factor of safety if, indeed, you do?

DR. MC CARTHY: Yes.

We not only have confidence in the factor of safety, we have high confidence, and the reason for that is, quite simply, we know more about the design of this part than certainly any other part that I've ever confronted in my entire professional experience. I do not expect again to have this kind of information for a long, long time.

We have the benefit of three failed crankshafts, all failing where we would predict them to fail from our analytical model.

That implies, first of all, we have an analytical model which we do and it is confirmed by the previous failures.

In addition, we not only have an

analytical model, but we have a dynamics model and a statistical model. By that I mean we have a dynamics model which allows us to predict the vibrations and deflections of the moving crankshaft which, in addition, has been verified by torsiograph measurements on that crankshaft.

We have a finite element model of the crank throw for both the old and new shafts which has been, in turn, verified itself, by measurements on the old shaft while operating and the new shaft while operating, and I might add operating in the engines, in the services -- in the service and in the block for which they are going to operate in the service lifetime.

These were not tests done in test engines back at the lab, but, in fact, done at the site in the service on the block in which they're going to operate.

Finally, the model predicts the old shaft failure and the new shaft survival by a wide margin.

The full scale --

MR. SCHEIDT: Judge Brenner, I'd object to this testimony.

The witness is reading his answer from a prepared sheet, appears to be reading it from a

prepared sheet.

MR. STROUPE: I don't have any problem.

JUDGE BRENNER: Why is that objectionable?

MR. SCHEIDT: Judge, this is an oral proceeding. Testimony is to be presented orally.

If he wants to distribute this sheet to the parties and let them evaluate that, I'd appreciate that, but it should be an oral presentation.

JUDGE BRENNER: Well, can you explain to me how you're prejudiced by doing it this way as opposed to stopping and letting him read it into the record? What I'm getting into, we don't have any problem with you representing the County or any other party in preparing redirect answers with the witnesses. Quite the contrary, we expect preparation taking place and you will indeed be doing it with your own witnesses along with preparing them to answer expected cross-examination questions from other parties.

If it went on for pages after pages, obviously you have a right to look at it.

Let's see where it goes and how much is involved and how startling it is, and then you can -- maybe you can be more specific as to whether you

suffered any prejudice in any way and we can see whether or not an adjustment is required.

Q. Thank you, Judge Brenner.

MR. SCHEIDT: Thank you, Judge Brenner.

DR. MC CARTHY: Finally there has been an inspection in strength measurements made on all the installed parts, eliminating that aspect of uncertainty in the design.

Factors of safety are based on our knowledge of the application. They're not in design books, indeed in the design references that I've cited.

Some factors of safety you apply to crankshafts. Some factors of safety you apply to airplane wings and some factor of safety you apply to obsoletes.

Basically factors of safety are based on your comparison of the knowledge of the design and your certainty about the expected service.

In this particular case, we have a margin of safety, 1.5, and an incredibly detailed knowledge of the service.

Not only are we confident that the engine, the crankshaft will enjoy unlimited life at 3500 kw, but we believe would enjoy unlimited life if

operated continuously at 3900 kilowatts.

MR. STROUPE: Judge Brenner, that is the redirect of Long Island Lighting Company.

JUDGE BRENNER: With that answer, Mr. Scheidt, I just don't see a lot of extensive detail. It would be difficult for somebody to take notes orally and follow it, and I want to emphasize that there may come a time in this proceeding somebody is going to try to pull out a sheet and read a long list of details and figures and so on and that would be a completely different situation and feel free to object if that happens.

The objection would be, but you did not state now, that you can't possibly be prepared to cross examine that kind of detailed material that you're now hearing for the first time out of the scope of redirect.

It should have been in the direct testimony originally.

Beyond that, minimum time to read it, that type of thing. So that's why your objection before was denied. Try again. If it happens again as I just described it --

MR. SCHEIDT: I'm now better prepared, Judge Brenner.

JUDGE BRENNER: Obviously I made that speech for the benefit of all the parties. I want to prevent the situation and give you tips, which you don't need from me on how to object.

Judge Morris has questions at this point.

BOARD EXAMINATION

BY JUDGE MORRIS:

Dr. Chen, would you turn to Exhibit C-18, page 11.

The first paragraph discusses the free-end amplitudes and I'm must confess I'm confused by what it says there.

It says that the SWEC test report shows a full array of the free-end amplitudes, and its corresponding true sum results (0.69 degrees) and the next experimental stress was .05 to 0.69 degree which several recordings were studied.

So I'm left to wondering what is the true sum, what is the correct amplitude.

DR. CHEN: Judge Morris, I think you're most observant to find this discrepancy, and when this report was written, I had a curve which is labeled B 33, and later on when I talked to the author and the project man who furnished me with the -- that trace, he told me saying that that trace was

labeled incorrectly. And tnat's why it was not used in the report.

And I had at that time access of many traces, and it should be corrected that the spread was very little, is .69 degree and the spread was not -- sorry. This phrase, experimental spread was .05 to 0.69 should be stricken and I think the correction should be forthcoming.

JUDGE MORRIS: Thank you.

Q. Dr. Chen, have you had an opportunity to review the testimony of the Staff on crankshafts?

DR. CHEN: Yes, I have.

Q. Do you happen to have a copy before you?

DR. CHEN: Yes, I have.

Q. Would you turn to page 4 please.

Then on paragraph headed "Crankshafts," the first sentence says: "We" that's the Staff -- "have concluded that at rated engine load, the torsional stresses in the crankshafts exceed the DEMA standard practices. "

Do I understand correctly that you disagree with that statement?

DR. CHEN: Yes, Your Honor.

Q. Have you had an opportunity to discuss this disagreement with any member of the Staff panel?

DR. CHEN: There was a telephone conversation. I don't remember when. And I think some of the consultants were involved.

At that time my calculations methods were questioned. The disagreement of -- their disagreement of my calculations were not brought up by the Staff consultant at the time, so it was not -- I did not know until I see this that there is a disagreement when I have a chance to review this testimony, Your Honor.

Q. Have you had an opportunity to review the testimony enough to discover the reasons for the disagreement?

DR. CHEN: Yes, I have.

Q. Do you agree with the arguments of the Staff?

DR. CHEN: No, Your Honor.

Q. Can you explain why?

DR. CHEN: I believe the agreement is -- the disagreement -- the agreement is in the methods, and the disagreement is in this specific area that we discussed somewhat is how many orders we should use.

And I've been saying the major orders and the Staff consultant thinks 24 orders, and I stated

this morning, again, that the rules never contemplate the use of 24 orders.

What happens next year you've got 48 orders. I don't know. The limits might have to be updated.

In fact, sometimes the code, Your Honor, does get updated as time goes on.

A good example is the ABS data upgraded limits upward, not downward, because we have better calculations today.

Q. Dr. Chen, were the Ts of N values the same that were used by you and used by the Staff?

DR. CHEN: I believe in my testimony I have stated that Ts of N are used is the Lloyd Ts of N. The Lloyd Ts of N sometimes is a little bit higher than what's measured on the sum orders. Sum orders are lower than what's measured. Since I have not made any measurement, I was not privileged to use the actual pressure time on the time gage on the engines. However, when this was brought up the last two days, I went back and reviewed my data and doing some -- with calculators, not with my computer, I find that the amount of difference in Ts of N, especially in those major orders areas were not -- would not affect my conclusion; in other words, if I

used Ts of N -- higher Ts of N figures than FaAA used, my calculations would still show the single order would be way below the 5,000 pounds and sum of orders of six orders would be still safely below the 7,000 pounds, Your Honor.

Q. Dr. Chen, have you had an opportunity to review the County's testimony on crankshafts?

DR. CHEN: I have reviewed them.

There are lots of them, and I did not make calculations on each case to confirm it. Some of those -- or -- I'll let it go at that.

Q. Dr. Pischinger, have you had an opportunity to look at the County's testimony?

DR. PISCHINGER: Yes, Judge Morris.

Q. Do you have a copy available? Dr. Chen could look at one, too, if you have one.

Please turn to Page 114.

On this page, Professor Christiansen testifies that he performed some calculations under Lloyds' rules for maximum allowable horsepower.

This is a subject that has not been discussed so far this week, and I'm wondering whether the LILCO panel has addressed this subject.

DR. PISCHINGER: I did not calculate or consider Lloyds rules for this engine.

Q. Do you consider maximum allowable horsepower in determining whether or not the Shoreham replacement crankshafts are acceptable?

DR. PISCHINGER: Yes.

Q. How did you do that and what was your conclusion?

DR. PISCHINGER: Well, I relied on the detailed assessment of the crankshaft by taking into account the experience with the failed crankshafts, the measurements on the failed -- one failed crankshaft, on the replacement crank shaft, by reviewing the FaAA investigation in this method and by doing my own calculations according to the Kritzer-Stahl criteria.

Q. Did you actually calculate the maximum allowable horsepower?

DR. PISCHINGER: Well, if I take this Kritzer-Stahl criteria and make use of the figure for conservatism which I explained, I think yesterday and today in the request of the NRC Staff present, I can find that for 3900 horsepower there will be a safety margin of about 15 percent, which I really would regard as the highest allowable, and I would feel good if this really would be only -- stay in overload and not used for continuous rating. But

I think this is a way of operation in the Shoreham plant.

Q. I guess you meant 3900 kilowatts.

DR. PISCHINGER: 3900 kilowatts. I always have been talking kilowatts. If this is not right in the record, I am -- 3900 kilowatts as overload

Q. One final subject.

I assume the panel is familiar with the Staff's position that additional testing may be necessary for them to remove their position of not having reached an unequivocal decision on the adequacy of the diesels.

I wonder if, perhaps, Dr. Johnston, you could comment on the need for the additional numbers of cycles to support your conclusion on the adequacy of the crankshafts.

DR. MC CARTHY: Failure Analysis Associates does not feel that testing these particular crankshafts to reach tenth to the seventh cycles at 3500 kilowatts as proposed by the Staff is required because of the demonstrated factor of safety that these shafts have.

We believe that this factor of safety has been confirmed by a very extensive program of

testing and analysis both on the original and on the replacement crankshaft.

We believe that the -- any current inspections that have been performed in the highly stressed fillets of the Shoreham engines after approximately 100 hours of operation of full load on each of the three crankshafts demonstrates not only that there are not cracks already growing but that there are no defects there that would lead to -- would lead to an initiation site for a crack.

It's because of the sensitive analysis and testing and inspection that has been done on these shafts to date that we feel it is not necessary to perform the requested test to ten to the seven cycles.

Q. Dr. Pischinger, do you agree with that?

DR. PISCHINGER: Yes. I completely agree.

I may add that in a case which is not this case, where really a concern would be appropriate, it could happen that you have to test for a much longer time, because there are examples known where you have to go to the ten to the eighths cycles to arrive at endurance limits with crankshafts, shown in the literature.

Q. Mr. Youngling, does LILCO have a position

on this?

MR. YOUNGLING: Yes, Judge Morris.

We feel that the program that we've put in place, the amount of independence from Dr. Pischinger from Dr. Chen, the work of FaAA, both on an experimental basis and an analytical basis gives us a good foundation that we have a sound situation at Shoreham and no further testing is required.

Q. Dr. Chen, what are your views on the additional testing?

DR. CHEN: I agree with the statement that no additional testing is required because this engine has received much more testing than normally done.

We have a very fortunate or unfortunate situation that we have three failed crankshaft and using that as a base and based -- and also additional calculations shows that we have more than sufficient safety factor to insure the life of the crankshaft, so I personally do not believe additional cycles are necessary.

Q. The last two members of the panel may comment, if you feel that you have something additional to say that hasn't already been said on this last question.

Mr. Montgomery?

DR. MC CARTHY: No. I believe I have nothing further to add to that.

Q. Dr. McCarthy?

DR. MC CARTHY: Yes. I would add this observation: That given this design effort and given this analytical effort on this product, this particular crankshaft, that if at this point in time after what is literally the best effort that can be made under current science in the sense that everything has been both modeled, experimentally evaluated, the results found confirmatory.

If, in addition, we were to take as a societal or design position that under such circumstances this were not yet enough assurance -- in fact, we had to test a part to infinite life and destruction, the requirement that would propose to design in the future anything would be just staggering.

This represents as much as any designer will ever know about any part. And there literally can be no more confidence obtained through the engineering method than has been obtained about these replacement crankshafts.

Q. Drs. McCarthy and Dr. Johnston, have you

reviewed the program of LILCO -- proposed program for surveillance and test with respect to the replacement crankshafts?

I think it's a simple question. Have you reviewed or haven't you?

DR. MC CARTHY: I have not.

DR. JOHNSTON: No, Your Honor.

MR. YOUNGLING: Judge Morris, I was just citing the documents that would be involved to refresh their memories.

JUDGE MORRIS: Well, I have their answer, they have not.

DR. JOHNSTON: Perhaps I should just explain. In writing the design review quality review evaluation report, our recommendations did not require further inspection of the crank pin fillets, for example.

And I'm not aware as to whether LILCO has, in fact, made some additional document including some extra inspections or not, but the design review quality evaluation report did not require any additional inspections.

JUDGE MORRIS: Thank you, gentlemen. That's all that I have at this time.

JUDGE BRENNER: I have some questions.

BY JUDGE BRENNER:

Q. Dr. Pischinger, in your testimony on the crankshafts, you had a change in your testimony, in your estimate as to the number of hours that the crankshafts should be able to operate at 3900 kw from 600 to 1200 hours.

Can you explain that change on your part?

DR. PISCHINGER: Yes.

The first estimate was on the very conservative side, and the further refinement of our calculations led to this changed figure.

Q. Can you tell me, more particularly, what caused that change? It's a 100 percent change in the number of --

DR. PISCHINGER: Well, I agree this sounds 100 percent -- 100 percent change sounds terrible, but if you you take into account the slope of the S-N curve, then very small amount of change in stresses at this point of the S-N curve gives already a lot of change. Comparable cycles. This is one of the reasons why these curves usually are used in a logarithmic scale, and we used some very conservative slope for this S-N curve, generally, and then we finally got to this based on crankshafts which is, in my best knowledge, the most reliable we

can arrive at, and -- well, the best thing I could choose is -- I do not have it at the moment with me, but if you -- the further you get with your lifetime, the less change in stresses is necessary to give a large change in predicted lifetime.

JUDGE BRENNER: I'm not sure I'm following it. In fact, I'm sure I'm not.

Did you end up changing the S-N curve or did you end up with the conclusion that you would place your predictions for these crankshafts on a different point on the same S-N curve?

DR. PISCHINGER: It was -- it was a combination of both we redid the old -- the whole Kritzer-Stahl procedure, I think it was a recalculation a third time and at the beginning we used only a rougher method of calculations, and now we did it and have it, of course, documented in our -- my company and in my files very exactly.

We used it really to the point, and then we used, as I said, the S-N curve which is most appropriate for this case.

I think the bearing of what it says in this case is not so important if you take into account the point of the S-N curve where these results were obtained.

But, of course, in any case, you have to take into account, this figure does not take into account the safety factor within the -- within -- applying this Kritzer-Stahl criteria, so these figures are really -- really have no meaning. In reality there's a large amount of safety.

As I said with overload, 15 percent of safety against failure.

JUDGE BRENNER: On that subject, at what point -- at one point you said you would be pleased to highlight what in your view are the main conservatisms in the Kritzer-Stahl criteria and I would find that somebody would ask you sooner or later, I'm not sure that somebody did, but let me ask you.

The other day you wanted to give us your view of what the main conservatisms were in the Kritzer-Stahl criteria was the way you applied that criteria to this case.

Can you succinctly tell me what those main conservatisms are in your view?

DR. PISCHINGER: The main conservatism is arriving at calculating the endurance limit of this -- endurance limit of the material for this crankshaft.

If you compare the figures for this

endurance limit, which we calculated, and these are 175 Newtons per square millimeter, that which has been evaluated by FaAA and which also is given in modern literature which FaAA related to and which I think we can trust you see this tremendous amount of difference, and this is the reason why this -- using this criteria we get so conservative figures.

Q. In your testimony, Dr. Pischinger, you also assumed a certain percentage increase in endurance limit from the shot peening. Your present testimony is a six percent increase.

Is that based on some evaluation by you or are you just making the assumption and then applying it to your result?

DR. PISCHINGER: Yes.

That's -- I did not take into account shot peening.

As being no expert in the field of shot peening, and having no experience with shot peening, I do not want to take it into account myself.

And I only calculated -- I applied this conservative Kritzer-Stahl criteria without taking into account that it is conservative, what would be needed to arrive at infinite life at overload, and this figure is -- would be a contribution from

whosoever but in this case where shot peening is discussed of six percent of increase in the endurance limit.

Q. In other words, your answer seven stands for no more than the fact supplied if someone were to ask the question given your calculations so far what percentage increase in the fatigue endurance limit dc I need to get to a limited life of 3900 kw and you give them the answer.

DR. PISCHINGER: That's right, that's right.

JUDGE BRENNER: However you get the six percent is somebody else's business.

DR. PISCHINGER: Yes.

JUDGE BRENNER: Okay.

I could ask this of anyone, although I think Dr. Chen is, perhaps, the recipient of most questions on this subject.

We have been discussing these orders of frequency and the different major orders and summation of the orders and so on.

Am I correct that an order is a multiple of the nominal frequency, in other words, if I have --

DR. MC CARTHEY: An order is a multiple, judge, of the firing frequency, so -- the firing

frequency of one cylinder, so one cylinder fires -- well, I beg your pardon.

An order is a multiple of the rpm, so that the first order corresponds to a cycle that repeats itself once per revolution of the crankshaft.

Because of the facts that each cylinder fires once every two revolutions of the crankshaft the lowest possible order is a point five order.

DR. CHEN: He is correct.

Q. Is there such a thing as a highest possible order as applied to this case?

DR. MC CARTHY: No.

DR. JOHNSON: No. In fact this series that has been cutoff at various numbers, up to about 12, I guess, among the people in this room, does, in fact, go on forever.

Interestingly enough, the torsiograph test measurement does not have in it such a cutoff, so, in fact, it is going on to some much higher number, depending upon the characteristics of the -- of the transducer, but, essentially, it is taking true infinite sequence and we're cutting it off at about 12.

Q. Of course, as we've learned, I think on the record, when you say cutting it off at 12, when

you take account of the fact that there are half orders, that gives you 24 points.

DR. MC CARTHY: Yes, it does.

DR. PISCHINGER: May I, perhaps, add for understanding, that if you cut off at six the 12 orders, we found that you lose in the nominal stress three percent, so the last 12 orders only contribute to three percent, so if you would go further than 24, that would not even be expressable in nominal figures.

Q. Staying with what I'm sure are some basics for many of you, we've been discussing some of the so-called modern methods being used as employing a modal superposition analysis method, and at one point someone, I believe it was Dr. Chen, compared that to a harmonic synthesis method.

Your task is to explain that succinctly as you can so that I have an understanding.

Seriously, if you could explain what distinction you were trying to draw in stating that one method was a modal superposition method as compared to harmonic synthesis method.

DR. CHEN: Let me try to be very brief, then I'll refer this to Dr. Johnston. I'm sure he can answer a little bit better than I do.

Basically, among the experts, there are two methods used.

The one I used is TORVAP C dealing with all orders and there was -- well, I shouldn't say all orders. Orders that we choose, selected, had all the modes and it's done by simultaneous solving of complex equations.

Those equations simulate each station of the mass elasticity system that we -- simulates what we described.

And there's another method that Professor Sarsten used is similar but the way of calculating is different.

I would rather leave that to Professor Sarsten or perhaps Paul to describe what they use.

DR. JOHNSON: There were a number of questions earlier on -- from Mr. Scheidt about whether or not all of these techniques were, in fact, modal superposition.

In fact, although we, I think, have generally answered that in a sort of a lose sense to indicate they were, that's not really technically correct. Although all the techniques can, in fact, produce the -- essentially the same number. I think there's very good agreement between the numbers of

different methods used, but it is technically a different way of calculating the equations.

I'll just very briefly try to explain. The modal superposition method breaks down a set of equations into a number of very simple equations for each mode.

It then solves --

DR. PISCHINGER: What is a mode?

DR. MC CARTHY: Okay. A mode of vibration is, in a sense, a mode shape would be the shape in which a piece of equipment or any structure will vibrate if allowed to vibrate itself.

And the modal superposition method allows -- reduces the equations to very simple equations for each mode, and then solves for each mode and each order separately, and then sums all the orders and also sums all the modes.

In the technique that is used by other people that I believe includes Professor Sarsten, although I haven't reviewed specifically his code, the approach is to start with essentially the same equations, but solve the set of equations in the complex plane, the damping introduces complex numbers into the situation, to solve the equations in the complex plane, and you solve the equations

once for each frequency or for each order that you're interested in.

And then you sum overall of the orders only.

Now, it just turns out that both methods basically effectively include the results of all of the modes acting, but there is a technical difference.

I think that we try to sort of generally agree with Mr. Scheidt's questioning, because the technique basically leads to the same answer.

Q. Would the harmonic synthesis label be the one applicable to the method that Professor Sarsten used?

DR. JOHNSTON: Well, the harmonic synthesis actually would be applicable do either method, because of the fact that both methods solve on an order by order basis.

It just happens that the modal superposition method solves not only on an order by order basis but also mode by mode basis.

Q. On the last point you said, nevertheless, it happens that both methods include all the modes -- all the modes of interest. I'm not sure I follow why the method that would solve order by order such

as the one you ascribed to Professor Sarsten's code would in proceeding that way also include all the modes.

DR. MC CARTHY: The method of solving the modal superposition is simply a mathematical approach of solving the problem.

It just turns out mathematically that you can simplify the problem, decompose into modes and then reconstitute the problem.

The technique used by Professor Sarsten in a sense gets there more directly, would be one way of looking at it, but the modes are, in fact, automatically included.

DR. PISCHINGER: Yes.

If I may, I just want to add really that both methods involve all the modes in which a crankshaft can vibrate.

It's just a way of proceeding differently.

Q. I was wondering if it would help the record to apply your discussion to a particular example, such as one of the tables that you have which presents the modes in Exhibit C-17, but I don't think it's necessary to go through it.

I will just put a footnote in the record

here that table 3.1 does list the five modes, at least it lists the natural frequencies for the five modes.

DR. JOHNSON: Perhaps I could point out that was just so those natural frequencies could be compared.

In fact, all of the modes were used, but the first five are probably -- or first three are probably of more interest, so the table was limited to those of more interest.

Q. Okay.

Changing the subject, one of the witnesses, I don't remember which one, told us that the ABS, the American Bureau of Shipping had an in-house staff which, among other things, would inspect engine crankshafts for those that they were contemplating issuing a certification for.

Is that an inspection of the particular crankshafts in a particular engine or is it, rather, some inspection of a sample crankshaft in an engine or prototype?

DR. CHEN: Maybe I can explain to the Judge.

I'm quite familiar with the way that ABS operates.

ABS approval consists of several steps.

The first step is to crankshaft design as a whole, to calculate the peening and the geometry, the webs based on the submission by the engine builder.

You have to specify what firing pressure you run and they would calculate the pinning and the web and see whether they conform to their codes to be sure that bending stress is not over -- is not exceeded.

Then the second step is that in the field every time a crankshaft is built that if they require ABS certification, they will send the surveyor from one of the field service all over the world, Germany, Japan, all over the world, to actually inspect the particular crankshaft, whether that crankshaft conforms to the drawings, material specifications.

DR. CHEN: In other words, the overall drawings including the material, and it also includes nondestructive tests performed, and the surveyor is more or less an inspector and auditor. He has to certify that. In other words, if we get ABS certification, it's a quality control of every crankshaft that we received.

Whether we have ABS torsional calculations or not -- torsional approval or not from foreign countries -- crankshaft from foreign countries, it is quite expedient for ABS to have their certification so that we know as an engine builder that the crankshaft will be built according to the drawings.

That's the second step.

The third step is every installation -- every installation that ABS will review the calculations performed by the engine supplier, the engineers as far as torsional is concerned that they make the torsional verification, whether the stress is within their limits, so this is a three step approval, so to speak, as far as ABS a concerned.

Q. Did ABS perform an inspection of all three crankshafts at Shoreham, the replacement crankshafts?

MR. MONTGOMERY: The American Bureau of Shipping has submitted to TDI on our three crankshafts the documentation contained in Exhibit C-11 through C-13 which reflect their review and approval of the TDI crankshaft drawing for its dimensionals against the first criteria which Dr. Chen just discussed.

C-12 presents three separate certificates, each issued by ABS with an ABS serial number indicating their review and concurrence with the chemistry and material strengths for compliance with the ABS grade four material specification, and C-13, of course, is their review of the TDI submittal for applications of these crankshafts in the specified torsional installation system at Shoreham. However, presence of ABS personnel at Shoreham site has not occurred.

Q. Dr. Chen, does DEMA issue any opinions on whether crank shafts meet its rules or, rather, is it up to the manufacturer or whoever else might be interested to make a determination of compliance or lack thereof of a particular crankshaft with the DEMA rules?

DR. CHEN: The DEMA, I think I talk about that a little bit is not a design code. They really do not have Staff to check whether they conform or do not conform. Just like the SAE standards or other standards, you have to, if you are a member, you have to self-police your calculations and whether all the DEMA allowables are met or not.

I think this is spelled out in the DEMA handbook that this is a guide reference for

engineers, consulting engineers, government agencies, users, suppliers, et cetera. It provides generally accepted standards for nomenclature installations, operations, et cetera.

It is not the purpose of this book to attempt to set forth basic design criteria

Q. I think I can finish the question before we need to break for lunch and I think that will be for the benefit of the parties. Let's see if we can go just a few more moments.

Dr. Chen, the County cross-examined you about answer 46 on page 30 of your testimony in which you state you do not know of any situation in which a crankshaft that met DEMA recommendations has failed primarily from torsional fatigue.

I'm not sure the County got an answer to the question that might be phrased as follows:

Do you know of any situation in which a crankshaft that met DEMA recommendations failed for any reasons due to failure of the crankshaft and assuming proper maintenance such as oil lubrication and so on was performed?

DR. CHEN: When there is a failure that occurs in the field, I would not limit this to DEMA. Any crankshaft failure in the field, and there's

always a very extensive and intensive investigation, whether they are for -- for what reason they have failed because there is a lot of liabilities involved.

So even the -- whether this is ABS shaft or a large Lloyd shaft or a DEMA members shaft, it is my experience that the DEMA members have not received any complaint or any cause for concern that their shaft have failed because of torsional vibrations.

I'm not saying that there's no crankshaft failures or replacement of crank shaft.

In my experience, and I think we can see that also in the experience in the -- which has very good experience history of many diesel engine used in the nuclear plant and elsewhere, that the records will show that if they failed, they failed because other reasons that I have mentioned yesterday, and --

Q. If I could interrupt, you mentioned, of course, that it may not be proper maintenance, and you mentioned failures of other components such as the bearings causing failure of the crankshaft.

DR. CHEN: Yes.

Q. I'm limiting my question now to failures caused by failures of the crankshaft assuming proper

maintenance.

DR. CHEN: If you say that the proper maintenance including the alignment, including the overloading -- excessive overloading, then I would agree with you saying that it's my experience, and the records also show all the diesel generators running in the nuclear plants, there's no crankshaft failure for any known reason of crankshaft by itself.

I do not know of any. I find nothing in the records that's available in the DRQR tracking records, the tracking records.

Q. But are you limiting your last answer just now to experience in the nuclear plant to backup diesel generators?

DR. CHEN: I think my testimony says any experience.

I find no experience in the marine applications or the municipal applications or the oil rig applications that the generator sets failed because of the torsional problems or bending problems.

I can almost include that. Considering that overloading problem is -- it's not what the designer expected.

JUDGE BRENNER: Why did you include the

word "primarily" in your answer in the first -- in the second sentence in answer 46?

Do you have that in front of you? The phrase I'm focusing on is primarily from torsional fatigue.

If I remove the word "primarily," does that change the correctness of the sentence?

DR. CHEN: I think to a certain degree that there's crankshaft failures. The crankshaft failures for the reasons that I mentioned, and all the experts get together, there's always a combined stress situation, so you have to -- we have to analyze very carefully whether the combined stress is primarily due to bending which is caused by misalignment or bad foundation or other reasons or overloading, overfueling or the combined stress is caused by torsionals; so when you talk about combine stress, you have all these other factors involved, so I stated that primarily because of torsional, for that reason, many times we have crankshaft failures is not primarily because of torsionals.

Sure, the torsional contributes to the combined stress, contributes to the failures, but it is not the primary force. The torsional is not the one -- the torsional stress did not exceed the

limits; however, other stress caused by other factors exceeds the design limits.

Q. Because of these other factors, is that the reason when analyzing an isolation on torsional stress that margins of safety are important?

DR. CHEN: Judge, you're right. This is why the normal is set at very low figures comparing with the endurance limit of the crankshaft.

When we -- if you looked at some other history, every company who has reference that their bending stress has to be below a certain figure and when the code was considered, they would say, well, all the other stress has to be below a certain limit, then the torsional nominal stress we use, whether it's five pounds, whether it's 7,000 pounds would be more than adequate to assure the safety of the overall crankshaft.

So I think even in the case of TDI crankshaft there's other stipulation about the safety of the crankshaft such as the maximum firing pressure that ABS considered in their approval of the design, and also in operating and maintenance manuals, it specifies the maximum web deflection that one can have in the installation, and in some other -- also, how much overhand weight you can have

on the modal sets.

Your Honor, the crankshaft --

Q. I'm sorry, I didn't hear the last word.

DR. CHEN: Overhead weight that you can have, limit how large a modal you can put out, even that you -- even though you satisfy torsionals, so the crankshaft design is a fairly complicated design and we have based on our experience and based on in-house rules which is frankly much more conservative than what's used in the code.

JUDGE BRENNER: All right. The last subject.

Dr. McCarthy, I'm talking about the tests run on the old crankshafts. You stated, I think, that the cracks were excavated. Was that your word?

DR. MC CARTHY: I guess.

Materials actually removed, so that there was not a crack like defect in the crank when we started.

Q. Cracks were still there, weren't they?

DR. MC CARTHY: No. A crack -- the remaining crank -- the test crank, there was a crack and if you remove the material to a depth below the crack, there's a ditch, and excavation but there is a crack.

Q. I understand that. Thank you.

You stated your opinion that once there was a crack in a crankshaft of -- I'd like to apply it to the type -- the new ones, the replacement crankshafts at Shoreham, that once there's a crack, there would only be a short time from the initiation of that crack to severance of the crankshaft, and -- am I stating your testimony correctly?

DR. MC CARTHY: Yes.

Q. Can you qualify what you had in mind by a short time, a little bit?

DR. MC CARTHY: Yes. We did early on a sensitivity study on that.

My recollection is you -- after you had a detectable indication -- my recollection is you didn't have a week, you didn't have 168 hours left.

Q. Would I be correct in drawing the conclusion that if that's correct inspections of the crankshaft would serve little purpose because there could easily be a crack leading -- if there were a crack after inspection, it would lead to severance before the initial inspection.

DR. MC CARTHY: Yes and no.

Initial inspection does serve a purpose in detecting the initial defect. In other words, if

you put a shaft in the service of an initial defect, we would recommend inspection installation.

JUDGE BRENNER: I'm sorry. I wasn't very clear and you're correct to point that out. I meant inspections after the initial preservice inspection, in ongoing inspection-type program. In-service inspections.

DR. MC CARTHY: I think it's safe to say that we would not be in front of you advocating the use of this shaft if, in fact, it took any periodic inspection interval to keep it in service.

They would have to be very short. They would be very difficult, and we would see little purpose to any sort of periodic inspection.

Q. Dr. McCarthy, in my layman's mind from the point of view of engineering and the technical disciplines represented on the subject, it seems to me that the experience with the old crankshafts do not support your view that there is only a short time from initiation of cracks to severance.

Must I assume that it was very good happenstance that cracks had only very recently occurred in the two crankshafts for which severance did not occur? Can you help me out on that?

DR. MC CARTHY: Yes, just a moment. If

you would turn to Page 2-3 --

JUDGE BRENNER: Is this the report on the old crankshafts I referred to?

DR. JOHNSTON: Yes.

JUDGE BRENNER: I have that handy but why don't you proceed.

DR. MC CARTHY: On table 2-1 on Page 2-3, on table 2-1 on page 2-3, the hours on 101, 102 and 103 are summarized.

An additional piece of information not on the table is that the 100 percent hours of DG 101 which are stated at 180 should be 273, because the asterisked TDI factor test hours at the top of a 128 contain 93 full load test hours.

That means if you look across the EDG 101 that failed had 273 100 percent hours. The EDG 102 had 254 test hours plus some -- a few 100 percent hours from the TDI factory testing, and EDG 103 had 249 plus some fraction of 140 hour test at TDI and they were all within a very close 30 hour 100 percent margin?

DR. MC CARTHY: Their 110 percent running hours were 16, 19 and 20 respectively.

The engines were very close in their experience.

JUDGE BRENNER: All right. That, of course, is part of the picture.

The other part would be do you have any basis for knowing how long the cracks were in the two crankshafts that did not fail, whether they were, in fact, relatively recent within the types of hours you gave earlier?

DR. MC CARTHY: Once again, given their size, forgive me, there's methods to do it precisely and analytically, but given the size of the indications of the cracks we saw, there was not significant remaining life.

In fact, the whole reason we went through the crack excavation is the remaining life was so short that we wanted to assure that there was enough life on the shaft to complete the test.

Q. But -- yes, that's the other part of it.

DR. MC CARTHY: I mean they had to be fairly recent.

Once a crack gets to that size, had it been there much earlier, the shaft would have severed. They had to be young cracks because they both had cracks and not failed.

Q. All right. I understand.

If I can interpret that. They either had

to be young crack or at least they had to have grown to the point of being a problem very recently, or you would have had severance.

DR. MC CARTHY: Yes.

With the understanding that once you have a stress field that will initiate crack growth as in the old crankshaft, growing to a problem is assured and it's a very short order event.

JUDGE BRENNER: Thank you.

That completes the Board questions. I'm sorry, I apologize particularly to the witnesses to keep them here that long, but I thought it would help the parties for their follow-up questions for us to complete before the lunch break.

We'll take a break until two o'clock and we'll come back for follow-up cross-examination by the County, and keeping in mind Mr. Scheidt's valid point that it will be follow-up and there's no need to go overall old ground and then go through the remaining follow-up rounds. With that principle firmly in mind, we might be able to get to shot peening today.

MR. STROUPE: I cannot have my witnesses here today. I have to have some tire to prep them.

MR. GODDARD: Dr. Bush is not here today

also.

JUDGE BRENNER: We'll start shot peening tomorrow morning.

That does not mean that somebody's you -- somebody's law, I don't know whose, Murphy's -- Parkinson, that does not mean we should apply Parkinson's law and fill up the remaining time.

If we finish early, we'll recess early today. I'm sure the parties have plenty to do. The Board certainly does. We'll put on shot peening tomorrow morning. We'll be back at two o'clock.

(Whereupon, at 12:35 p.m., a luncheon recess was taken, to reconvene at 2:00 p.m.)

AFTERNOON SESSION

JUDGE BRENNER: We're back on the record. Good afternoon.

Mr. Stroupe, you wanted to raise a preliminary matter?

MR. STROUPE: Judge Brenner, I've been informed that Dr. Pischinger has a 5:30 flight from Kennedy to Dusseldorf. I would like to ask the parties if they would like to consider directing their questions to him on recross so he can make that flight.

JUDGE BRENNER: Can we do that, Mr. Scheidt?

MR. SCHEIDT: No problem at all, Judge Brenner.

JUDGE BRENNER: How much do you have totally?

MR. SCHEIDT: Approximately three questions.

JUDGE BRENNER: Why don't you proceed.

RECROSS-EXAMINATION

BY MR. SCHEIDT:

Q. Dr. Pischinger, you stated that you attempted to verify your calculations at rated speed of the sum of all 24 orders.

Have your results at that rate of speed changed at all as a result of your attempt to verify that information?

DR. PISCHINGER: You are referring to the results regarding the original full load, 3500 and 3300, and 3200; yes?

Q. I believe you stated that you had checked your calculations at rated speed at those three --

DR. PISCHINGER: Yes. Yes. And the figure stated as I had been given, yes.

MR. SCHEIDT: The County would request

that it be provided with a copy of Dr. Pischinger's calculations reflecting his predictions for 3200, 3300 and 3500 kw. At five percent above, below and at rate of speed.

JUDGE BRENNER: Why don't you talk it over with the other parties off the record, and see what happens.

You don't mean you want it this moment, do you?

MR. SCHEIDT: It's not necessary that I have it at this moment, Judge Brenner. You know where we are in the sequence of completion of questioning the witness on this subject, we'll see what happens.

Discuss it with LILCO and we'll see what happens.

Q. Dr. Pischinger, does the Kritzer-Stahl design criteria specify a recommended factor of safety?

DR. PISCHINGER: No discrete factor of safety.

Q. Well, does it provide any sort of recommendation at all as to what an appropriate safety factor is, value is?

DR. PISCHINGER: I can answer the

question in that way that if it is used, it holds true what I answered in the morning that depending on the input you have, a safety factor, calculations from 15 percent up to 13 percent is usually regarded.

Q. Thank you.

Dr. Chen, how many crankshaft failures in crankshafts of a size comparable to those of the replacement crankshafts have you investigated the cause of?

DR. CHEN: In this country, there are only two engines that are comparable to the size that we're talking about, one is the TDI in question, so we have done a lot of work on that, as you well know, for the Owners Group and so forth.

The other engineers, the PC2 series of engines, which has a little bit higher rpm and the horsepower rating is comparable, the BMEP level of the PC 2.5 is 20, 30 percent higher.

Q. How many crankshafts have failed on those engines that you have investigated the cause of?

DR. CHEN: As I mentioned, that there are several crankshaft taken out of the engines for different reasons, and none of them were for torsional reasons.

One crankshaft that failed, as I

mentioned before, that I have seen many crankshaft failures but none of them failed in the field for the reasons of torsionals.

I have seen -- we in the shop, in the laboratory we have failed a crankshaft and simply because we didn't -- did not treat the damping factor correctly, and the stress at that time indeed is much higher than we -- that we used to compare with calculations; in other words, the torsional failure is in the shop but we investigated -- it was primarily the failure because of torsionals in the testing stage.

We have to do other things to make the crankshaft work, so that's the other experience on torsionals, explicitly torsional failures, and the other failures in the field are caused by -- I investigated, I looked into, but mostly two reasons.

One reason is the lubrication, I think I mentioned.

The other problem is sometimes you got salt water in the lubrication system. The first lubrication problem is actually bad maintenance; in other words, they plug up --

JUDGE BRENNER: Forgive me. I wonder if I could interrupt. I lost the thread. I thought

the question was how many failures.

MR. SCHEIDT: It was.

JUDGE BRENNER: How many?

DR. CHEN: I don't -- I cannot remember exactly how many, but I would say several crankshafts have failed in the field and taken out of the engines, three maybe.

Q. The County has no further questions, Judge Brenner.

JUDGE BRENNER: Staff, anything based on questions since you last inquired?

MR. GODDARD: Yes, based on questions by Judge Morris and redirect by Mr. Stroupe.

BY MR. GODDARD:

Q. Dr. Chen, you indicated that you did calculations I believe, by -- using a calculator rather than a computer to generate new figures based upon six orders; is that correct?

DR. CHEN: I said this morning that because of Ts of N come up, I go back to using calculators and estimate the -- the sum of six orders using the new Ts of N figures and approximate -- and based on that approximation I would say that it still stays within the allowables.

Q. What was your -- some of the sum of the

orders using the new T of N values?

DR. CHEN: Sum of six orders?

Q. Yes. What was that sum?

DR. CHEN: It would be -- you mean figures?

Q. Well, yes.

DR. CHEN: The figures will be in the order of 66, 6700 psi.

Q. Dr. Chen, how would you define the term major orders?

JUDGE BRENNER: Mr. Goddard, I don't remember that in anything asked since you inquired, but, more fundamentally, it doesn't strike me as being something new. It is quite a bit in the original cross-examination by the County of these witnesses, unless you want to represent that there's some new point that you're going for that if they'll proceed from that question, I'm not going to allow it.

MR. GODDARD: I can tie it up rather quickly.

JUDGE BRENNER: You didn't answer my question.

MR. GODDARD: I believe it was based upon

the redirect --

JUDGE BRENNER: I asked him about the orders, I know that. But I didn't ask him how he defined major order.

MR. GODDARD: You didn't ask him how he defined it. I'm asking him how he defined for the purpose --

JUDGE BRENNER: But he was asked that by the County. Is this just a lead-in to another question?

MR. GODDARD: Yes, it is.

JUDGE BRENNER: Why don't you ask the other question.

BY MR. GODDARD:

Q. The term "major orders" is not defined in the DEMA rules; is it, Dr. Chen?

DR. CHEN: The DEMA rule only says major orders. It was not -- it was not possible to define what orders to look at. It depends on the crankshaft design and the speed you are working at.

Q. And you have heard in the discussion of the Staff's testimony that doctor -- that Professor Sarsten used 24 orders in his calculations; is that correct?

DR. CHEN: Yes.

Q. And you also heard that those 24 orders in Dr. Sarsten's calculations exceeded the DEMA limits of 7,000; is that not also correct?

DR. CHEN: That's in the County's --

Q. In the Staff's testimony.

DR. CHEN: Staff contention, yes.

Q. You've also heard Dr. Pischinger testify this morning that the use of 24 orders is standard European industry practice; is it not?

DR. CHEN: I heard that, yes.

Q. But in view of the fact that both Dr. Sarsten and Dr. Pischinger have used 24 orders in their calculation and the fact that the DEMA rules do not define how many orders should be used in major orders, does it influence your evaluation of these crankshafts in any way to know that the 24 order calculation of Dr. Sarsten exceeds the DEMA limits whereas your six order calculation comes up under the DEMA limits by only 300 to 400 kw psi?

DR. CHEN: I believe that we have done this thing fairly clearly, maybe it wasn't clear to you, that you cannot use one type of calculations trying to satisfy codes or the desired rules of another association or classification society.

The methods used has to be consistent

with the methods and experience that society has.

First of all, I believe that the amount of a so-called over the 7,000, it's less than -- less than a few percent, very small percentage, and I also mentioned that in all these societies and calculations, you can -- if you have better material, you can go in and make -- make a case, and also furthermore, the most important thing, if you were treated -- if you world treat this as a classification type of thing, if you have test data, and the strain gage data, torsiograph data, you can also make a case.

So I don't think that the -- even using 24 orders that the increase from the 7,000 psi is a very small percentage. I believe it's less than -- I don't remember the figures, but very small percentage.

Q. Less than five percent?

DR. CHEN: Less than five percent.

Q. In your 6600 or 6700 calculation you use the new Ts of N values also within five percent of 7,000; is it not?

DR. CHEN: Five percent the other way, sir.

Q. That's correct.

And this does not give you any question about the calculations which would indicate to you that these crankshafts are adequate for their intended service?

DR. CHEN: No. It does not; because I think I mentioned before that there's a lot of conservative safety factors building in the 5,000 and 7,000 pounds, especially at 7,000 pounds. At 5,000 pounds, the calculation answers very close, quite a bit below the 5,000 pounds. The 7,000 pounds, I think I mentioned that is the experience of the American builders and DEMA that 7,000 pounds using the methods that are described earlier and using the major orders the crankshaft is safe, and we have the rare opportunities to have three crankshafts fail when it exceeds the DEMA by a margin of a big amount, 9,000 pounds, four orders. It failed. And that's a benchmark. It runs for four million cycles.

I think that any -- I shouldn't say any, but most technical experts will agree that's a good benchmark and if DEMA knows about this, they will be -- they will say, well, their limit is very safe, because 9,000 pounds, it lived four million cycles, so 7,000 pounds would be very safe based on that.

Q. But there's limited operating experience

on the 13 by 12 inch crankshafts; is that not correct?

DR. CHEN: Well, this is where the engineers come in.

I have to base my experience and my observation and using the right analysis to predict whether the engine is safe or not.

I'm betting and I'm willing to bet on my own money that the crankshaft is very safe.

Q. I don't think we were getting into the area of betting, Dr. Chen, but --

DR. CHEN: But I'm willing to.

Q. In the event that an engine with limited operating experience and a conflict between experts as to the qualification of those crankshafts, would not testing of those engines be one way to resolve the possible difference of expert opinion?

DR. CHEN: I would say that if you go back to the classification society, they would say that they want some more torsiograph testings and they want you to submit some torsiograph readings, they want you to submit some strain gage data and they would evaluate it from them.

I'm sure that I can convince the classification societies that we have ample evidence

that this shaft will be safe.

Q. When I said testing, Dr. Chen, I was thinking in terms of operating experience at given load levels, not torsiograph testing.

DR. CHEN: You mean endurance testing?

Q. Endurance testing.

DR. CHEN: If this is a new engine, you don't have any prior experience, you don't have any failure records, I agree with you. I think I testified in my deposition that if this is a brand new engine, certainly I would do that, but since I have this background and this analysis made and this -- knowing exactly how much this crankshaft can take, I'm fairly confident that I don't need any more endurance testing.

Q. You just said a brand new engine.

Have you applied the same reasoning to a brand new crankshaft?

DR. CHEN: I think what I said is if it's a brand new engine with a brand new crankshaft, which I don't have any prior experience, I would do some endurance testing.

Q. Do you feel that the prior experience on the 13 by 12 crankshaft is enough from which you may draw a valid conclusion as to its adequacy?

DR. CHEN: I said -- I think what I said is that the 13-by-12 crankshaft have -- have some input, but the most important decision is made based on the 13-by-11, the torsiograph data.

My calculations on DEMA exceeded limits on that, and my -- and the improvement, the improvement of the real strength of the crankshaft from the 12 inch to 11 inches there's a major -- that's a major improvement of the strength in fatigue limit as well as the strength because of the design.

Q. Thank you.

The Staff has no further questions.

BOARD EXAMINATION

BY JUDGE MORRIS:

Q. Dr. Chen, I just have one quick question.

Mr. Goddard was trying to get some idea what you meant by major orders. Let me postulate something and see if you agree with it.

Supposing you take the sum of the orders, add them up, get the sum of the orders, then suppose you excluded any orders beyond that which were less than ten percent of the sum, would you be left with what you might characterize as major orders?

DR. CHEN: Judge, I believe what you said

is -- add one more order if the answers will be only ten percent higher or less than the rest of major orders.

I would say that after the six orders are picked none of the other orders would be adding ten percent. It will add one or two percent.

May I say something. Really sometimes you add orders you subtract something at different shaft sections. This is the truth.

In other words, you go to another shaft section, add an order, it does not always increase.

Q. Thank you for that information, but I'm still trying to get just --

DR. CHEN: I agree with you that would be one way to define maybe --

Q. I'm just trying to get a ballpark idea of --

DR. CHEN: Right.

Q. It's not 50 percent, it may be ten percent or something less, but --

DR. CHEN: For example, if you add one more order you would probably have two percent, three percent, after the six order in the case we're talking about.

In another case, I can mention that I had six orders, the increase of stress level -- increase

another six lesser orders, my increase is only seven percent, or six of them.

The accumulative effect of six of them is only seven percent.

Q. I'm trying to separate what you did from some general approach.

If you start off with 24 orders and certainly some of the contributions will be very small, less than one percent, and I believe you did, in fact, exclude some that were less than the order of one percent.

But you included those which you thought were major, I suspect, not only because of their magnitude but because of the way your program is constructed of calculating for six at a time, for example.

Is that correct?

DR. CHEN: The orders, the two factors in the orders, one is the magnitude of the orders. The other is phase angle.

I hope that I can give you a very truthful answer. If you look at the --

Q. Excuse me, Dr. Chen. But I think you're trying to tell me more than I need to know or want to know.

I just want a very broad answer --

DR. CHEN: Yes? I think what you said would be very conservative -- conservative estimate what I tried to do -- what I tried to say.

I hate to say this, the issue is really more complicated, because you have to look at all sections before I can make that judgment -- all shaft sections. So we did that.

Q. I'm really looking for a ballpark idea of --

DR. CHEN: I'm pretty sure of --

Q. Wait a minute -- of what is meant by major, and, you know, some people would say major means 90 percent or more. Others might say five percent or more. Just looking for the ballpark of what you consider to be a major contribution. Was it the order of ten percent or less? Was that approximately what you would say is major?

DR. JOHNSTON: I think that a rule of thumb of ten percent on the sum or maybe 20 percent on a single order by order basis is a reasonable rule of thumb.

It's not a specific scientific guideline obviously as spelled out in DEMA but you're in the right ballpark if you're talking about ten percent, one order being ten percent more is about the type

of thing that would be involved here, and I think that you can see that by looking at some of the exhibits that we referred to before, if my recollection is correct, if you look at Exhibit C-17, table 3.3, I think there that you can see that the amplitudes which are approximately proportional to stress will show that if you start throwing out orders that are on the order of ten percent or less, you're getting rid of just the smaller ones, and that is a reasonable ballpark number.

DR. CHEN: May I add one thing, I think I can clarify that. I was a little bit worried when you say that the next order is ten percent -- is -- I think -- after you pick four orders, okay, after you pick the four largest orders, then the next one's contribution will be definitely less than ten percent.

If you pick one major order, then the second one could be quite -- could be substantial, so you have to pick four -- the largest orders, then the fifth one, contribution, would definitely be less than ten percent.

Q. Well, I really wasn't asking that question. It's helpful additional information.

I just -- I was really looking for an

answer to Mr. Goddard's question of what is major and what isn't, and I think Dr. Johnston has answered that the way I was expecting an answer.

And I'll ask you if you agree with that answer.

DR. CHEN: Yes.

Q. Dr. Pischinger, would you agree?

DR. PISCHINGER: This certainly would be a reasonable definition of major orders.

Q. Thank you.

JUDGE BRENNER: After all we've been through, I don't know if there's any remaining call left, but I'll ask LILCO do you have any redirect?

MR. STROUPE: LILCO has no redirect, Judge Brenner.

JUDGE BRENNER: Would the County?

MR. SCHEIDT: No, Judge Brenner.

JUDGE BRENNER: Staff?

MR. GODDARD: No, Judge Brenner.

JUDGE BRENNER: We can excuse the witnesses at this time.

I think you're under the traffic in this area, you'll catch your plane at least this time of day.

Thank you very much for your time, Dr.

Pischinger. I don't know if we'll see you again. If not, it's certainly nice to hear your testimony, get the benefit of it as we're trying to get some insight into the merits of this.

Thank the rest of you also. I don't have my list who we will be seeing and who we'll not be seeing, and it depends to some extent what may happen with some of the possible future issues so let me thank you now very much for your assistance as we try to grapple with this and put it all together with regard to the merits of this case and you're excused at this time.

We have nothing else today.

MR. STROUPE: Not from me, Judge Brenner. I understand a little bit what happened this week in terms of -- I'm guessing, the parties had to wait until later in the week to know -- get a better hand on whether we would even get to shot peening this week at all and usually want to bring the witnesses in and not get to them, but let's be a little more solicitous of the time in this proceeding and less solicitous of witnesses' time in the future. We'll balance it off. Next time it will be for us.

MR. STROUPE: I guess I should point out we had the crankshaft witnesses all last week

waiting for pistons. That's what we based our decision on --

JUDGE BRENNER: Yes. I understand that I observed that and I directed my comments with that knowledge.

At some point, LILCO is going to inform us of what it is they are asking us to find in the context of my previous request given the Staff's testimony and the replacement plans for the -- not replacement plans, but additional plans for the new diesel engines made by, I guess, Colt, Fairbanks, Wilson diesels, Morse diesels and so on. We'll hear that sooner than later, I hope.

MR. STROUPE: I can speak partially to that at this time, Judge Brenner.

JUDGE BRENNER: I just want to know when.

MR. STROUPE: We are only asking at this time for this Board to qualify --

JUDGE BRENNER: I don't want to hear it now because I'm going to have to hear from all the parties on it, and what I was going to suggest is before you tell us on the record maybe inform the other parties off the record what it is you intend to do, and I wanted to add something which I will do now and that's another reason why I don't want to

hear it now.

We were given a photocopy of the letter to the Staff last week, and I don't know what to do with --

JUDGE BRENNER: We're not going to -- somebody is going to inform us of, I guess, LILCO, is the author of the letter, of what they think that letter means in the context of this proceeding since we have a contested issue before us, and this Board makes the decision, not the Staff on this test of issues, and I was careful this morning to emphasize through the witnesses, and you may have noticed what basis they're talking about here and that's the way we're proceeding.

And I don't know what effect LILCO expects this letter to have, but so far in this proceeding, it has no effect and will not have any effect as things are proceeding.

That may tie in with the context of my other question also.

We keep being tantalized with news bulletins about something else may be in the offing regarding, I guess, the blocks, and we're only looking at what's before us.

I don't want to be surprised in terms of

scheduling and things like that, because we've made some other decisions based on the schedule in this and other cases based on what we have before us.

I guess nobody is ready to tell us about anything further on the potential settlement regarding cylinder heads or whether they've volunteered to do that.

I would hope to hear about that tomorrow morning and I also insist on hearing tomorrow morning as to what the sequence will be for the cross-examination of LILCO witnesses after we complete shot peening which will be a cylinder panel, Staff and LILCO, and after we complete Professor Sarsten on crankshaft.

MR. GODDARD: Judge Brenner, the Staff has one matter which we think we should comment on at this time with regard to the convenience of the parties and not the witnesses.

Tomorrow we're going to be starting shot peening with the LILCO panel and, of course, Dr. Bush.

It is conceivable that we could finish with shot peening tomorrow and at that time presumably Dr. Sarsten would be called.

JUDGE BRENNER: Go ahead.

MR. GODDARD: I would like, if at all possible, to have Dr. Sarsten excused from the proceedings tomorrow, recognizing that we might finish prior to our normal closing time of 12:30, 12:45.

JUDGE BRENNER: I guess maybe I appear more unreasonable than I mean to be sometimes.

I certainly would not have expected you to bring a witness in who is not here. I don't know if he's here or not.

MR. GODDARD: Dr. Sarsten is here but I'd like to excuse him tomorrow.

JUDGE BRENNER: I don't think we'll finish shot peening by very much, with very much margin left tomorrow if we finish it at all.

I can understand not wanting to keep a witness here on the possibility that maybe we get a half hour or in that order of testimony.

MR. GODDARD: : Fine, thank you very much.

JUDGE BRENNER: I was talking about losing more time and I'm thinking ahead to your other witness schedule problems, if somebody has to leave after a certain day, and given that, I would like to have started. Enough said about it.

MR. STROUPE: Judge Brenner, at the risk of being the most unpopular fellow in the room --

JUDGE BRENNER: That still is reserved for me.

MR. STROUPE: I may win the prize this time, I wonder if it would be possible in the event that shot peening goes longer than people are anticipating to go later tomorrow to be able to finish that rather than my having to bring people back on Monday from Chicago and other points.

JUDGE BRENNER: I highly doubt that we will want to do that. We have too many other things going on as judges in this case, in other cases.

There are class schedules involved for Judge Ferguson. We need to be more orderly in the way this proceeding is scheduled for those reasons, and but that's our problem.

JUDGE BRENNER: It has also been my experience that if there's only another hour or so would legitimately take care of the testimony that usually parties can be more efficient and work it in so that we finish at the time frame; on the other hand, when parties say, well, maybe we can finish in another hour, it turns out that we never do, and, therefore, you were granted it.

One reason I'm so negative about it, we have done things, we have gone along with requests such as yours in the past and when I was younger I experienced and I've been sorry about 95 percent of the time because the goals hoped for by the requester either have not been achieved or could have been achieved.

I don't see any good reason why shot peening could not be finished tomorrow, but I didn't ask anybody for time estimates and you can answer them if you want.

Well, I don't know which County attorney I should ask. We can go off the record with all this. Let's close the record for the day.

(Whereupon, at 3:40 p.m., the hearing adjourned, to reconvene at 9:00 a.m., September 20, 1984.)

CERTIFICATE OF OFFICIAL REPORTER

This is to certify that the attached proceedings before the UNITED STATES NUCLEAR REGULATORY COMMISSION in the matter of:

NAME OF PROCEEDING:

SHOREHAM NUCLEAR POWER STATION

Long Island Lighting Company

DOCKET NO.: 50-322-OL

PLACE: Hauppauge, New York

DATE: September 19, 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) HELEN DOHOGNE

Helen Dohogne

Official Reporter

Reporter's Affiliation