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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

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LONG ISLAND LIGHTING COMPANY : Docket No. 50-322-OL

(Shoreham Nuclear Power Station):

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Court of Claims,
State Office Building,
Hauppauge, Long Island,
New York.

Thursday, March 7, 1985.

The hearing in the above-entitled matter was reconvened, pursuant to adjournment, at 9:00 a.m.

BEFORE:

JUDGE LAWRENCE BRENNER, Chairman,
Atomic Safety and Licensing Board.

JUDGE PETER A. MORRIS, Member.

JUDGE GEORGE A. FERGUSON, Member.

APPEARANCES:

On behalf of Long Island Lighting Company:

TIM ELLIS, Esq.,
Hunton and Williams,
Richmond, Virginia.

ODES L. STROUPE, JR., Esq.
Hunton and Williams,
Raleigh, North Carolina.

wb

On behalf of Suffolk County:

ALAN DYNNER, Esq. and DOUGLAS SCHEIDT, Esq.
Kirkpatrick and Lockhart,
Washington, D. C.

On behalf of the Commission Staff:

RICHARD GODDARD, Esq. and BERNARD M. BORDENICK, Esq.
Nuclear Regulatory Commission
Washington, D. C.

wb
3/7/85

C O N T E N T S

Witnesses:	Direct	Cross	Board	Redirect	Recross
Spencer H. Bush) Adam J. Henriksen) (Continued)					
By Mr. Dynner (Cont'd)		28,599			
By Judge Ferguson			28,674		
By Judge Morris			28,698		
By Judge Ferguson			28,704		
By Judge Brenner			28,705		
By Mr. Goddard				28,716	
By Mr. Stroupe					28,720
By Mr. Dynner					28,731
By Mr. Goddard				28,748	

Lay-ins:

(Resolution of Cam Gallery Monitoring Issue) flws 28,766

Exhibits:

(None)

Morning recess - 28,638

Luncheon recess - 28,673

Afternoon recess - 28,720

P R O C E E D I N G S

JUDGE BRENNER: Good morning.

I suppose the first thing we are interested in knowing is what the status is with respect to the proposed crankshaft rebuttal testimony. Can somebody inform us?

MR. STROUPE: Judge Brenner, I believe the parties have reached agreement that the Staff will make certain modifications to the testimony which will be read into the record this morning that I think all the parties have seen and discussed. We had a meeting to discuss it.

There will be no rebuttal testimony, based on our understanding that no one has any concern about these fast starts and/or step changes in load that we were talking about.

MR. DYNNER: Again, for about the third or fourth time this week, we have been left out. We don't have-- We have not been given by the Staff any proposed changes to their testimony. We have notifed them that, based upon discussions with our consultants, though we don't think that that particular subject matter is going to cause a problem, we have not been given the courtesy of seeing what these changes are going to be that presumably are proposed.

JUDGE BRENNER: Do you, Mr. Stroupe, know what the changes are that the Staff is going to propose?

MR. STROUPE: I just saw the changes, Judge Brenner.

JUDGE BRENNER: Well, I am not going to permit the Staff to give the changes until the County is informed in advance of what those changes are, so we will have to defer that until after another break.

We have addressed it several times, as Mr. Dynner has correctly said.

Next subject.

MR. GODDARD: Very well, Judge Brenner.

The Staff, pursuant to our--

JUDGE BRENNER: I should give you the courtesy of asking you: Is Mr. Dynner correct, as far as the Staff knows, that he has not been informed of the changes?

MR. GODDARD: There is no question with what Mr. Dynner says. The changes to the testimony that the Staff proposes are as a result of the meeting between LILCO, NRC Staff and consultants, and Mr. Bridenbaugh, the consultant to Suffolk County, which was held at eight o'clock this morning. It is a direct result of that meeting that these changes are made.

I did not know the particular wording of the changes to be made by the Staff or to be proposed by the Staff had not been seen by Mr. Dynner, but I certainly accept what he says as correct.

JUDGE BRENNER: Do you think Mr. Bridenbaugh was told what the particular changes are?

MR. GODDARD: I assumed that was the case. The attorneys were not involved in this meeting. It was strictly a technical meeting to resolve this issue. It was the purpose of the meeting.

JUDGE BRENNER: Why don't you take a minute and see.

MR. DYNNER: The answer is Mr. Bridenbaugh hasn't seen any particular changes. He said he took part in that meeting but we haven't seen the changes.

JUDGE BRENNER: All right. We will wait until after a break.

MR. GODDARD: Very good.

Tbe Staff has other proposed changes to its testimony which are made as a direct result of the direction from the Chairman yesterday with regard to a line-by-line review of the testimony based primarily on the unfortunate absence of Professor Arthur Sarsten from participation in this testimony.

JUDGE BRENNER: All right.

Before we do that -- that will be directly related and lead into the continuation of the cross-examination -- are there any other preliminary matters?

I thought the parties were going to be ready on the camshaft gallery agreement.

MR. ELLIS: Yes, sir, we are.

The situation is precisely as I described it to you yesterday. However, we have discussed the matter further, and we ask the Board to approve the settlement on the basis of the inspections that are covered in the agreement, every three months or 30 hours of operation, whichever comes first.

Of course if the 30 hours triggers an inspection, then the three months would begin from the date of that inspection and not from the date of the previous three months inspection or one month inspection.

JUDGE BRENNER: All right. We will discuss it among the Board members during a break, but that sounds acceptable. However, I want to discuss it. You will have to give us that in writing to reflect the change as soon as you get a chance. Am I right about that?

MR. ELLIS: Yes, sir.

Originally, as you recall, on the record you asked Mr. Dynner to send a letter and ultimately we had indicated-- We sent the Board a letter indicating that this issue still had not been resolved.

Would you like for us to do it by way of a letter to the Board or--

JUDGE BRENNER: Just a report saying that these are the words of the condition.

What I am going to ask the parties to do in proposed findings is to make sure that any conditions that the

parties have agreed upon or are advocating in support of their proposed findings be spelled out so that if we end up of course adopting an agreed-upon condition which we in advance said was acceptable to us that we certainly want the particular words of the condition for that.

And if a party in the other situation as an advocate is going to propose a condition in addition to just what the good idea is that the party has, we want the particular words and whether or not it should be a condition of the license in the tech specs or whatever, so that that would be something that we can catch up on.

And if we are going to have a dismissal of an issue then those words have to be written down somewhere. We can bind it into the record as an exhibit, or whatever is convenient. We may not be here any more by the time you set it in writing.

MR. ELLIS: We will try to do it this week so that we can do it before we take up the block. It might be more efficient if we do it that way.

JUDGE BRENNER: All right. You can simply lable the paragraph as the condition, if that be the case, or tech spec, and on the record the parties can say they agree to it, and we can make it an exhibit or something of that nature.

Procedurally there are a lot of options. I just

wanted to see what the words are.

MR. ELLIS: Yes, sir.

JUDGE BRENNER: But we certainly have the idea of the substance from what you have just told us, and we'll discuss it during a break among the Board members.

MR. ELLIS: One thing I wasn't clear about.

In going through now next line-by-line I think it will necessarily -- it will be necessary at that time I think to go through in addition the changes that we talked about before we went to the cam gallery, that is, the changes that Mr. Dynner indicated he hadn't seen. And it seems to me only reasonable to go ahead and give them now as opposed to waiting because if you are going to go through it line-by-line, you might as well-- This is one of those line-by-line items.

JUDGE BRENNER: The only problem is the parties think they have an agreement, and it would be unfortunate if a misunderstanding over a word or two which wasn't discussed led another party to have to be cautious or profess out and out disagreement when it could be smoothed out off the record. And that's why all the parties are supposed to meet and exchange this information.

So why not just leave those changes out, and after the break we will come back and do those changes?

MR. STROUPE: Judge Brenner, if I might suggest, I really think in three minutes it could be--

JUDGE BRENNER: All right. That's a good idea, Mr. Stroupe.

(Discussion off the record.)

JUDGE BRENNER: Back on the record.

We can tell you that we can approve the settlement on the camshaft gallery, as explained by Mr. Ellis, however we would like to see the precise words in writing, mostly so that we can assure there is no disagreement among the parties and everybody will know exactly what the condition or tech spec will say.

Occasionally in writing something like that out a detail occurs to the parties, such as the one you added Mr. Ellis.

All right. We can go back to you, Mr. Goddard, and you have changes that you wanted to make in the testimony.

MR. GODDARD: Yes, Judge Brenner.

As a result of your directions yesterday, the Staff has reviewed the testimony with a view to making certain changes. As a result of the cam gallery agreement which was discussed by Mr. Ellis, subsequent changes will be made to the block testimony deleting large portions, that which dealt with the cam gallery monitoring but that will not be presented at this time.

JUDGE BRENNER: All right. Do that in writing. In other words, give us all a written paper, including the Reporter, and we'll bind it into the record.

MR. GODDARD: We will do that.

JUDGE BRENNER: Give that to us in advance so we

don't have to waste any time going through it orally, and that way the parties will be assured they understand what's being deleted.

MR. GODDARD: We will do that.

Would it be satisfactory to make the deletions on the original testimony itself and present that?

JUDGE BRENNER: We can't, it's already bound in.

MR. GODDARD: Okay. We can resubmit the block testimony, if you prefer.

We'll worry about that off the record.

JUDGE BRENNER: You figure it out.

Whereupon,

SPENCER H. BUSH

and

ADAM J. HENRIKSEN

were recalled as witnesses and, having been previously duly sworn, testified further as follows.

MR. GODDARD: At this point I would like Dr. Bush to read into the record the changes to the Staff's prefiled testimony at this point.

WITNESS BUSH: The first change would be on the title page, which would now read:

"Spencer H. Bush and Adam J. Henriksen," and delete the words "and Professor Arthur Sarsten."

Page one, the last paragraph, that starts off

parenthetically "Sarsten" would be deleted.

Page five, the center paragraph that begins with the words "the testing," and ends with "engine operability," would be deleted completely.

Page 11, an answer to question seven, it should read "Henriksen, Bush," close paren, with the clarification that I am responding to the middle paragraph on page 12 and not the entire testimony.

JUDGE BRENNER: The one that begins: "The 20 hours of operation...?"

WITNESS BUSH: Yes, sir.

Page 13, under answer nine, item one would be dropped and also "Sarsten" in the answer, so it will read: "Bush, Henriksen."

Page 14, question 10 and answer 10 would be deleted.

Page 15, the page would be deleted.

Page 17 --

JUDGE BRENNER: Page 15, you are deleting that figure, is that right?

WITNESS BUSH: That's right, because it is cited in the paragraph that was deleted.

This may be subject -- this is a clarification, in the bottom paragraph the statement, the parenthetic statement that states: "As discussed in response to question 12," has been deleted and the statement: "Based on my extrapolation

of data in FaAA-84-3-16," replaces it.

JUDGE BRENNER: Could you do that again? This is the bottom paragraph of page 17, is that correct?

WITNESS BUSH: Yes, sir. It replaces the parenthetic phrase: "As discussed in response to question 12," and it reads: "Based on my extrapolation of data in FaAA-84-3-16." To my knowledge, that is a part of the official record.

Page 23, in answer 16, delete "Sarsten" and that's it -- I'm sorry, and "Henriksen" so I would be sponsoring question 16.

That's it.

JUDGE BRENNER: All right.

Thank you. We will just have to rely on the transcript page for now as the errata to the previously bound-in testimony and if the parties on their own want to oppose doing anything further they can but, if not, I think this would be acceptable.

Mr. Dynner?

MR. DYNNER: I don't know whether it is appropriate, there was a suggested last-minute change which Dr. Bush has just made which, in looking at it, I think too much was taken out and I would like to ask about it because it was made in the last 15 seconds when the Board re-entered the room.

If I could ask one question of Dr. Bush....

JUDGE BRENNER: I'll let you do that in a moment.

I still don't think we have on the record -- and I thought that's what we were going to have at the outset before we even went to the witnesses -- what the parties positions are with respect to the concern raised in the previous Staff testimony which we struck because there was not a sponsoring witness who was qualified, not because of any other reason.

And I want to know if -- let's get the position of the parties: Do all the parties agree that that is not a matter in controversy? Is that the situation?

MR. STROUPE: Judge Brenner, I would like information from both the Staff and from the County that indeed neither the subject of fast starts and/or step changes in load and any transients associated therewith is not an issue in this litigation and will not be questioned, so that I may let Dr. Pischinger and others go.

JUDGE BRENNER: Mr. Dynner, what's the situation from the County's standpoint?

MR. DYNNER: Yes, sir, that's correct.

JUDGE BRENNER: Okay.

MR. GODDARD: That is correct as stated by Mr. Stroupe.

JUDGE BRENNER: All right.

I guess I'm not speaking clearly. That's what I thought we would hear at the outset and that's why I didn't understand how deletions by Dr. Bush, who is not a diesel

expert anyway, would tell us that, as an expert in operation of fuel racks and diesels.

MR. STROUPE: Judge Brenner, we will furnish the Board with the transcript references from Mr. Knox's prior testimony taken at the hearing for purposes of allowing the Board to have those references that will need to be stricken also; I think you had requested that some time ago.

JUDGE BRENNER: All right. I don't know that it's necessary now that there has been an agreement among the parties; in other words, if we had ruled in one party's favor over the objection of another party, I think that would have been more necessary and I think I could save you the trouble of doing that now that you've got the agreement of the parties.

CROSS-EXAMINATION (Continued)

BY MR. DYNNER:

Q. While it's still fresh in mind, Dr. Bush, you'll recall that in the last 15 seconds or so of our little conversation it was suggested that on page five, the second paragraph be deleted to the extent that it merely summarized question and answer 10 which had been deleted.

Am I correct that the first sentence of that second paragraph does not go to the summary of question and answer 10 and really should not have been deleted?

A. (Witness Bush) I think you are correct. More

correctly, it would be the "however" and through "operability" in this instance. This was, as you say, something we recognized when we agreed on another page because it was essentially a summarization of a later page.

Q. So it's correct to say that --

A. (Witness Bush) You're quite correct.

Q. -- in the second paragraph on page five, the first sentence remains in your testimony and the balance of the second paragraph should be deleted, is that correct, sir?

A. (Witness Bush) That's correct.

Q. Thank you.

JUDGE BRENNER: Let's go off the record for a minute.

(Discussion off the record.)

JUDGE BRENNER: On the record.

BY MR. DYNNER:

Q. Dr. Bush, please turn to page 13 of your testimony. In the third line at the top of page 13 you refer to crankshaft stresses.

What did you mean by crankshaft stresses?

A. (Witness Bush) These would be the combined stresses or separate stresses and bending in torsion that would tend to control the possible failure and fatigue.

Q. Combined and singular, both combined and torsional stresses, is that correct?

A. (Witness Bush) Yes.

Q. Are there any other stresses that you were referring to there?

A. (Witness Bush) Depending on the geometry you might look at the tensile stresses there that would occur also. But generally the ones that would control would be bending and torsion.

Q. Well in the sentence were you referring at all to the tensile stresses?

A. (Witness Bush) Well the values I was looking at were both the combined and the bending and the torsion, so I was giving primary emphasis to those.

Q. Primary emphasis.

Were you looking at all -- When you wrote that sentence were you also considering tensile stresses?

A. (Witness Bush) Probably not.

Q. Well were you or weren't you? And do you now or do you not?

A. (Witness Bush) I would consider that bending and torsion would control, so those are the ones I would be looking at.

So the answer is I would not use tensile in that case.

Q. Thank you.

Do you know what the bending and torsional combined and single stresses are in the crankshaft at Shoreham at 3000

Kw?

A. (Witness Bush) I never looked at it definitively at 3000. We examined at 3300 and 35- and at 39-. And at about 36-, that's as far as we went under those circumstances.

Q. When you say "we went," who are you referring to?

A. (Witness Bush) Well this was intended to be a joint effort, doing the calculations, which would have consisted in that instance of -- Arthur Sarsten was there, Adam Henriksen was there, Dr. Laity was there, Dr. Dingee was there, Mr. Alzheimer was there and several others were there.

Q. Can you tell me now what are the bending and torsional stresses in the Shoreham crankshafts at 3300 Kw?

A. (Witness Bush) Only by extrapolation. I extrapolated from the -- to a major degree in the calculations we used we used extrapolation technique, using the data that were available to us from the FaAA report cited earlier, which gives numbers for the -- at 3500 and it also gives change in numbers for 3800 and extrapolates to 3900 and, by like token, you can use a similar approach to back-extrapolate from those to 3300.

Unfortunately we did not have access to the total original data, which would have included data, strain gauge data at 2800, which would have permitted an interpolation rather than an extrapolation.

Q. What page are you referring to, what document for the --

A. (Witness Bush) This is --

Q. Let me finish the question, please.

A. (Witness Bush) -- the FaAA --

Q. Let me finish the question, please.

A. (Witness Bush) I'm sorry.

Q. What page are you referring to in what document with respect to the torsional and bending stresses, both combined and single, for the crankshaft at 3500 Kw?

A. (Witness Bush) Page 3-9 of Failure Analysis Report 84-3-16.

Q. You told me in your previous testimony -- I'm sorry, I think you told Mr. Stroupe in your previous testimony that you are not an expert at calculating torsional values and stresses or bending stresses.

Are you an expert at extrapolation of stresses in the crankshafts?

A. (Witness Bush) I don't think that requires any particular degree of expertise, sir. If I have values there and I can establish what type of a slope it has and the degree of extrapolation is limited, I would not expect it to be particularly difficult.

Q. Did you make this extrapolation on a strictly linear basis?

A. (Witness Bush) Well in this instance, as a first approximation, it's linear, that's correct.

Q. Well how did you know whether or not a linear basis of extrapolation is appropriate in this case?

A. (Witness Bush) Because the error of any other slope or any other change would be minimal.

Q. I'm sorry.

A. (Witness Bush) Unless there were a pronounced change in slope and function because of the relatively short range over which one is extrapolation, it should have a minimal effect.

Q. But you don't know what that slope is, do you?

A. (Witness Bush) If I have essentially three points on there, I can, as a first approximation, see what it's like. If you mean do I have it, I did not try to do a regression analysis or something of that nature which is impossible based on the amount of data in question.

Q. Yes, and therefore you would not know whether the slope might drop off dramatically or not, would you?

A. (Witness Bush) Well obviously we cannot put much credit on engineering judgment, but based on almost any other type of equipment I would not expect a dramatic drop-off.

Q. But you don't know whether it would drop off dramatically or not, do you?

A. (Witness Bush) If you mean can I confirm it there,

the answer is probably not.

Q. Is it not or is it probably not?

A. (Witness Bush) I would not expect it to drop off dramatically.

Q. But you don't know whether it drops off dramatically, do you?

MR. GODDARD: Objection, asked and answered.

JUDGE BRENNER: No, overruled.

BY MR. DYNNER:

Q. You don't know whether it drops off dramatically, do you?

A. (Witness Bush) You're quite correct. I do not know that the sun is going to rise tomorrow either, which in my estimation is in the same category.

Q. Your estimation is based on your experience in doing torsional vibration and bending vibration characteristic calculations?

A. (Witness Bush) My experience is based in general on failure analysis, our research, of many components.

Q. Well would your experience in failure analysis of many components enable you to determine what happens to torsional vibration in a crankshaft under various conditions?

A. (Witness Bush) I'm not quite sure I understand what you're getting at in that question. Could you rephrase it perhaps so I can understand it better?

Q. I'll try.

Does your experience enable you to determine how the torsional vibration in the Shoreham crankshaft reacts at various power levels and load levels?

A. (Witness Bush) I'm using the strain gauge data which gives me a measurement of that and that's what I'm extrapolating from.

Q. That's not my question. My question is whether your experience enables you to determine how torsional vibration characteristics in the crankshafts react at different power and load levels.

A. (Witness Bush) Other than looking at the existing data the answer is that's how I determine it. I look at the data at different power levels, I observe the changes that occur at those power levels and I draw inferences from those values.

Q. So the answer to my question is no, isn't that right?

A. (Witness Bush) I do not consider that a no answer.

Q. Well let me try again.

Does your experience enable you to determine changes in torsional vibration characteristics of the Shoreham crankshafts as the load changes on the crankshaft? Does your experience allow you to determine that?

A. (Witness Bush) If it is within --

Q. Just try to give me a yes or no answer, then you can explain your answer.

A. (Witness Bush) If it is a matter of reading strain gauge data, the answer is yes. If it is a matter of an analytic calculation -- which is what we went through yesterday -- then obviously the answer is not yes.

I am using strain gauge data to a major degree under these circumstances for that purpose.

Q. So that your experience that you are referring to is confined to your ability to read strain gauge data that you have cited in the FaAA report, is that right?

MR. STROUPE: Objection, asked and answered.

JUDGE BRENNER: No, it may have been asked but the cross-examiner is entitled to leeway to get answers in terms that he is trying to ask the questions to identify with great clarity just what the situation is, so it's overruled.

WITNESS BUSH: As I say, the experience I am basing it on is looking at strain gauge data that were available in this report, that's correct.

BY MR. DYNNER:

Q. Now Dr. Bush, please look at page 16 of your testimony.

Where did you obtain -- Well let me ask it this way:

Who reported to you the hours and loads that are cited at the top of that page with respect to the operation

of EDG 103?

MR. STROUPE: I am going to object to that on the basis that it is answered in the footnote.

WITNESS BUSH: It came out of that report.

BY MR. DYNNER:

Q. It came out of the report that is noted in the footnote, is that correct?

A. (Witness Bush) That's right.

And if you are asking the next question if I was co-author of that one, I participated in it but I'm not quite sure -- I don't remember whether my name is on the cover or not.

Q. Did you review the actual test data for the operation of EDG 103 at those hours that you are referring to?

A. (Witness Bush) Collectively we looked -- well maybe I should ask for a clarification.

We looked at the reported hours but what approximated 3500 kilowatts; the same thing was true at greater than 3500. I am aware of a rather substantial number of telephone calls made attempting -- to LILCO attempting to clarify the precise status, for example, of the second item which is the greater than 3500 kilowatts. So we would have a more precise value. So basically this was obtained by discussions and from documents.

Q. Discussions and what?

A. (Witness Bush) And documents.

Q. Did you review the test documents for these hours that were run personally?

A. No, I did not.

Q. Were you able to receive or develop accurate and precise information as to the number of hours that these -- that EDG 103 was run at particular loads, at specific loads, or were you only able to generalize as you do here?

A. (Witness Bush) This is about the best we could do. We attempted to do a better job of quantification and were unable to do so.

Q. All right.

A. (Witness Bush) That's the reason for the word "approximate."

Q. You refer to a prediction of cumulative fatigue damage from these loads in the next sentence on that page and then you discuss Miner's rule in the Manson approach.

Did you personally undertake a prediction of cumulative damage fatigue for these particular loads?

A. (Witness Bush) Yes -- well, more correctly, I set up a matrix of conditions since, among other things, for the one used in the Manson approach, the ordering is important.

So what we did was established this matrix and including the additional hours at 3300 and actually conducted a series of analyses based on M/N relationships to determine

what I would call the degradation or the possible effect on the endurance limit.

We ran a substantial number of cases with these various permutations because the only absolute point that we knew for certain was the 3300 and we knew that was the past test that was run.

I used engineering judgment, engineering experience, to assess what I thought would be the most severe case versus the least severe case and ran these results. And by and large, they all showed the same thing and that is that the combination of loads and the stresses that were utilized are such that we are either very close to the endurance limit or we are below the endurance limit.

Q. And Dr. Bush, you say that you established a matrix of conditions.

A. (Witness Bush) Yes.

Q. Was this for the purpose of using the Manson approach --

A. (Witness Bush) Yes.

Q. -- while at the same time using the Palmgren-Miner cyclic ratio summation theory?

A. (Witness Bush) I was emphasizing the Manson approach because of the ordering effect that might have an impact on it, so I was attempting to look at it in the context of the possible impact of the ordering of the loads.

In other words, if the 3500 at 119 hours was the first load, would that have a greater impact than if the 3900 kilowatts at seven hours were the first load.

Obviously there is another case in there which, because of lack of data, we did not try to analyze, and that is that these could be broken up into increments so that the 119 hours actually was broken into a series. We did not go that far because we had no data that would permit us to go that far.

Q. When you are speaking of "we" as you answer these questions, are you speaking of yourself and someone else or are you just speaking of yourself?

A. (Witness Bush) This tended to be a collective effort in the sense that I was responsible for establishing the conditions but I did not push the buttons on the computer to get the readouts to establish what the values were.

Q. Well am I correct then that you used the Palmgren-Miner cyclic ratio summation theory, coupled with the Manson approach?

A. (Witness Bush) I primarily considered the ordering which would be used in the Manson approach rather than the Palmgren-Miner.

Q. And is that because the loading sequencers would have a significant effect on the predicted fatigue limit?

A. (Witness Bush) I think so. In the absence of

definitive data, the Palmgren-Miner approach certainly is appropriate. And I recognize that the Manson approach can either give higher values or lower values depending on the ratio.

I might comment that I suspect based on the results of the Manson analyses that the Palmgren-Miner would have given me almost exactly the same, namely, because of the relatively narrow band of stresses; in other words, that the change in stresses were not that large.

Q. Well which stresses are you referring to?

A. (Witness Bush) The combined stresses of bending and shear under these circumstances where we could establish a ratio of these which would give us an input to the equations and then we can look at the number of cycles for a so-called maximum stress and establish, based on the assumption that the onset of the endurance limit was essentially 10 to the 6, we could establish from that the effective life of each of the stresses.

Q. Are you talking about the stress levels at 3500 compared to 3300 again, when you made that statement?

A. (Witness Bush) This covered 3900 and 3500, we used the value of about 3600. These were somewhat corrected for the others and they also incorporated the 3300, that's correct.

Q. And when you used these values, am I correct that

you were using the values that Professor Sarsten had developed that you referred to previously?

A. (Witness Bush) No, because unfortunately Professor Sarsten wasn't able to generate bending moments and so I pretty much had to depend on the extrapolations or interpolations from the strain gauge data.

Q. Earlier in your testimony you had referred to the Collins work entitled "Failure of Materials in Mechanical Design Analysis Prediction Prevention," that had been cited in Figure 1 on page 15 which we have since deleted.

A. (Witness Bush) Yes.

Q. It's correct, isn't it, that in the Collins book Collins supports you in the position that you have taken that the loading sequences have a significant effect on predicted fatigue limits, isn't that correct?

A. (Witness Bush) That's correct. Professor Collins obviously prefers the Manson approach over the Palmgren-Miner approach, and I tend to concur based on experience.

Certainly if you have what I call a fairly high load for a number of cycles, as was cited in testimony yesterday by Dr. Pischinger, one would expect to have a pronounced effect. The effect as the stresses over a range get closer and closer together, they begin to get washed out because you don't see that one.

In other words, if everything falls within roughly

a 5 to 10 percent band and that band tends to be fairly low so it tends to be not too far from the endurance limit, you do not see much effect.

On the other hand, if you are higher than that for some finite number of cycles, then you can see a rather pronounced effect.

Q. You agree with Professor Collins that the rate of damage accumulated at a given stress level is a function of prior cyclic stress history then, don't you?

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A. (Witness Bush) I do.

With the caveat that I mentioned, if there is not much change, then, obviously, it tends to -- it all will wash out. But, certainly, if there's a substantial change, then I would tend to support that approach.

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Q. Dr. Bush, I think you referred to the fact that, in making your analysis under the Manson approach, that you took into consideration hours ranging from 3300 to 3900 kw on the crankshaft. Is that correct?

A. (Witness Bush) Yes, sir.

Q. There were, in fact, fairly large numbers of hours on the crankshaft at below 3300; isn't that correct?

A. (Witness Bush) Well, I'm aware of some hours below 3300. The numbers I'm aware of are not that large. Perhaps we should understand what you mean by "large".

Q. Do you recall prior testimony that the total approximate hours of all loads on EDG's 103 crankshaft was about 1,323 hours?

A. (Witness Bush) We used about 750 hours, I think, or 740, in our analysis.

Q. Yes. The 740 hours would be the hours at 3300 and above. Isn't that right?

A. (Witness Bush) That's right.

Q. And do you recall the previous testimony that the total number of hours on the crankshaft approximated 1300 hours?

A. (Witness Bush) If that has been available, I don't have access to it.

Q. Can you help us, Mr. Henricksen?

A. (Witness Henricksen) Yes. I think you're referring to prior to the last 525 endurance test.

Q. Yes.

A. (Witness Henricksen) Well, that was agreed to wash everything that was below 3500 at that time. It would not count. And I'm not sure Dr. Bush is aware of that.

Q. Yes. But are you aware, Mr. Henricksen, that there are approximately 1300 total hours at all loads on the EDG 103 crankshaft?

A. (Witness Henricksen) The figure seems to be correct.

Q. If Mr. Henricksen is correct, then, Dr. Bush, there are about 600 -- 550 to 600 -- hours that the crankshaft was run at loads below 3300. Isn't that right?

A. (Witness Bush) If that's the case, that would be true, yes.

Q. And you didn't take those into consideration in the Manson approach analysis that you performed, did you?

A. (Witness Bush) That's correct. However, if the other values are indicative, they would not have contributed to the Manson approach, simply because they would be too low.

Q. But it's true, isn't it, that the Manson approach

does consider all of the cyclic history of the crankshaft and not just selected portions of the cyclic operation? Isn't that correct?

A. (Witness Bush) I believe if you read Collins' dissertation on the Manson approach, when you have stresses that are substantially below what I will call the terminal endurance limit, that he indicates that they have little or no contribution -- essentially, no contribution. In other words, you should have an infinite life under those circumstances. So the cycles have, essentially, no contribution under those circumstances.

Q. Well, do you know whether the torsional and bending stresses on the crankshaft at loads below 3300 are substantially lower than the stresses at 3300?

A. (Witness Bush) The answer is: as of this morning I know more than I did yesterday.

Q. My question --

A. (Witness Bush) The answer -- at the time I wrote the report, the answer is: I wouldn't have known that. We discarded those data.

Q. And you say you know now that the stresses below 3300 are substantially less than at 3300?

A. (Witness Bush) Yes.

Q. All right. What are the stresses at, let's say, 3000? You don't know that, do you?

A. (Witness Bush) I could take this report and I could interpolate from the 2800 data and come up with a value. I did a quick examination this morning, and between 3300 and 2800 on the bending and the torsional stresses, the shear stresses, there was about a 16 percent differential. And if I work backwords -- 18 percent, I believe it was. And if I work backwards from that figure to about 3000, it would probably be around 11 or 12 percent lower.

Q. You say you looked at this quickly. You didn't make an actual calculation. You just eyeballed it: is that what you mean?

A. (Witness Bush) Well, what I did is I took the values at 2800 and I took the values at 3300, and I looked at the delta values between these two levels of kilowatt in the bending stress and in the shear stress, and made an assumption that, as a first approximation, it would be linear, and established what the percentage change would be per hundred kilowatts, and worked backwards from that. That was the approach I used.

Q. Yes. Well, you don't know at what loads these extra 550 and 600 hours were run, do you?

A. (Witness Bush) No.

Q. Does Manson consider a difference -- if we take your estimated figure of 18 percent, and make that assumption, does Manson consider it appropriate to ignore data where the

stresses are 18 percent lower?

A. (Witness Bush) Calculations I've seen, by any of these techniques -- when you're substantially below the stabilized endurance limit, essentially no consideration is given to the values.

Q. My question is: does Manson consider it appropriate to ignore data which is 18 percent lower?

A. (Witness Bush) I cannot speak for Manson per se. I can only speak for the sources I examined which utilized the Manson approach.

Q. All right. What source was that?

A. (Witness Bush) Primarily Collins.

Q. And does Collins believe that it's appropriate to ignore --

A. (Witness Bush) As I indicated --

Q. Let me finish this question.

A. (Witness Bush) Sorry.

Q. Does Collins believe and state that it is appropriate to ignore data which is 18 percent below, in this case, the 3300 kilowatt stresses -- if, in fact, that 18 percent is correct?

A. (Witness Bush) As I interpret Collins' commentary on Manson, with regard to values substantially below the endurance limit, he would rot consider that as a contributor.

Q. You keep saying "substantially", and I keep saying

"18 percent". So let's find out whether, in your view, Collins believes that an 18 percent differential is substantial, in the way that you've used it.

A. (Witness Bush) I cannot predict what Professor Manson, or Dr. Manson, would have said in that case. All I can say is that the utilization of the data below the stabilized endurance limit, based on all the experience I've seen in any type of case, I would not be concerned with it, no matter what system I used for analysis.

Q. And the fact is that you are now saying that you believe that 18 percent is substantial, but you don't know whether Professor Collins believes 18 percent is substantial in the way you've used it; isn't that right?

MR. STROUPE: Objection. Asked and answered.

JUDGE BRENNER: Overruled.

WITNESS BUSH: All I can say is -- well, the way we did the analysis is --

BY MR. DYNNER:

Q. Will you answer the question, please? And then you can explain. That's correct, isn't it, that you determined what you thought was substantially below the required level and you didn't consider it, but you can't point to any place where Professor Collins says that 18 percent is, in fact, substantial enough a difference to ignore, can you?

A. (Witness Bush) You asked me the wrong question,

sir, and I --

JUDGE BRENNER: Dr. Bush, you have to try to answer his question; and then you can explain it.

BY MR. DYNNER:

Q. That's true, isn't it?

A. (Witness Bush) I don't consider it true. That is the problem I have. I cannot answer a half-truth. That's my difficulty.

Q. Let me try to restate, to clarify the question, Dr. Bush.

It's true, isn't it, that you cannot show me any place in which Professor Collins says that it's all right to ignore data where there is an 18 percent differential. Isn't that right?

A. (Witness Bush) He doesn't even refer to that type of an approach, so I can't say.

Q. Okay. Does Professor Collins say that it is all right to ignore data where there is a substantial difference in the stresses?

A. (Witness Bush) If the values are below the endurance limit, he says yes.

Q. All right. Does Professor Collins ever say that data which is 18 percent below other data is a substantial enough difference to ignore?

A. (Witness Bush) If you will define what you mean

by "other data", I might try to answer the question.

Q. Well, we're talking in this case about 3300 kw data, that is, data showing the hours accumulated at that load versus, in our hypothetical, 2800 kw data. And as I understand your testimony, you're saying that under the Mason approach it's all right to ignore the hours run at 2800 kw. Isn't that correct? Isn't that what you're saying?

A. (Witness Bush) That is because all of our numbers --

Q. Isn't that what you're saying?

A. (Witness Bush) All right.

Now, you are postulating that the difference in stresses between 2800 and 3300 is about 18 percent; is that right?

A. (Witness Bush) I'm not postulating. That's what I looked at this morning, and that's what it indicated it was.

Q. Those are the estimates that you made?

A. (Witness Bush) That's the estimates I made; that's correct.

Q. All right.

Now, do you believe that that difference is substantial?

A. (Witness Bush) Yes. That is substantial.

Q. All right.

Now, is there anywhere in the Collins book where Professor Collins states that a difference of that magnitude --

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that is to say, 18 percent -- is substantial enough that you need not take into consideration the cycles run at 2800 kw?

MR. STROUPE: I'm going to object to that question. I don't, frankly, see what difference it makes what Professor Collins says one way or the other to this inquiry.

JUDGE BPENNER: You don't think it's relevant?

MR. STROUPE: I don't think it's relevant.

JUDGE BRENNER: Well, that will be overruled. I thought you were going to renew your asked and answered.

I think it has been asked and answered now, Mr. Dynner.

MR. DYNNER: Has it been answered "Yes"?

JUDGE BRENNER: It's been answered. I'll give you the answer. It's been answered that Collins doesn't express it in those terms. And through this series of questions you asked -- which we gave you ample leeway to ask -- about his position, I have some confusion, if you are going to leave this point, that I would like to ask about.

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MR. DYNNER: I see.

Judge Brenner, please go ahead, while we're looking at some data here, and ask your questions.

JUDGE BRENNER: Dr. Bush, you say that in your view the stress differences between those at 3300 kw and those at 2800 kw were substantial, the difference was substantial -- correct? -- in your view.

WITNESS BUSH: Yes.

JUDGE BRENNER: All right.

And you also thought that as a reasonable approximation it was okay if you wanted to extrapolate the data to learn what the stress was at a value in between 3300 and 2800 to assume that the progression was linear. Is that also correct?

WITNESS BUSH: I didn't use it but that's correct. The error that would be introduced I think would be nominal under those circumstances.

JUDGE BRENNER: All right.

Now is it also correct that you testified that the difference in the crankshaft stresses at the measured values from 3300 kw to 3900 kw was not substantial?

WITNESS BUSH: That's correct. We're talking of a few thousand psi on bending and somewhat less than that on torsional stress.

JUDGE BRENNER: Did you also say that if you wanted to perform an extrapolation in that range to arrive

at the stresses at values that were not measured, it would be reasonable as an approximation to assume that the progression would be linear there, too, in that range?

WITNESS BUSH: That would be the way I would do it as a first approximation. That's correct.

JUDGE BRENNER: Jddge Morris suggests I should specify the range. I'm talking now about 3300 to 3500 to 3900.

WITNESS BUSH: I would have to extrapolate it when I did this to 3300, but I would have interpolated, for example, between 3500 and 3800.

JUDGE BRENNER: Does the linear angle shift suddenly at 3300? Is it linear from 2800 all the way up to 3900, or is there a sudden shift, yet still linear, at 3300, a change of slope.

WITNESS BUSH: I suspect if one were to take all the data which, as I indicated, we didn't have at that time and the points and plot them over the entire range, that one would have -- would not have a linear relationship. Then one would be able to pick off of that particular curve what they are.

We were faced with having data points at 3800 and 3500 based on the strain gauge data, and an extrapolation to 3900 because I don't believe any strain gauge data exists at that value, and then we could extrapolate from 3500 to 3300,

assuming a similar relationship to that that occurred between 38 and 35.

JUDGE BRENNER: I guess if you've answered my question I've missed it.

Would you expect a sudden change in slope at approximately 3300 kw?

WITNESS BUSH: No, I wouldn't. I would expect any change to be gradual.

JUDGE BRENNER: All right.

Is there an inconsistency in your testimony as to what you would expect to occur in the range of 3300 to 3900 as compared to what you said you believe occurs in the range of 2800 to 3300 if there is no sudden change in slope at 3300?

WITNESS BUSH: Well, I didn't think so or I don't think so because every case we examined in the range of 3300 to 3900 indicated to us essentially that we were at or below the endurance limit and therefore, anything below that we wouldn't consider as contributors, no matter how many cycles.

So even thought I was unaware of those, I would have probably given them kind of second- or third-order credence.

JUDGE BRENNER: Yes, but I'm asking now just about the quantification of the differences in the measured stresses at the points for which you had measurements, and I will try

to state it broadly.

I don't understand how you can say the changes, as a matter of quantification now, are insubstantial between 3300 to 3900, yet substantial between 3300 and 2800, yet also tell me that it would be reasonable as a first-order approximation to assume linearity for purpose of extrapolation a nd also to tell me that there is no sudden shift in the slope, or any significant shift in the slope at around 3300. And that's why I'm confused.

WITNESS BUSH: Obviously we didn't even consider the cases below 3300. The data that were used in the reference I cited this morning gave us the strain gauge values at 3500 and at 3800. The difference there essentially is 4 percent.

By extrapolation one comes up with a 5 percent value at 3900, and by extrapolation backwards you come up with a change of about 2-1/2 percent at 3300. That's as far as we took it of course.

So the questions I have been asked below that one are-- Until I had seen the report that I looked at this morning, I had never seen these data before.

JUDGE BRENNER: But you looked at a measurement at 2800. Correct?

WITNESS BUSH: This morning?

JUDGE BRENNER: Yes.

WITNESS BUSH: That's the first time I ever saw it.

JUDGE BRENNER: And you told us it was 18 percent below, or approximately, than the value you saw at 3300, wasn't it?

WITNESS BUSH: Yes. That's a difference of about 500 kilowatts which-- It is somewhat larger incrementally than one would see in the other range.

JUDGE BRENNER: I'm sorry, I thought the difference between 3300 and 3900 kilowatts would be 600 kilowatts; therefore, I thought it was comparable to talk about those two ranges.

WITNESS BUSH: Oh, I was-- The 500 I was talking about was below that, and the difference there would come out to be about, assuming a reasonable extrapolation both ways, about 7-1/2 to 8 percent. The other one would certainly be larger, and I can't profess to say what because as I say, the first time I saw the data was this morning, below.

So my testimony essentially is based on 3300 to 3900 because those are the only cases we examined.

JUDGE BRENNER: I guess my question comes down to aren't some of the assumptions that you told us you were making in doing some of the extrapolations inconsistent with what the measured data show, according to that report that you looked at?

WITNESS BUSH: We were trying to.... You are

comparing a report that was written some time ago to something that I had never seen until this morning, so that's a little difficult.

JUDGE BRENNER: But you're the one who-- I'm sorry. Go ahead.

WITNESS BUSH: Well, I was asked a question and I tried to answer it. Perhaps I shouldn't have.

JUDGE BRENNER: But you're the one who changed your testimony that --"based on my extrapolation of data in the report,"et cetera, and I thought in your oral testimony here you indicated how you were relying on that data for your conclusion.

WITNESS BUSH: Well, I certainly wouldn't expect-- Between 35 and 3300, in the absence of a point, I would not expect a major change. That's about all I can say under the circumstances.

JUDGE BRENNER: Let me try something a little different.

If you assume with me for the moment that we have testimony on the record from Professor Sarsten that he does not have reasonable assurance, using his methods of calculation-- Let me amend that -- using the methods of calculation which he deemed appropriate for whatever standard he was employing, be it the DEMA standard or something else, that he testified he did not have reasonable assurance that the crankshafts

would meet that standard at 3500 kw.

And if I now wanted to apply some of what you're telling me as to judge the acceptability of the crankshaft at 3400 kw or for short-term operation in the range of 3400 to 3500, is there any way I could explore with you whether or not I was on an equal footing in making those comparisons with the say Professor Sarsten arrived at his earlier conclusions in order to compare it with the information you could give me today?

WITNESS BUSH: Judge, I think we're comparing apples and oranges, to tell the truth.

There is a large difference-- I looked at this not in the context of whether it met a standard or not, but whether there were appropriate margins so that I could attest to the reliability of these crankshafts under certain operating conditions so that, say under an emergency, there would be an acceptably high probability that they would function without failure for the necessary period.

And that is different from a comparison against a standard with an undefined margin of safety. You could exceed those values and I think if Professor Sarsten were here-- And we did talk about this. He certainly recognized the difference between meeting a standard and stating that a crankshaft would fail. They are not the same thing at all.

MR. DYNNER: Objection.

JUDGE BRENNER: I am not going to rely on that.

MR. DYNNER: I move to strike that.

JUDGE BRENNER: All right, granted.

I was only going to add we talked about those two things quite a bit previously, and I am reasonably confident, although I don't have a specific recollection, that among others, Professor Sarsten was asked questions going to that. Certainly others were.

All right. I think your apples-and-oranges observation answers my rather broad question.

This isn't a question but let me just state for the record so the parties can think about it as appropriate in questions or findings or whatever, if is possible that one might perceive and I might presently perceive that we have an agreement of the parties, including the Staff, that the crankshafts are acceptable at 3300 kw.

I don't know all the details that led to that agreement. We've accepted the agreement. It references the fact that because all the parties agree the crankshaft meets the various standards included in the contention or the guidelines, whatever you want to label them, and we also may have testimony -- I'm certainly not saying now what the testimony is; I'll check it, but testimony and emphasis in the Staff's proposed findings based on that testimony that there is not reasonable assurance that the crankshaft meets

at least some of those guidelines or standards at 3500 kw.

So if one might then take that information and say well, you know, something significant in somebody's mind occurs between 3300 and 3500 kw, and then I have to match that against testimony by some witnesses that nothing significant in terms of stresses happens between those values, and that's something that we'll have to think about.

Now maybe some of the assumptions I just told you will have no record support, in which case that would take care of it. But to the extent there might be record support for some of those it is something we'll have to pull together, and it would behoove the parties to think about pulling together in their proposed findings.

And that relates to what I said before about using the existing record in the proper context, the earlier record in context with what parties are asking the Board to find now.

All right. I'm sorry I interrupted you as much as I did, Mr. Dynner.

BY MR. DYNNER:

Q Dr. Bush, isn't one of the purposes of doing your Manson analysis to determine the endurance limit of the crankshaft?

A (Witness Bush) Yes, sir.

JUDGE BRENNER: Mr. Dynner, forgive me. I must

state one more thing.

Implicit in everything I said was the possibility that we would find that there is going to be operation above 3300. It is also open to us to make certain findings with respect to that question. But of course the parties, when they prepare their proposed findings, cannot assume that we would make the other finding.

Forgive me.

BY MR. DYNNER:

Q Given that answer, Dr. Bush, how can you ignore loads below the endurance limit as you testified that it was okay to do?

A (Witness Bush) Because they don't contribute to the failure mechanism.

Q But you don't know what the endurance limit is.

If you are carrying out the Manson analysis in part to find out what the endurance limit is, then how do you know what loads to exclude because you don't know what the endurance limit is.

A (Witness Bush) The primary basis for establishing the endurance limit was the fact that the crankshaft underwent 10 to the 7th cycles at and above 3300.

Q Yes. And now I would like you to answer my question.

If the purpose or one of the purposes of your Manson analysis is to determine the endurance limit of the

crankshaft, how do you know what loads to ignore that are -- quote -- "below the endurance limit" -- unquote?

MR. STROUPE: Asked and answered, Judge Brenner.

JUDGE BRENNER: I am going to overrule that. You may be correct but I am not convinced that we will get the same answer.

WITNESS BUSH: If I can explain my thought process I could indicate. I don't know how to do it otherwise, to tell the truth.

What we did was we worked back from an obvious situation, namely that this crankshaft had seen a fixed number of cycles at a series of loads. A very important factor in our evaluation was that there was a careful examination of this crankshaft after 10 to the 7 cycles which established that there was no evidence of flaws at or near the surface.

Therefore, that would indicate to us rather definitely that, given the combination of loads at and above 3300 that the endurance limit indeed, based on analysis, would be around 3400 plus, between 3400 and 3500 at a minimum. It does not say it is that low; it simply says that we feel under the circumstances that we can unequivocally establish that it is at that level or above, but we cannot quantify it precisely as to how much higher it is.

The calculations that we did then were essentially as a cross-check against what I call the physical evidence

that was established by the run at 10 to the 7th.

BY MR. DYNNER:

Q Let me ask you this:

As I understand what you're saying, do you assume that because the crankshaft ran for about 227 hours at or above 3500 kw and upon later inspection there were no cracks, that that establishes that the endurance limit would necessarily be at around 3500? Is that what you're saying?

A (Witness Bush) You have to include the hours at 3300, too, in that analysis because the inspection was done after that, and we had essentially 7 times 10 to the 6th cycles at 3300 which is a very important contributor because if indeed the endurance limits had been quite low, since we had 3 times 10 to the 6th cycles at and above 3500, and if indeed the endurance limit had been substantially above 3500, I would have said that there was a very high probability, almost a virtual certainty that we would have initiated cracks, as was done in the earlier crankshafts under those circumstances, and then the 3300 kilowatt loads would have simply served to propagate the cracks, and in my estimation, possibly to failure, but most certainly they would have been highly visible.

Q. You said if the endurance limit had been substantially higher than 3500 or 3430, as you sometimes say, you would have expected that any cracks would have propagated, is that correct?

A. (Witness Bush) If I said higher, I should have said lower.

In other words, the situation of concern would be where our stress -- all of our stresses are well above or above the endurance limit and the number of cycles are sufficient to exceed the S-N line under these circumstances, the slope, and so we would expect the initiation of crack; in other words, we have exceeded the high cycle fatigue limit by the combination of loads.

Q. Would it make any difference whether the operation at the lower stress levels of 3300 had taken place before rather than after the 220 hours at 3500 or above?

A. (Witness Bush) It could have.

JUDGE BRENNER: Mr. Dynner, we could take a mid-morning break whenever it's convenient. Even though the Board and the parties have not been here that long, given the false starts this morning, I think the witnesses have been in the room doing various things since 9:00.

MR. DYNNER: If I can just ask one more question.

BY MR. DYNNER:

Q. It's true, isn't it, Dr. Bush, that the original

crankshafts saw a large number of hours at loads well below 3500 Kw before the final loads at around 3900 Kw where they broke or where later cracks were developed, isn't that true?

A. (Witness Bush) Yes, but that's only part of the story.

My reading of the record indicates that there had been previous cracks at the lower loads that were actually removed, that had been ground out and they went on, and certainly that to me is a significant fact that we were in the stress pattern, we were in the stress regime in that respect. At least that was my interpretation of some words in that one.

Q. If you are incorrect about that and if in fact there were no cracks that had earlier been found and ground out, then that answer would not be correct that you just gave, isn't that right?

A. (Witness Bush) If there were none earlier, then it would have tended to be controlled by the final part of the history at the higher loads.

MR. DYNNER: We can take our break now, if you wish, Judge.

JUDGE BRENNER: Let me just ask Dr. Bush:

With respect to what you thought, I think you said, the record showed, did you mean the hearing record?

WITNESS BUSH: This I took off some of the reports

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that I can't be absolutely sure were bound into the record. I have handwritten notes on that. But unfortunately I'm not completely aware of what did get bound into the record and what did not get bound into the record.

JUDGE BRENNER: All right. Let's break until 10:55.

(Recess.)

JUDGE BRENNER: Back on the record.

BY MR. DYNNER:

Q. Dr. Bush, were you here during Dr. Pischinger's testimony about the cumulative damage analysis that he had performed?

A. (Witness Bush) I heard portions of it.

Q. Did you have an opportunity to review Dr. Pishinger's cumulative damage analysis?

A. (Witness Bush) I read... You're talking about the latest package?

Would you define which one you're talking about?

Q. I'm talking about the cumulative damage analysis that Dr. Pischinger testified to yesterday.

Do you recall that, where he was testifying about the results of his cumulative damage analysis as to the stress differential between 3300 Kw and 3500 Kw?

A. (Witness Bush) Well, I'm not sure I heard those numbers. I came in on only a portion of that discussion.

wb2

Q. So you're not familiar with that particular analysis; is that right?

A. (Witness Bush) I am aware of what I read here, and I'm aware of what I heard yesterday only in that portion, yes.

I don't know how much I missed, in other words.

Q. And you don't recall reviewing any documents which set forth that particular analysis, do you?

A. (Witness Bush) No.

Q. Will you please turn to page 17 of your testimony.

You have a reference in the first paragraph to 1 x 10 to the 6th cycles. How many hours of operation is 1 x 10 to the 6th cycles as you are referring to it there?

A. (Witness Bush) That's a generic statement. It has nothing to do with hours as such.

Q. You cannot translate the number of cycles into the number of hours without knowing what the rpm of the engine is; is that right?

A. (Witness Bush) That's correct.

Q. Is there any other data you would need to know to transfer that cycle data into hours?

A. (Witness Bush) No.

Q. And that paragraph refers to Table 1 which is on page 18 and page 19 that follow; is that correct?

A. (Witness Bush) That's correct.

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If you wish me to relate it to the specific hours that will be required in the case of the Shoreham crankshafts I can do that. But these data are not related specifically to the Shoreham crankshafts.

Q. Yes.

Well, let's take a look at Table 1 for a minute, please. You said that several of the values in this table are for aircraft or automobile crankshafts. And I notice that you have a Footnote A which shows that -- I think there are four crankshafts that are listed there that are aircraft engine crankshafts; is that right?

A. (Witness Bush) Yes, sir.

Q. And are the rest of the crankshafts on this table automobile crankshafts?

A. (Witness Bush) These data-- Oh; the other reference, 5, which cites automobile crankshafts are-- Indeed, that is the case; they are automobile crankshafts. The others are not necessarily; they are simply cyclic fatigue data, high cycle fatigue data, to indicate that you would expect the onset of the endurance limit to be in the vicinity of 1 x 10 to the 6th to 2 x 10 to the 6th. That was the purpose.

Q. I want to make sure that I understand your answer.

Reference 5 appears to be, on page 19, from the American Society of Metals, ASM Metals Handbook.

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A. (Witness Bush) That's correct.

Q. Is it your understanding that everything you cited from that handbook is automobile engines -- automobile crankshafts except the aircraft engine crankshafts that are cited in Footnote A?

A. (Witness Bush) No.

Q. Well, then, I don't understand.

Is it your testimony that all of the crankshafts listed on Table 1 which show Reference 5 are automobile crankshafts?

A. (Witness Bush) Reference 5 covers material -- items other than automobile crankshafts.

Q. All right.

Now, let's start down the list.

A. (Witness Bush) All right.

Q. Let's take the first one, which says-- I guess the easiest thing is to refer to the material. --1047 steel.

What kind of crankshaft is that?

A. (Witness Bush) It isn't a crankshaft. I never professed that this table.... It just by happenstance includes crankshaft data.

The whole purpose of this table is to establish where I would expect the onset of the endurance limit, and whether I did it on rotating bend specimens or whether I did it on full-scale samples, or whether I did it on bending

wb5

samples or something, the purpose was not to relate it to crankshafts, the purpose was to indicate that, by and large, the onset of the endurance limit falls within a fairly narrow band; nothing more than that.

Q. Well, what kind of component was this first one that is made out of 1047 steel?

A. (Witness Bush) It probably wasn't even a component, it was probably a fatigue test.

Q. It might have been a steel bar, or it might have been something else?

A. (Witness Bush) It could have been.

Q. So is it your testimony that it doesn't matter whether or not some of these items were crankshafts or not; is that right?

A. (Witness Bush) By happenstance I found data that, indeed, represented results on crankshafts. My purpose basically was to establish where I would expect the endurance limit to initate under high cycle fatigue in ferritic material. That was the purpose. I wanted to look at a range of heat treatments, a range of compositions, to see if there was -- or surface treatments, to see if there was any particular variable or parameter that would grossly affect the onset of endurance limits. That was the purpose of the table.

JUDGE BRENNER: Dr. Bush, forgive me. I don't think you answered his question. It would assist us if you could

wb6

try to focus on the words of the question, and try to answer it in the terms of the question as asked. And then, of course, you can supply any explanation. Because, otherwise, I have to wade through four or five sentences of transcript when one sentence might do, to find out what your answer is.

Believe me, your testimony is important to us. And when I go back to the cold transcript later I want to understand what it is.

Could you ask the question again, Mr. Dynner?

MR.DYNNER: I'll try to rephrase it.

BY MR. DYNNER:

Q. Is it your testimony that it is irrelevant whether or not any of these items on Table 1 are or are not crankshafts?

A. (Witness Bush) That's correct.

Q. Well, is it relevant to the high cycle fatigue limit, or the endurance limit for these items as to what the nature of the stress is to which they were subjected?

A. (Witness Bush) Relevant in what context?

Q. In terms of their endurance limit.

A. (Witness Bush) Yes, to a degree it would be. But it would not tend to affect -- it would tend to drop, rotate downward without shifting markedly in the horizontal plane, which is what my interest was under these circumstances.

Q. What would rotate downward?

A. (Witness Bush) The endurance limit under cyclic loads

wb7

compared to what I will call the virgin endurance limit; the one without any testing will tend to drop somewhat, perhaps not a great deal.

The purpose of this examination was to examine whether the values would tend to fall in a relatively narrow band with respect to the horizontal scale on, namely, the number of cycles. That was the only purpose of this table.

Q. If you can, I would like for you to give me an example. Let's take one of these aircraft crankshafts, let's take the second one, which shows the beginning of fatigue limit at 1 x 10 to the 6th cycles.

This table shows the location of the initiation of the endurance limit -- is that correct? --for that crankshaft?

A. (Witness Bush) That's right.

Q. And does that mean the place in which -- the cycles under which you would expect to find a crack initiating?

A. (Witness Bush) No.

Q. --if it was above that endurance limit?

A. (Witness Bush) Oh; I'm sorry.

If it were definitely above that one, and if I exceeded a given number of cycles -- in other words, I crossed the transverse line, then there would be a definite possibility of a crack initiating; that's correct.

Q. And if it was below the 1 x 10 to the 6th cycles for this particular crankshaft, is it your testimony, then, that

wb8

you wouldn't expect to have a crack initiate?

A. (Witness Bush) That's a function of the stress. You would have to define the stress for me.

Q. Yes; well, I was about to ask you to do that for me. Because what I don't understand is, if you have that crankshaft subjected to 500 kilowatts versus 5000 kilowatts, that would make a very large difference as to when you would expect to find a crack initiate, wouldn't it?

A. (Witness Bush) If I could use some type of -- degree of relationship to convert kilowatts to stress, for example, and if the stress in the one instance -- let's say your 500-kilowatt example -- should be far, far below the endurance limit, I would expect essentially no effect.

On the 5000 kilowatts, if I had an endurance limit -- which I will cite in kilowatts -- of, say, 4000, just for a round number, if I had enough cycles at the stress that corresponds to 5000 kilowatts I would expect that component to fail.

Q. So you'd have to know what the endurance limit is in order to make sense of this Table 1?

A. (Witness Bush) No; because the purpose of this table was simply to establish where I would expect the onset. So I'm concerned here with the sloping line, the S-N line on there, so that I could use it as a basis, first, for interpreting -- well, in such a thing as a Manson analysis, and,

wb9

secondly, to give me a degree of confidence with regard to the actual experimental data under which the Shoreham crankshafts were -- to which they were exposed.

Q. When you say "onset," do you mean the beginning of the fatigue limit?

A. (Witness Bush) I'm concerned here with the intersection of the S-N line, the one that goes from the ultimate down and intersects the endurance limit. And my interest was to establish essentially how many cycles would I expect on a repetitive basis in ferritic materials -- where would I expect that line to fall. That was the real purpose of this one. And that's the only purpose.

Q. Is that intersection the same as what is called on this Table 1 "Beginning of fatigue limit?"

A. (Witness Bush) Exactly.

Q. Could you define for me what is the beginning of the fatigue limit in words; in other words, is that where you would expect to find a crack to initiate, or is it something else?

A. (Witness Bush) In this case it is simply the point of intersection of the line, the sloping line that extends from, say, the ultimate and intersects the horizontal endurance limit line. That's what it is.

Q. So you would not necessarily expect a crack to initiate at the beginning of the fatigue limit; is that right?

wb10

A. (Witness Bush) For clarification, if you want to look at Figure 2 on page 20 and at the dark line in there, the intersection point I'm discussing would be where the two lines cross.

Q. My question was: You would not expect to find a crack to initiate at the beginning of the fatigue limit, would you?

End 6

A (Witness Bush) You're defining now the value that corresponds to a stress at that value and at that number of cycles. I want to be sure I understand what you are asking.

Q I'm asking you a question that is simple.

There's a column here. It's entitled "Beginning of Fatigue Limit."

A (Witness Bush) That's right.

Q And my question is would you or would you not expect to find a crack initiate at the beginning of the fatigue limit?

A (Witness Bush) I wouldn't expect that, no.

Q All right.

A (Witness Bush) But the statement there, that presumed that I've run a cyclic load at that particular stress to that number of cycles, and that's the only thing that I'm responding to when you asked that particular question.

Q Right.

So in order to answer that question you would have to know what the stress level was with that number of cycles -- Isn't that right? -- before you knew whether or not a crack could be expected to initiate?

A (Witness Bush) You are reading more into the table than was ever intended there.

To answer your question, given a specific case with a specific component, and given the knowledge of where the

onset was, I would have to know the stress.

Q Well, what difference does it make what the beginning of the fatigue limit is for the Shoreham crankshafts? In your analysis what difference does that make?

A (Witness Bush) A great deal. If I swing the-- Let me refer again to Figure 2 where I have shown that nominally at 10 to the 6 -- and let's cite a hypothetical case where the onset were either say 10 to the 5, which means that that sloping line rotates markedly to the left, recognizing that we have a log scale, or we can go the other way which is the more probable one, up to 10 to the 7.

In the analysis that I do by the Manson approach or by the Miner rule, et cetera, is going to be based on essentially the length of that line for a given stress level to where it intersects that sloping line. And therefore, the position of that sloping line is a very critical factor indeed.

And what I was attempting to establish in this table was that as a first approximation, a value close to 1 x 10 to the 6 is very important.

Q Yes.

And therefore, for example, if you found that the beginning of the fatigue limit or of the endurance limit was 10 to the 7 rather than 10 to the 6, that would have an important impact on the validity of your analysis, wouldn't it?

A (Witness Bush) It would be extremely important;

that's correct.

Q Okay.

Now you came to your conclusion that the fatigue limit is close to 10 to the 6 cycles by reference to Table 1. Is that correct? By your analysis of the data on Table 1?

A (Witness Bush) I said about 10 to the 6; that's correct.

Q Is it correct that you came to that conclusion on the basis of the data on Table 1?

A (Witness Bush) That's right.

Q Now that would depend, as I understand your testimony, on which of the items in Table 1 are made out of the same or similar material as the Shoreham crankshafts. Isn't that right?

A (Witness Bush) No, I'm sorry, it is not right. And the whole purpose of this table was to cover a spectrum of compositions of steels, and a spectrum of heat treatments, and indicate that the onset of the fatigue limit is relatively unaffected by these parameters. That was the whole purpose of this table.

Q Well, take a look at the third paragraph on page 17.

In that paragraph I am right, aren't I, that you tried to make some kind of comparison between the steel in the crankshaft on EDG 103 and some of the materials in Table 1.

Isn't that right?

A (Witness Bush) Yes.

Q Okay.

Well, what is the relevance of making that comparison?

A (Witness Bush) I think it simply is a further convincer if I can indicate that I have a steel that has a comparable composition and if I can also indicate that, regardless of composition or heat treatment, I don't expect a major variation, that I simply find that as further convincing evidence.

Q All right.

So you say in that paragraph that the EDG 103 crankshaft is ABS Grade 4-S, and that corresponds roughly to AISI 5050 steel in composition.

Is there any item on Table 1 that is made out of AISI 5050 steel?

A (Witness Bush) No.

Q When you say in the next sentence in that paragraph the tensile strength is about 100 ksi and the yield strength is about 60 ksi, are you referring to the crankshaft material or to the 5050 steel material?

A (Witness Bush) That's the crankshaft material.

Q And then you refer to the fact that the mechanical properties -- and by that you mean the mechanical properties of the crankshaft steel?

A (Witness Bush) That's correct.

Q -- would correspond to some of the 4,000 series steel cited in Table 1.

Can you identify for me which ones you are talking about?

A (Witness Bush) Well, depending on the tempering temperature, the 4140 steel that is cited as the first item in the second class Number 5, the one that has 1.5 4140 quenched and tempered, could well have properties that are somewhat comparable.

In other words if I tempered back I could get 100 ksi ultimate, and my yield would be in this range.

Q Well, do you know what the tempering temperature was on that item that is composed of the 4140 steel that you referred to?

A (Witness Bush) I have absolutely no idea. I was not concerned with that aspect of it, sir.

Q How closely would this approximate the steel in the crankshaft? In other words, what would be the differences?

A (Witness Bush) Relatively minor differences in alloy additions.

Q Differences in alloy--

A (Witness Bush) Alloying additions. That's correct.

Q Anything else?

A (Witness Bush) The other obvious variable would be

the quenching and tempering conditions for this steel.

Q And what do the quenching and tempering conditions-- What impact would they have?

A (Witness Bush) Well, the severity of the quench in materials such as this will essentially give the very high hardness and a very high strength. It also renders the material fairly brittle, so I then rely on a tempering temperature to reduce the hardness and reduce the brittleness of the material and in the process reduce both the ultimate strength and yield strength.

Q And therefore, this particular item might be similar in tensile and yield strength to the crankshafts or it might be different, depending upon the quenching and tempering. Isn't that right?

A (Witness Bush) Oh, yes, that's quite right.

Q Are there any other items on Table 1 besides the one you just cited which you believe would correspond in mechanical properties to the crankshaft?

A (Witness Bush) The first item under the aircraft, I could develop the same type of properties; in other words, the one that has the value of 0.7 and shows a 4140,x4340 steel could do that.

I can do the same thing in the automobile crankshafts in the normal heat treatment because then I could get surface properties that are reasonably comparable.

I could do the same.... Those would be the most obvious ones. I could probably do it in Reference 6 in the first item because again I could control the quenching and tempering condition, and I have a sufficiently high hardenability of these materials that I can in essence exceed the mechanical properties.

Q If you take the first two examples you gave, that is to say on page 18, the item which shows a 1.5 fatigue limit, beginning of fatigue limit with the material 4140 and then you go down to the first of the aircraft crankshafts, that shows a .7 beginning of fatigue limit, and that is also 4140,x4340.

That is quite a difference in beginning of fatigue limit, isn't it, between those two items even though in your testimony they are composed of basically the same kind of material, because you have got twice as much -- more than twice as much beginning of fatigue limit of one over the other, don't you?

A (Witness Bush) I don't consider that a major amount under the circumstances. In the context of the number of cycles it would be about twice as many, yes.

Q Well, it would be possible, wouldn't it, that the number of-- Well, strike that.

It is true, isn't it, Dr. Bush, that as you previously testified, the geometry of the crankshaft design

has an important effect on the life of the crankshaft, doesn't it?

MR. STROUPE: Objection. That has been asked and answered several times.

JUDGE BRENNER: I thought it was even struck.

WITNESS BUSH: It was.

MR. DYNNER: I will rephrase the question.

JUDGE BRENNER: All right.

Remember we struck answer 5, and we said we are not going to rely on things derivative of it.

MR. DYNNER: This is a totally different issue. It is testimony which I was reminding the witness of. It had nothing to do with the differences between 33 and 3500 kw.

JUDGE BRENNER: I know the issue is different but the question of his expertise as to know about the effects of the complex geometry of crankshafts was part of our ruling. If you can try to put it in a different context then we'll evaluate it later.

MR. DYNNER: I will.

BY MR. DYNNER:

Q Do you know whether or not the geometry of a crankshaft is important to the fatigue life of the crankshaft?

A (Witness Bush) Yes.

Q Is it?

A (Witness Bush) Yes.

Q And do you know whether or not the torsional stress characteristics of the crankshaft have an important effect on its fatigue life?

MR. STROUPE: Objection. That again was asked and answered yesterday, and it is also part of what has been stricken.

MR. DYNNER: I asked him whether he knows or not.

JUDGE BRENNER: The objection is overruled in terms of it being part of what was struck. He may know, and we'll see the context.

If it was asked and answered yesterday, I am concerned it was in the other context.

What adds to the complication here is that the attorneys recognize what the County is probing here is not something that they want to agree with Dr. Bush on. It certainly changes the approach of the County here as opposed to they way they felt about Answer 5.

So for all [illegible] reasons we will allow the question.

WITNESS BUSH: The torsional stresses are a significant contributor, yes, providing they are high enough to be a problem.

BY MR. DYNNER:

Q So in setting the endurance limit it would be important to take into consideration the torcional vibratory

stresses as well as the geometry of a particular crankshaft, wouldn't it?

A (Witness Bush) That is one of the purposes that by happenstance came out of this table, namely that these are actual data on crankshafts.

Q Yes, but you didn't answer my question.

It would be important to have that information, wouldn't it?

A (Witness Bush) Yes.

Q But you didn't take into consideration the geometry of the crankshafts or their torsional vibratory characteristics, that is, of the crankshafts at Shoreham, in establishing the endurance limit, did you?

A (Witness Bush) No. We depending on experimental evidence primarily, or essentially; completely.

Q And in fact the geometry of the crankshaft and its torsional vibration characteristics would indicate that the proper high-cycle fatigue limit would be significantly more than 10 to the 6 cycles according to those issues. Isn't that right?

MR. STROUPE: Objection. I don't think there is any foundation in the record for that question.

JUDGE BRENNER: I need to hear the question again. I was listening but I lost the gist of it.

(Whereupon, the Reporter read from the record

as requested.)

MR. DYNNER: I would also add, Judge Brenner,--

JUDGE BRENNER: I'm sustaining the objection, to save you the trouble, for the added reason that it is so vague that I can't tell if there is a basis in the record or not. Maybe you can back up and get at the point in another way, Mr. Dynner.

MR. DYNNER: All right.

BY MR. DYNNER:

Q Let me put it in these terms:

The composition of the metal in the crankshaft is only one item that needs to be considered in determining the location of the initiation of high-cycle fatigue limit for the crankshaft. Isn't that right?

A (Witness Bush) That's correct.

Q In the analysis that you did, you did not do anything to also take into consideration the torsional stresses or the geometry of the crankshafts. Isn't that correct?

A (Witness Bush) We used the stresses in combination with the bending stresses to do our analyses after the fact and to convince ourselves that -- or you might say to validate the test at 10 to the 7 cycles.

End 7

Q. Dr. Bush, in the analysis that you conducted under the Manson approach, did you assume any particular sequence of loads?

A. (Witness Bush) Yes.

Q. Could you tell me what sequence of loads and times for those loads that you assumed?

B8

A. (Witness Bush) 3900, 7 hours --

Q. I'm sorry. Would you repeat that?

A. (Witness Bush) 3900 kilowatts, 7 hours; 3600 kilowatts, 101 hours; 3500 kilowatts, 119 hours.

The next case considered the 3500 first, the 3600 second, and the 3900 third.

The third case considered the 3500 first, the 3900 second, and the 3600 third.

The fourth case considered the 3900 first, the 3500 second, and the 3600 third.

The sixth case considered the 3600 first, the 3500 second, and the 3900 third.

The next case was 3600, 3900, and 3500.

Another case was 3500 plus three cycles of 3600, each cycle being 2200 hours, 3900 for two hours, plus a cycle of 3600 for 23 hours, plus 3900 for one hour, plus 3600 for twelve hours, plus 3300 for 525 hours.

JUDGE BRENNER: I lost you somewhere. Did you say one of them assumed 2200 hours, in the last sequence you gave,

Dr. Bush?

WITNESS BUSH: If I did, I misspoke myself. I'll go over it again.

3500, 119 hours; three cycles of 3600, 22 hours each cycle; plus 3900 kilowatts for two hours; plus one cycle of 3600 for 23 hours; plus 3900 kilowatts for one hour; plus 3600 kilowatts for twelve hours; plus 3300 kilowatts for 525 hours.

JUDGE BRENNER: I must have heard that 22 hours incorrectly. I'm sorry.

BY MR. DYNNER:

Q. What was the basis for your selection of that last analysis, or that last sequencing?

A. (Witness Bush) Well, we discussed this, and in the absence of documented evidence, which we unfortunately had not been able to obtain, we believed that probably the higher kilowatts -- namely, the 3600 -- was not run all at once. And the same thing applied to 3900. It was a very arbitrary assumption. We considered that would be a reasonable basis, based upon experience of the diesel generator experts as to how you would test it. So this was a collaborative effort on the parts of Messrs. Sarsten, Henricksen, and others who were in attendance at that particular meeting but who have not participated in these hearings.

Q. So, as I understand it, all of the sequencing of

models, if you will, were based upon assumptions rather than upon actual facts? In other words, you didn't know the number of hours that the engine was run in particular sequences. Is that right?

A. (Witness Bush) That's correct. We were unable to obtain the data.

Q. Why did you, in one case, break up the 3600 hours, but you didn't break up the 3500 hours in any cases? Was there any reason for that?

A. (Witness Bush) Nothing particular. We could have broken that one up, too. It was just -- what we were looking at was to see if there was much significance.

I might comment that no matter what condition we got about the same answer, namely, none of them seemed to be significant, which is one reason for the degree of confidence in the fact that we probably have an endurance limit that is certainly around 3500, or very close to that -- possibly higher.

Q. What stresses did you assume at these various levels of kilowatts?

A. (Witness Bush) We used the stresses and extrapolated -- we used the stresses that were available from the Failure Analysis report. And we were able, then, to use a number of cycles. We used the maximum -- I want to use the right word -- the combined stresses that would give us the

brb4

biaxial stress state. And we could use that as a maximum value and we would then interpolate between a value at 3800 and a value at 3500, and, then, we could -- to get the 3600; extrapolate to get the 3900; and, again, extrapolate to get the 3300 value.

Q. And am I correct that that extrapolation was also done on a linear basis?

A. (Witness Bush) Essentially a linear basis; that's correct.

JUDGE BRENNER: Do you mean you adjusted it some way? What do you mean by "essentially"?

WITNESS BUSH: Well, I should say "a linear basis". What we simply did is took the two points we knew and the citations that -- the 3900, which I presume was extrapolated by someone else, represented a one percent change; and then we used a similar logic to obtain the 3300 value.

BY MR. DYNNER:

Q. Your conclusion, as stated on page 21 in the first paragraph, refers to the probably high cycle fatigue limit. Can you quantify the probability of that high cycle fatigue limit that you referred to?

A. (Witness Bush) We considered -- all of our analyses would indicate that it is at, and probably above, about 3430. I think I can make a convincing argument that it was close to 3500, and that's about as far as I can go.

brb5

Q The difference between the 3500 and the 3430 would be the allowance for the instrument error; is that correct, Dr. Bush?

A (Witness Bush) That would tend to be the instrument effect, yes.

Q Are there any other factors that we should take into consideration in terms of determining that probability, such as, for example, the accuracy of your extrapolations?

A (Witness Bush) I don't think they would have a major effect, on the basis we worked backwards from the experimental evidence, namely, the ten to the seven.

It's obvious that the slope of the line that we used -- in other words, where it intercepts can have an effect. My opinion would be it would tend to be a second order effect, because a ratioing effect -- the ratios would be the same, plus the fact that all of these stresses, whether they be at 3900 or 3300, are fairly closely grouped. I would not be that confident if there was, say, a twenty percent difference between the high stress and, say, the stress at 3300; then it would be difficult, more difficult, to make that assumption.

Q Did your cumulative damage analysis come out with a specific prediction of the number of hours that the crankshaft can safely be run at above -- at any particular level above 3500 kilowatts?

brb6

A. (Witness Bush) Not in that context. We looked at the actual data and the fact that one of the conditions was that further testing would all be at 3300, with the possible exception of accident conditions.

And, as I say, every case washed out, which indicated that we were probably below the endurance limit -- or, the summation of these was such that the 3300 pretty much controlled under those circumstances.

We did not attempt to make a calculation that would say if I ran it for 500 hours at 3900 what would happen to the crankshaft.

Q. Dr. Bush, take a look, will you, at page 21 of your testimony. There you say that you believe the crankshaft can survive up to an hour of overload to about 3900 kw without crack initiation, but the probability of crack initiation cannot be quantified.

What is the basis for your belief that the crankshaft can survive up to an hour at 3900 kw?

A. (Witness Bush) One factor, of course, is it has already been subjected to seven hours at 3900. And that is a part of the analysis that we went through. And there was a careful examination after 10 to the 7 cycles, with no evidence of cracking, which gives us a degree of confidence in that case that a load of limited duration at 3900 shouldn't initiate cracks -- or, if it did initiate cracks, presuming

brb7

that further time at a lower cycle is not excessive, would probably not propagate the failure.

Q. Would it bother you, or would it change your confidence about the seven hours at 3900 if you knew that EDG-102 survived 19 hours at 3900 before it broke in half?

A. (Witness Bush) That's a different crankshaft.

Q. Yes.

A. (Witness Bush) And it's a different size.

Q. Yes. But the concept is the same, isn't it? That is to say: isn't it true that the mere fact that a crankshaft survives a particular number of hours at a particular load in the past doesn't mean that it's going to survive that load in the future. Isn't that right?

MR. STROUPE: I'm going to object to that question. There's no evidence that there was any inspection of that crankshaft after those loads.

JUDGE BRENNER: We had testimony from Mr. McCarthy, among others, on that point. But we're going to allow the question, to probe this witness' conclusion as it's related to some of his other testimony, also -- some of Dr. Bush's other testimony.

WITNESS BUSH: That's a fact that would probably give me further confidence, because this crankshaft is a larger crankshaft. If I examined the strain gauge data on one of the original crankshafts that has cracked, and the cracks

brb8

had been removed, and then at that particular location they had measured the strains, we would see that we would have much higher stresses at that location in comparison to the similar location in the new crankshaft. So, as far as I'm concerned, that, if anything, would give me additional confidence, not lessened confidence.

BY MR. DYNNER:

Q. Aside from the fact that the 103 new crankshaft survived seven hours at 3900, what other factors lead you to the conclusion that you believe that that crankshaft can survive up to another hour at 3900?

A. (Witness Bush) Well, the combined loads at 35, 36, and 39: the relatively narrow span of stress levels over these particular kilowatt values would indicate to me that if I have a crankshaft that has been carefully examined after ten to the seventh cycles with no evidence of either surface or subsurface defects, that a relatively limited period at 3900 should not lead to failure of the crankshaft.

Q. So you are saying -- if we eliminate the 3900, you are saying that the testing and operation of the crankshaft at levels of 3500 and 3300 means that the crankshaft can be, in your view, assured of surviving at 3900 for up to an hour? Is that right?

A. (Witness Bush) I thought I considered all values -- that would be the 33, the 35, the 36 and the 39 -- and the

brb9

fact that, after examination, there is no evidence of degradation of the crankshaft.

Q You don't know whether the crankshaft ran at 3600 hours for any period of time, do you?

MR. STROUPE: Objection. That has been asked and answered.

BY MR. DYNNER:

Q At 3600 kw?

JUDGE BRENNER: I assume you knew it was "kw" when you objected.

MR. STROUPE: I assumed kw.

JUDGE BRENNER: I'm overruling the objection in any event.

WITNESS BUSH: We know that there are some values above that. We do not know the precise one; and we selected the value of 3600 for that purpose. But, if you ask me do I know of the exact level of kilowattage for that period of time, I cannot define it. I think that's why we say "approximately".

End WRB 8

WRB9/wbl

BY MR. DYNNER:

Q. When you say you cannot quantify the probability, or the probability of crack initiation, what do you mean by that statement?

A. (Witness Bush) Well, if I were to do a probabilistic fracture mechanics analysis in a case such as this for this period of time, and given the stresses, I'm pretty much convinced that it would give me an extremely low number providing I keep the time down. I did not conduct such an analysis. It's not an easy thing to do. Therefore I cannot put a precise value-- I cannot tell you whether the probability of its survival without cracking is 10 to the minus-9 or 10 to the minus-7. My engineering judgment is that the probability is fairly high that it would survive. But I cannot establish it unequivocally because I don't have sufficient data.

Q. What is your engineering judgment based upon,then? What is your engineering judgment that the probability is pretty high or pretty low; what is is based on?

A. (Witness Bush) The previous experience with this particular crankshaft, the 103, the 12x13, and on other equipment for overloads of reasonable periods of time, and their survival under these conditions. Plus the fact that, as I say, the relative stress at stresses at 3900 versus the stresses at about 3500 are not that different.

wb2

Q. You say in your conclusion that you think the crankshaft can survive up to an hour. Are you sure about whether it can survive for twenty minutes or thirty minutes, or don't you know?

A. (Witness Bush) Well, if I said I thought it would survive for an hour I would presume that any lesser time would be of lesser significance because it's a direct function of the number of cycles that it sees under these circumstances.

Q. I guess what I'm asking is, Have you quantified the probability for any lesser amount of time?

A. (Witness Bush) No more than I for the forty to sixty minutes.

Q. You state on page 22 that,

"The question is that if a crack initiates during a LOOP/LOCA will it propagate to the point of engine shutdown before the engine is no longer needed?"

Do you have any idea of what the rate of propagation of a crack in a crankshaft would be at 3900 Kw?

A. (Witness Bush) I didn't do such a calculation. It's a fairly straightforward calculation. About all you do is, you use a fracture mechanics approach on it, you presume the crack, and you take the number of cycles, and essentially the load at the crack tip in this case-- In fact, the easiest way to do it under the circumstances would be to use some of the plots that already exist, DADN or DADT plots, and one could

wb3

calculate in a reasonably s' raightforward fashion: you presume the crack and then you see the number of cycles to failure.

I've done it on other components, I didn't do it here.

Q. You didn't do it here, and therefore it's true, isn't it, that you don't know how long it would take for a crack in a crankshaft to propagate to failure under any particular loading characteristics; isn't that right?

A. (Witness Bush) The only way I could do it--

Q. I just asked you: You don't know, do you; isn't that right?

A. (Witness Bush) If you want to ask it that way the answer is yes.

Q. You do know?

A. (Witness Bush) Yes, I don't know.

Q. You don't know. Okay. Thank you.

You also state on page 22 that the only way to quantify your judgment would be to conduct a three-dimensional finite element analysis combining the LOOP or LOOP/LOCA load histories that were imposed on a crankshaft having an initial crack and determine the final crack size.

Have you conducted such a 3-D finite element analysis?

MR. STROUPE: Objection. I believe that was asked and answered a little while ago, Judge Brenner.

JUDGE BRENNER: Well, I'm not sure. Let's just get a

wb4

short yes-or-no answer.

WITNESS BUSH: The answer is, very definitely I have not done it.

MR. DYNNER: Okay.

BY MR. DYNNER:

Q. Dr. Bush, on page 22 there is set forth an assumed LOOP/LOCA load profile. Are you the one who calculated this LOOP/LOCA profile from the data that is cited in this Answer 15?

A. (Witness Bush) This came out of the FSAR.

Q. Does the FSAR have exactly the same load profile in it?

A. (Witness Bush) I think with the exception of the first item, which is just a hypothetical one, this was the case.

Q. Could you tell me exactly where that LOOP/LOCA profile is located in the FSAR?

A. (Witness Bush) No. It says Table 8.3.1-1A and 8.3.1-2.

Q. I'm correct, aren't I, that you would have to take the numbers in those tables and then do some kind of calculation in order to arrive at this profile; isn't this right?

Have you got those tables there? Maybe Mr. Henriksen can help you out.

JUDGE BRENNER: What's the question?

MR. DYNNER: The question is that those tables just

wb5

set forth numbers and you would have to do some kind of calculation to arrive at the profile.

BY MR. DYNNER:

Q. Isn't that right?

A. (Witness Bush) That's right.

Q. Did you personally do--

A. (Witness Bush) I did not personally do it, no.

Q. So you don't know whether these numbers are correct on the load profile or incorrect, do you?

A. (Witness Bush) If you mean did I validate them, the answer is no, I did not validate them.

Q. It's your testimony. Do you know who gave you this load profile information?

I'm just asking if you know who supplied this?

A. (Witness Bush) I can't remember now.

Q. Was it somebody on the Staff?

A. (Witness Bush) There was a lot of correspondence back and forth on it to come up with these particular numbers. But I simply accepted the values as valid and based on the FSAR.

JUDGE BRENNER: You didn't answer his question, though. Do you know if it was someone on the Staff?

WITNESS BUSH: I can't answer it.

MR. DYNNER: I have no further questions at this time.

wb6

JUDGE BRENNER: We'll take the lunch break and then go to the Board's questions and then redirect.

Does the Staff know how much it has in terms of redirect?

MR. GODDARD: I'm sorry, Judge Brenner?

JUDGE BRENNER: Do you have a rough time estimate for your redirect? I know it depends on the Board's questions.

MR. GODDARD: At this point, probably not more than a half an hour.

JUDGE BRENNER: Mr. Stroupe, do you have any idea?

MR. STROUPE: Approximately half an hour to forty-five minutes.

JUDGE BRENNER: I guess it is fair to say the likelihood of finishing the hearing this week is becoming markedly less.

MR. STROUPE: Judge Brenner, if I might, in an effort to be cautious and be safe rather than sorry -- I think I know the answer to this; but we would like -- LILCO would like to release Dr. Pischinger to return to Germany. I assume that since we have eliminated the question of these transient loads, neither the Board nor the parties have questions they would like to ask Dr. Pischinger about that, and that the loads that we're talking about being cyclic and intermittent loads is indeed those loads referred to in the County's testimony and LILCO's testimony.

JUDGE BRENNER: That's right. We have accepted the

wb7

fact that the parties do not wish to put that matter into controversy, and on our own we don't want to pursue it, given that situation.

Your next question, your unasked question: Is there anything else we might want Dr. Pischinger for?

MR. STROUPE: Yes.

JUDGE BRENNER: Give me a moment.

(The Board conferring.)

JUDGE BRENNER: We are not going to seek to recall him, to recall Dr. Pischinger. So we'll let him go.

Just as a precaution: Do the parties have -- do any of the parties have any showing of good cause by which they wanted to ask Dr. Pischinger any questions based on any examination of Dr. Bush?

MR. DYNNER: No, sir.

MR. GODDARD: The Staff has nothing further for Dr. Pischinger.

MR. STROUPE: Thank you, Judge Brenner.

JUDGE BRENNER: Since Dr. Pischinger is still in the audience: Thank you, Dr. Pischinger.

All right; let's break until 1:40.

(Whereupon, at 12:10 p.m., the hearing in the above-entitled matter was recessed, to reconvene at 1:40 p.m. the same day.)

AFTERNOON SESSION

(1:50 p.m.)

JUDGE BRENNER: Good afternoon.

Judge Ferguson will start off with the Board's questions.

Whereupon,

SPENCER H. BUSH

and

ADAM J. HENRIKSEN

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

EXAMINATION BY THE BOARD

BY JUDGE FERGUSON:

Q Dr. Bush, I would like to first of all apologize for starting with you immediately after such a long session this morning, but what I would like to do is perhaps bring together and clarify some things that have been said that would be helpful to the Board.

Much of what I want to ask you about relates to Figure 2 in your testimony, so if you will turn to page 20 of your testimony, and let's look at Figure 2. Let me see if I can broadly summarize the thrust of what I want to ask, and then in your answer I would appreciate it if you would say whatever you want to say briefly to pull together all of the concepts that you tried to relate to us this morning.

Looking at Figure 2, I would like to ask a few questions that will reflect my understanding of Figure 2. You tell me where I go wrong, if I do.

Looking at Figure 2 I see a plot of stress versus number of cycles, and I see a line or a curve in that graph that is labeled "Fatigue (Endurance) Limit."

Now am I correct in broadly interpreting that figure to mean that values that are -- of those two parameters, namely stress and number of cycles, that are above that line are beyond the endurance limit, fatigue or endurance limit, and values that are below that line are below the fatigue or endurance limit?

Let me be very clear and give you an example.

For example, if I had a machine to which this curve applied and I subjected it to a stress of 60 ksi and ran it for 10 to the 7 cycles, that would be above the fatigue or endurance limit. Is that correct?

A (Witness Bush) More importantly, it would also be to the right of the angled line, and one would predict failure.

Q Right.

So it is above the endurance limit and all points above the endurance limit would be points at which the device would fail. Is that correct?

A (Witness Bush) Providing you have enough cycles

to substantially cross the angled line. In other words if you are to the left in there, and one could put in a substantial number, it does not follow that you would have failure. You must cross the line.

Q When you say "cross" you mean be above and to the right in this figure?

A (Witness Bush) That is correct.

Q All right.

A (Witness Bush) The bad area you could cross-hatch, for example, would be above and to the right.

Q Okay. That's fine.

Now in like fashion if I were to choose two values of the parameters for stress and numbers of cycles, the parameters being 40 ksi and, say, 10 to the 5th cycles, that would give me a point to the left and below the line, and that would then be below the endurance limit. Is that correct?

A (Witness Bush) That's correct.

Q And the device then should not fail.

A (Witness Bush) That's correct.

Q Okay.

So then generally it is true that for any value of those two parameters, namely stress and number of cycles, that are above the fatigue endurance limit, above and to the right, the device fails; otherwise it does not fail.

A (Witness Bush) That's correct. In fact, for

clarification, on your last example of 40 ksi, I would have said the same thing if you had said 10 to the 9th cycles as compared to 10 to the 5th.

Q Very good.

But that is only because of the nature of that -- the shape of that endurance curve.

A (Witness Bush) That is correct. This is unique to the ferritic materials and a limited class of other materials. Most materials do not display this behavior.

Q I understand. Very good.

So then I would like you to clarify for me what I believe you designated this morning as the knee in that curve as being the beginning of the fatigue or endurance limit.

A (Witness Bush) I defined that as the intersection of the slanting line and the horizontal line as being that specific location, presuming that this is what I would call the stable endurance limit, or the ultimate endurance limit.

Q Okay.

Then if what you say is what you believe to be the truth, then I've got to go back and look at that line again, the S-N line.

A (Witness Bush) Yes, sir.

Q The slanting portion of that line, is that also the loci of points that are in fact on the endurance limit; that is, is this line that I am looking at in this figure the

endurance limit and as we have just agreed before, any points above and to the right of that line, the total line, both the slanted and the horizontal, are points for which the device would fail and below which it would not fail?

A (Witness Bush) Yes, sir.

Q Okay.

A (Witness Bush) For clarification, Judge Ferguson, I want to make sure I understood your one statement in there.

The endurance limit per se is only the horizontal portion of the line, just for clarification on that point.

Q Well, maybe that is where all of the confusion, at least in my thinking, arises.

Pick the point 60 ksi,--

A (Witness Bush) Yes.

Q -- and 5 x 10 to the 5th cycles. That is above the slanted portion of the line.

A (Witness Bush) That's correct.

Q Does the device fail or not fail?

A (Witness Bush) I would expect there's a high probability it would crack. That may not be enough cycles to cause ultimate failure. I cannot predict that unequivocally.

We are certainly in the regime where we would expect failure and if we define failure as cracking, then the answer is I would anticipate such cracking under those conditions.

Q Does the word "fatigue endurance limit" that you have labeled the curve, does that refer only to the horizontal portion of the curve?

A (Witness Bush) The so-called endurance limit or fatigue limit is the horizontal portion.

Q Only the horizontal portion.

Tell me what-- Pick a point on that horizontal portion.

A (Witness Bush) Yes.

Q Tell me what difference there is between that point and a point on the slanted part of that same curve. I don't mean give me the values or parameters but--

A (Witness Bush) The difference would simply be that unless I take the juncture that I would be at a specific stress level for that particular condition. In this instance essentially 45 ksi would represent the so-called endurance limit for this example.

Q Then it is true, is it not, that the point that we chose, say 60 ksi and 5 x 10 to the 5th cycles, the machine as you indicated may or may not fail although it is above the line.

A (Witness Bush) That's true, sir. In other words, like all such situations, it is not a clear line. It is a probability function around here. However, the farther you move in, the more certain you are that indeed it will crack

and lead to failure.

Q Okay.

I thought that is what the shaded portion around the line represented.

A (Witness Bush) That is pretty much a probability event; that's right.

Q When the shaded portion-- When the dots end, does that mean that the probability is one failure?

You see, it is unclear to me--

A (Witness Bush) I'm sorry.

Q -- how you've broken that line up.

A (Witness Bush) That's more of an artist's conception than anything else. It's simply to indicate that we have a fuzziness in there. However, in the example we are talking of, I think you would be correct in saying that at that number of cycles and at that stress, the probability essentially is one that I would have cracking.

I just was simply saying I can't absolutely guarantee it would fly into pieces.

Q What additional information would you need on such an S-N plot to put that in?

A (Witness Bush) If I-- Let's presume that I have adequate experimental information I derived under those circumstances. First I need to establish the number of cycles at a specific stress, and let's use your example for crack

initiation.

That is really where the probability bend comes in because even though we say according to this curve that it would initiate essentially at 10 to the 5th cycles, in fact it may be two or three times 10 to the 5th cycles before it initiates because there are many factors that relate to this: the geometric effects, the surface conditions -- if it is rough it is more liable to crack early than late; it it has a specific surface treatment it is more liable to crack late than early; things of that nature.

Once it has cracked, you now can use a fracture mechanics model which, on the basis of the stress and the number of cycles from the point of inception of the crack, will permit us to predict the crack growth rate and then we can look at the total section and say when we have essentially cracked through a given fraction of that section, there is a very high probability it will come apart.

Q Let me give you two other coordinates.

A (Witness Bush) Yes, sir.

Q 60 ksi and 10 to the 8th cycles.

A (Witness Bush) That's easy. I would say unequivocally that it would have failed by then.

Q What basis do you have for saying it in that case and not in the previous case?

A (Witness Bush) Because at 10 to the 8 cycles-- I

would have expected cracking somewhat past 10 to the 5th cycles in one instance. Then it is a question, is it going to take 2 x 10 to the 5th cycles or 3 x 10 to the 5th cycles to reach the point of instability with regard to the size of the crack.

Q Forgive me for interrupting.

A (Witness Bush) Yes.

Q What leads you to that belief, 10 to the 5th would start cracking?

A (Witness Bush) Oh, I'm just using this as a diagram, taking your 60 ksi, coming down there and saying the point of possible crack initiation is -- should be about 10 to the 5th or perhaps slightly less or slightly above, as indicated by the shaded line. Nothing more than that.

Then based on--

Q Hold on just a minute.

A (Witness Bush) Yes.

Q That's the thing I want to clarify, at least in my mind.

A (Witness Bush) Yes.

Q I guess my question is at that 60 and 3 x 10 -- or 10 to the 5th at 60,--

A (Witness Bush) Yes, sir?

Q -- you said you would suspect cracks to initiate.

A (Witness Bush) Given that this is the actual shape

of the fatigue curve.

Q And that is based on some other information that is not really in this picture. Is that correct?

A (Witness Bush) This is what I call a typical curve that is a follow-up of attempting to benchmark at 10 to the 6th. I think you can see, for example, that if that curve which is -- crosses the shall I say approximately 80 ksi, which would be .9 of ultimate strength -- that is the conventional one at 10 to the 3rd cycles.

If I swing that line it gives me a variability, but for this particular case if this applies then I would say, under those circumstances at that particular stress level and for that number of cycles, then some place in that band I would expect cracks to initiate.

Q All right.

Now repeat for me if you will for me to be certain why is it at the other parameters, the 60 and the 10 to the 8th, that you would be absolutely certain the machine would fail?

A (Witness Bush) Well, because that is the highest stress level, 60 ksi, as indicated by how far it is above the endurance limit, so that is an important factor.

The crack initiation is usually the one that is hardest to pin down, so if it moves a little farther to the right, normally talking of 5 x 10 to the 5th, then I may have

a very limited number of cycles and whereas the crack grows, it doesn't fail.

However, when I go from 5 x 10 to the 6th through 10 to the 8th, I am now talking of a very, very large increase in cycles and under those circumstances, I would -- presuming again that I have this constant tensile stress field or stress field, there is no doubt in my mind that the component would have failed probably well before then.

End 10

Q. Is that a feeling that you have, or is it something that --

A. (Witness Bush) No. There's lots of evidence in the literature where there have been overload conditions such as this.

Q. So it's based on your experience?

A. (Witness Bush) A lot of it is experience; that's right, sir.

Q. Nothing that has come out in the record that we have developed thus far?

A. (Witness Bush) No. When you're at a very high stress, such as we're talking about, the situation is pretty straightforward -- very straightforward.

Q. Would you have any strong convictions about failure if the stress was reduced to, say, 49 ksi at 10 to the 8th, regarding failure?

A. (Witness Bush) It would still be a -- under those circumstances, I'd say there's a high probability that it would fail.

Q. But not as high as before?

A. (Witness Bush) No. That was obviously an eyeball judgement in going over, but it still is definitely above there; and, assuming the accuracy of this curve, I would say yes. I would anticipate failure before 10 to the 8th cycles.

Q. Did you -- maybe I've overlooked it, but did you

AGB11/brb2

give us a reference for this set of data represented in Figure 2?

A. (Witness Bush) Figure 2 is really a schematic. What I did for this case is, I used the table as a justification for benchmarking at 10 to the 6th, and I simply drew these lines in on there. And so itprobably would be better to show that as a schematic.

I could probably find an example of behavior similar to this. But it should be better recognized as a schematic diagram.

Q. I guess my point was that you were the author of this particular table?

A. (Witness Bush) Yes, sir.

I'm the author in the sense of going into the literature and finding the sources and putting them together; that's true.

Q. Speaking about bringing the material in from the literature, would you turn to Table 1, I guess it is. In Table 1, in the second column of Table 1, the column is titled "Beginning of Fatigue Limit."

A. (Witness Bush) Yes, sir.

Q. And I believe you did testify this morning that those numbers for that particular column correspond to the break in that curve that we have just been talking about.

A. (Witness Bush) That's correct.

brb3

Q. Could you very briefly explain how data points on such a curve as Figure 2 are obtained? That is, you just told us how you got the points, but how would you go about actually getting those -- a point, a data point for such a curve?

A. (Witness Bush) Well, there are two methods. One that is used from the experimental point of view, often is to use what they call rotating beam specimens. These are hourglass-shaped specimens that are loaded somewhat in tension and also with a bending moment in a machine that puts on a very large number of cycles in a relatively short period of time. You can adjust it so that whatever load you're concerned with, a combined bending and tensile load, for example, corresponds to some value on the equivalent stress. You simply take them to failure. You usually run more than one sample, sometimes several samples at a given stress level, to see the width of this error band, or scatter band.

Q. Just for clarification. You say you take them to failure. You mean at some particular stress level for the number of cycles required for failure?

A. (Witness Bush) You simply take it until it fails. The machine has a reader on it that tells you how many cycles. And you simply do that.

You continue to do that, dropping stresses and taking them to failure. And in the process you can generate a curve. Eventually you'll get to the point where you'll run

brb4

it out to perhaps 10 to the 8th, or even 10 to the 9th cycles, and it doesn't fail, and therefore you argue you are below the endurance limit.

Now, those represent a very special class of sample. They are highly polished things. And one needs to use adequate caution in the use of such data.

The other source, obviously, is in the use of actual failure, presuming you had sufficient information where components have done it. And in some instances, on some components, they have done exactly the same thing. Automotive crankshafts--

Q. I think I understand. That's very helpful. Thank you.

You indicated earlier, I believe, that you had done torsional stress calculations and bending moments, that you were working with torsional stresses and bending moments. Is that correct?

A. (Witness Bush) Not... I didn't calculate them in the context of using a modal analysis approach; what I did was, we took the data from the strain gages and worked backwards.

Q. I understand.

But you I thought also indicated earlier today, I believe, that you did nothing so far as tensile stresses are concerned; is that correct?

A. (Witness Bush) Essentially we're combining

brb5

predominantly the bending and the torsional loads.

Q. Do you feel that there are points on the crankshaft during its operation that tensile stresses are important?

A. (Witness Bush) They could be.

Q. Do you think those stresses are of a magnitude at times that may cause, or initiate failure mechanisms?

A. (Witness Bush) Well, the tension forces that I would worry about would be where the crankshaft was attempting to be pulled in this direction, and generally because of the bearing positions, et cetera, I would expect the bending moments to control more than the tensile: I guess that was the logic process that we went through on there.

The other, of course, is the twisting action that you get.

Q. Okay. Well, I guess my specific question is: Do you believe that there are conditions under which tensile stresses might be large?

A. (Witness Bush) I think the answer is Yes, there could be.

Q. Do you feel that they can be neglected, that they're large but can be neglected?

A. (Witness Bush) Not necessarily so. Obviously you have to recognize that the way I approached this problem was to work back from a fait accompli; namely, that we had gone to 10 to the 7th cycles without failure and without indication

brb6

of cracks, and then attempted to analyze it from that point of view. We could have used a formulation that would have considered all of the principle stresses to establish the bi-axial stresses and work through that way, in which case we could have incorporated that.

Q. Well, since the tests -- is it correct to argue that since the tests were done -- you did not get failure. You analyzed the tests only on two types of motion, namely, bending and tortional, but recognizing that there was a third source of stress, namely, tensile stress.

A. (Witness Bush) That's correct.

Q. Then, at least, it was not large enough to cause failure, since there was no failure. Is that correct?

A. (Witness Bush) I was working back from that point, and I was using the stresses more in the sense of attempting to establish, if I could, where the endurance limit might be than anything else. That was the purpose.

Q. Okay. Perhaps -- do you have any feel for, since you didn't calculate the tensile stresses, but do you have any feel for the relative sizes of those three stresses arising from those three types of forces?

A. (Witness Bush) Yes, sir.

Q. The three I'm thinking of are tensile, torsional, and bending. Could you tell us what the order is, in terms of listing the largest one first?

brb7

(Pause.)

A. (Witness Bush) You'll have to forgive me. As I said, the first time I had a chance to look at this document was this morning.

If we take a given kilowatt level, based on conversion from the strain gauge data -- and, again, recognizing that I haven't had an opportunity to do anything to validate it -- this would show a torsional shear value of less than 14,000, a bending of about 23,000, a shear of about 17,000, a compressive of about 15,000, and a major principle of about 30,000, as a range.

Q. Of those different categories of stresses that you have just mentioned, would shear be closest to what we are calling tensile?

A. (Witness Bush) The major principle, I think, would be.

Q. And what was the value of that?

A. (Witness Bush) About 30,000 in this case.

Q. And that's the largest number that you mentioned?

A. (Witness Bush) That's the largest number; and, as I say, I haven't had an opportunity to look to compare the locations there and so forth, so I'm quoting numbers without benefit of comparison.

Q. Okay. So we should interpret this testimony of the fact that you are just looking -- do you adopt that?

brb8

A. (Witness Bush) I cannot say that I would adopt it. The farthest I have gotten so far is to look at these tables and look at the Failure Analysis report, which I have reviewed in considerable depth, and attempt to compare the numbers on the replacement crankshaft and see if I can correlate from a table here to a table here. (Indicating.) That was what I was attempting to do.

Q. Judge Brenner is whispering in my back to say that when you say "here and here", perhaps you had better go back over that --

A. (Witness Bush) Yes. I recognize the -- I was comparing the values that appear in the Failure Analysis report, FaAA 84-3-16, to a document titled "Field Tests of Emergency Diesel Generator 103 With a 13 by 12 Crankshaft", authored by Stone and Webster, with input from FaAA.

JUDGE BRENNER: Is the latter document the one you saw for the first time this morning?

WITNESS BUSH: I received it yesterday. That's the first time I have seen it, sir.

BY JUDGE MORRIS:

Q. Do these stress levels relate to some power level, Dr. Bush?

A. (Witness Bush) Yes. They are strain gauge data, rosette data, that -- where the strains are converted in the particular directions. There are power levels of 38, 35, 28,

brb9

and two lower levels, 2700 and 1750, if I read this correctly.

But, as I say, I haven't had an opportunity to try to correlate the front of the report with the back of the report, so I'm simply quoting from the table, noting more, at this stage.

Q Well, do I infer correctly that these strain -- these stress levels weren't made all at the same power level?

A (Witness Bush) Well, I suppose it would be better to ask Failure Analysis. Certainly, I interpret the table and I interpret the FaAA report as, indeed, that to be the case. What they did on this particular crankshaft was rig it up to certain power levels and then take these strain gauge readings, and then converst the strain gauge readings into stresses at those levels. I don't know if this report is a part of the record or not, quite frankly.

EndAGB 11

AGB12/wb1

BY JUDGE FERGUSON:

Q. Let me thank you for what you said thus far. But let me go back to Figure 2.

You said Figure 2 is really your attempt to schematically represent data that you have taken from references that you have looked at; is that correct?

A. (Witness Bush) More properly, it is a true schematic. I had the purpose there to show the fact that the endurance limit is a horizontal line, and that the other line comes down, and that these values would be something that one wouldn't be surprised at.

Q. What do we have in the record to support this particular curve? You say it comes from references that you have looked at, and somehow tried to summarize in a picture that looks like this.

Is there anything in the record that you're aware of that would support this particular drawing or your interpretation of the data that you have looked at in order to draw this Figure 2?

A. (Witness Bush) Well, certainly the testimony of Dr. Pischinger yesterday relates specifically to this type of curve, where he was defining the endurance limit in that instance, rather than stress in terms of kilowatts. He came up with 3505 kilowatts for example, as the level which would be the horizontal portion and below which, of course, he would

GB12/wb2

not expect anything to occur. And presumably the slanted portion would be benchmarked on 9/10th of the ultimate tensile strength. But that's fairly common.

Q. Excuse me for interrupting. I think that's clear. But perhaps my question is not clear to you. I think the concept is clear: you have made that clear by the drawing.

But I'm not asking about the concept, I am asking about the source, really, of the information depicted in Figure 2. Where is the source?

A. (Witness Bush) I could take any ferritic steel and I would get this shape curve.

I think what you want is to have a curve that has the explicit values on the curve. Perhaps the best thing I should have done is to erase the stress and have a stress x-axis, but leave the cycles below, and then it would be truly representative, and I wouldn't have to worry about the question of the source.

Q. But even that modification would still not give me a basis for understanding the basis for the curve.

To make it clear: I'm not disputing that this in fact is the way stress and numbers of cycles relate to one another for ferritic steel; I'm simply asking whether or not there is a basis for the curve that I'm looking at.

A. (Witness Bush) There is none, other than the fact that, as I say, this is the shape of the curve, and if I were

wb3

to put x values on the stress axis it could apply across the board under any circumstances.

Q. All right.

I want to move back just quickly to the discussion we were having about bending, torsional and tensile stresses.

A. (Witness Bush) Yes, sir.

Q. You gave me some numbers, and we will accept those and evaluate them based on what you have just, that you just looked at them today, just having received them yesterday.

But if we can believe those numbers, my recollection was that for the bending and torsional stresses they were on the order of fifteen or so thousand ksi, and the major --

A. (Witness Bush) The principal stress--

Q. -- the principal stress was on the order of twice that; is that correct?

A. (Witness Bush) Thirty, I think it was. 21,000 roughly for the bending, I believe about 13 for the torsional, and--

Q. Just roughly 15.

A. (Witness Bush) Yes, from that point of view.

Q. The thing that I'm drawing from that is that so far as stresses are concerned that torsional and bending are about half of the major. And I thought the original discussion we had identified the fact that you had not considered the major or the tensile stresses; is that correct?

wb4

A. (Witness Bush) For the purpose of the analysis I was doing, which was primarily to benchmark the endurance limit, the answer is I did not attempt to do that. I could have used a sine method, or something like that.

Q. That's fine, I think I understand.

But the point was that you did not?

A. (Witness Bush) I did not.

Q. And I guess my question is, Do you feel that was correct? Do you feel that the results that you have gotten by neglecting a stress that was maybe twice that you were considering would give you results that you would be comfortable with? --or a conclusion that you'd be comfortable with?

A. (Witness Bush) Well, as I say, the approach from which I came wasn't particularly concerned with that. So I guess I was not.... I started with the knowledge that it had not failed, and, as I say, I was simply trying to benchmark; nothing more.

Q. I see.

A. (Witness Bush) We did look, and did use the maximum bi-axial stress state values, the SQA values for a purpose of comparison on there, which would pretty much cover the spectrum of stresses in there. That was -- I wouldn't say it was an afterthought, it was just more set of values that we had; nothing more.

Q. All right.

wb5

A. (Witness Bush) This had been done in depth by Failure Analysis.

Q. All right. I have nothing further. Thank you.

zxz

BY JUDGE MORRIS:

Q. Dr. Bush, let me follow a little bit on Judge Ferguson's questions.

Looking at the horizontal part of the curve which is labeled "Fatigue endurance limit," does the value of stress for that horizontal part have any relationship to the yield stress of the material?

A. (Witness Bush) I has a better relationship to the ultimate stress of the material. It will run about 40 percent, essentially, of the ultimate -- for the virgin...what I will call the virgin endurance limit. And then the cycles will tend to drop it somewhat, but probably not a great deal.

Q. 40 percent of ultimate. That's true for a variety of ferritic materials? --ferritic steels?

A. (Witness Bush) I really can't answer that particular question as to whether-- I know it applies for a certain class of materials. I would hesitate to say across the board that it would apply. So I really can't answer that question.

Q. Would it apply to the crankshaft for the 103 diesel generator?

A. (Witness Bush) Yes, it would. In fact, the values I used were based explicitly on the crankshaft data.

wb6

Q. In reaching your conclusions based on the arguments which are related to this curve, would your conclusions vary if the inflexion point in the curve were translated, say, to the right by a factor of half a decade?

A. (Witness Bush) I don't think it would affect the conclusions, it would certainly affect the numbers that we came up with, because our capital-N values, the numbers of cycles to cross that curve, would change.

Could I clarify one thing?

Of course, all our calculations pretty much indicate that almost all of our stresses are down in the below region. That's why we kept coming up with negative results, so to speak.

So essentially our endurance limit, calculated first by working from the actual experimental evidence, and then going through a series of calculations in an attempt to see if we could indeed establish whether they were somewhat higher than that because we hadn't had failure, indicated that essentially we were right in that region. So the difference between the endurance limit that we came up with and that that Dr. Pischinger came up with is between about, roughly, 3450 and 3500 Kw: they're very close to one another.

Q. So if the inflexion point were 5 x 10 to the 6 cycles it would not affect your conclusions significantly?

A. (Witness Bush) I guess I can't say that that would

wb7

be the case. If it moved over that far, and given that we had only gone to 3 x 10 to the 6th cycles for the higher loads, and if indeed the endurance limit were lower than we had anticipated in there, it's remotely conceivable that we could be above that inflexion point to a degree, but the summation of the cycles might still have just barely to the left of the curve.

So that would have said-- If that were the case, that would have said if one ran for another 10 to the 6th cycles, for example, at one of these stresses -- let me say 3600 or something of that nature -- for this hypothetical case it's conceivable that it could have caused cracking.

Q. So that's roughly the limit of the uncertainty on your conclusion?

A. (Witness Bush) That's why I spent a lot of time on Table 1, to try to indicate that I would expect that inflexion point to be not a great deal different from 10 to the 6th. Most of them I found went as high as 3 x 10 to the 6th, and some were down around .7 or so. So I believed I was justified, as a first approximation, in using that.

Now that, incidentally, is in the Palmgren-Miner approach. The so-called C-constant that's set to 1 is on that basis.

Q. Well, turning to Table 1 and your Column 2, all of these examples were for actual failures; am I correct in that?

wb8

A. (Witness Bush) These were undoubtedly established by mechanisms where they could unequivocally establish it. And that pretty much meant that they had to do -- that they had to go through the technique to where the samples, enough samples had failed to establish the slope of the one line, and enough samples had not failed to establish where the endurance limit is; that's true.

Q. Do I therefore correctly infer that these numbers are not from a single measurement but from a series of measurements which establish the shape of the curve?

A. (Witness Bush) These would be many measurement; that's right.

It takes a fairly large number of samples to do this. Small samples: it's straightforward. Obviously, when you get to crankshafts, automotive crankshafts, it becomes a much more complicated situation.

Q. Thank you, Dr. Bush.

Mr. Henriksen, I believe the other day you made a comment with respect to the testing of the Shoreham emergency diesels, that you wouldn't have run the tests that way.

Do you recall that?

A. (Witness Henriksen) Yes.

Q. And were you referring to the endurance tests, or were you referring to future surveillance tests, or both?

A. (Witness Henriksen) Well, I did make the qualification

wb9

that I'm not necessarily used to run these endurance tests, my tests are usually being of much shorter duration, and the object was maybe different. In my case it has always been the object to get as precise power and fuel consumption as possible; in which case, obviously, the runs are much shorter. Usually each fuel run is about an hour duration, possibly two to three hours at each load. That all depends upon the agreement between the parties.

Q. And for these kinds of tests are the generators hooked up to a transmission line?

A. (Witness Henriksen) They're usually hooked up to a bus. It's assumed that the load on the bus exceeds the load that you intend to run the engine on. There's no point in blocking. And you use a different method. You usually use a load box, which is nothing but a resistance where you can regulate the load. But this is not the case here.

End 12

Q But is it your opinion that the load on the Shoreham diesel generators can be controlled that closely?

A (Witness Henriksen) You are now talking about the surveillance tests?

Q Yes.

A (Witness Henriksen) If I understand previous testimony correctly, I understand that they have ample load on the bus and I would expect them to have a governor that has this capability. And yes, in that case I would do that if for no other reason, to avoid the controversy over plus or minus 100 kw.

Q Well, perhaps I didn't understand previous testimony correctly, but it was my understanding that not blocking the governor but trying to control as closely as possible, the fact that the emergency diesel generator set was tied to the transmission line caused interactions such that they couldn't avoid fluctuations in the output of the diesel generators.

A (Witness Henriksen) Well, then possibly I misunderstand how it was hooked up. I would not, with what I learned from the testimony, expect that to happen.

As far as I am concerned, the only way the load would change then would be if the load dropped below what the engine was trying to do, and I understand that that wouldn't be the case.

Q I am not familiar with the way these things work, but if you block the governor, what does that in fact do? Does it limit the--

A (Witness Henriksen) Yes, you limit the load that the engine can do. You set the load limit and there is no-- It cannot pass it.

Q So it sets an upper limit?

A (Witness Henriksen) It essentially stops the rack at a particular point. The governor is directly tied in with the fuel racks.

Q So it sets an upper limit as to what the engine can produce?

A (Witness Henriksen) Yes.

Q But the engine could in fact go lower?

A (Witness Henriksen) If the load dropped below that point, yes.

So if you were to run a surveillance test over a period of time with the governor blocked, and with the performance that I have heard about, that there is a necessary oscillation, the peak value would not exceed what is blocked by the governor, but necessarily the average load would be less than that.

A (Witness Henriksen) That is correct.

Q Thank you, sir.

BY JUDGE FERGUSON:

Q Something you said, Mr. Henriksen, that would be helpful if you explain to me:

Judge Morris was just indicating that there was a fluctuation or at least the applicant found that the output of the diesel fluctuated. You indicated that the way you would run the test would be one where you would have excess load, run the diesels; there should be no fluctuation if it were run that way if you have excess load.

I guess my question is why-- In your opinion, what was the source of the fluctuations that the applicant has reported?

A (Witness Henriksen) I don't know really what flucturation they were referring to. The only one I can see with a blocked governor would be that the load dropped below what the engine was trying to put out.

Q You don't know whether that was in fact true or not true?

A (Witness Henriksen) No.

BY JUDGE BRENNER:

Q Dr. Bush, you may have been asked this earlier by Mr. Dynner but if so, I am not sure it was precisely these terms.

As you have used the terms in your testimony, is "endurance limit" the same as "high-cycle fatigue limits"?

A (Witness Bush) In the context, again if you

relate it to the horizontal line, yes. Both the terms appear in the literature so I used them in that fashion, so you could consider that the high-cycle fatigue limit and the endurance limit are both representing that horizontal line.

Q At page 23 of your testimony, the third paragraph on that page which is the second paragraph of answer 16, in the last sentence of that paragraph you say:

"....surveillance tests can add over 3 x 10 to the 7th cycles during the assumed 40-year life of the Shoreham....Plant."

Is that the figure you meant to put, 3 x 10 to the 7th?

(Pause.)

A (Witness Bush) That would be 2200 hours.

Q Or 2250, somewhere in that range.

A (Witness Bush) That would assume--

Q Is the number correct?

A (Witness Bush) That's what I'm wondering. About 50 hours a year. Yes, I think that would be the case because if you assumed--

Well, I'm trying to think when I saw the testimony -- not the testimony but the SER, because this would be assuming a certain number of hours a month, plus a 24-hour run to come up with about 50 hours a year, and assume that that occurred every year to come up with that

particular number. That would be the basis.

If the 24-hour run were delayed then this number would tend to drop but it would still be above 10 to the 7th.

Q It would be about 10 to the 7th?

A (Witness Bush) Yes, sir.

Q In that same paragraph, the first sentence, you state in part that:

"....the endurance limit can be established with certainty as being only at or above 3300 kw...."

On page 17 I think among other places, in the last sentence on page 17 you state:

"....the high-cycle fatigue limit is at or above the value corresponding to 3500 kw minus known instrument error, or 3430 kw."

A (Witness Bush) I think you're correct. A more reasonable value here would be the 3430. However,--

Q A more reasonable value where? I didn't ask my question,--

A (Witness Bush) I'm sorry. I apologize.

Q -- but you've anticipated it.

A (Witness Bush) My apologies.

Q All right. Go ahead, you've got the drift of it. Where?

A (Witness Bush) Where you cited it first, namely

in view of the endurance limits on page 23. The obvious reason for this was to indicate that since much of the testing had been at 3300, it didn't appear justifiable to go substantially above this for surveillance testing.

Q But you still--

A (Witness Bush) It should be-- Really to be consistent, you are quite correct, it would be better to have the same number here as in the other location, namely 3430.

Q Let's put aside the possible variation based on your assumption of the one direction load variation error just for simplicity for now and talk about 3500 kw.

A (Witness Bush) Okay.

Q What is your basis for believing that 2 x 10 to the 6th cycles at or above 3500 kw necessarily would have caused at least crack initiation if the endurance limit is below that value?

I guess it is my own elliptical way of trying to understand why you think the knee of the curve would necessarily be at 3 x 10 to the 6th cycles or lower.

A (Witness Bush) I think that is exactly the same question I answered for Judge Ferguson.

Q I didn't understand your answer.

A (Witness Bush) I will attempt to clarify it. All right.

Q I want to know what your basis is.

A (Witness Bush) The argument I attempted to advance was that I would expect the highest probability of the intersection of the line would be about 1 x 10 to the 6th.

Q What is your basis for that?

A (Witness Bush) That was the reason for Table 1, to try to indicate that with the spread in there that a reasonable assumption is that it would be close to 1 x 10 to the 6th. That doesn't say I can unequivocally guarantee because I do not have enough data points to tell me what the slope of that line is.

If indeed it is 1 x 10 to the 6th and if the endurance limits, the location of the line in terms of kilowatts for purposes of this is something like 3000 or 3300, I think there would be enough difference in those circumstances that the cumulative fatigue that I would achieve from the different conditions would have a good possibility of initiating cracks.

You're quite right, if I swing that line further -- I believe that gets back to another question of the panel -- of the Board -- then the degree of certainty in that is reduced. That's no doubt about it.

If it were to swing as far as 5 x 10 to the 6th, then the argument utilizing 3 x 10 to the 6th becomes more tenuous. About all one can do is obtain as much information as possible and see what the trends are, and that is what I

attempted to do here since I have no other basis.

I don't have a method really for benchmarking the onset of the endurance limits absolutely.

Q You have explained that Figure 2 is schematic,--

A (Witness Bush) Yes, sir.

Q -- and not to be relied on for any quantification.

What is the basis for supporting the fact that that is the shape of the curve that would apply to the type of metal that the Shoreham crankshaft is made of? That is I think you said ferritic steel.

A (Witness Bush) All fatigue curves have this shape, sir. This happens to be one that I would be using with the Manson approach where I plot stress and even log stress up there, which is another possibility in here. But they all display this particular shape.

Are you thinking that it might be curved or something of that nature?

Q Yes.

What is your basis for believing that it becomes a horizontal line somewhere in the range beginning at 10 to the 6th or 10 to the 7th cycles, if I can give you that big a range?

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brb 1

A. (Witness Bush) Everything in the engineering literature would indicate that, in the case of an object that was made of a ferritic material and was free of initial flaws, that it would display this behavior. In other words, it's not unique to one steel or one condition or anything of that nature. I can take any text at random that deals with fatigue and show you the same type of curve.

Q. All right.

One reason for my pursuing this is because you have expressed your level of certainty -- or, one might call it your level of uncertainty, the same point -- in discussing 3 times 10 to the 6th cycles, with respect to a load level of approximately 3500 kw.

And what I am asking is: are you telling me that you have no doubt that if you were to run cycles approaching 10 to the 7th for ferritic steel that you would definitely be to the right of the knee of the applicable fatigue curve for ferritic steel?

A. (Witness Bush) Yes, sir. In fact, that was the basis for the initial suggestion that a test be run to 10 to the 7th cycles.

Q. If one were to assume that the stress that would correspond to the load level of 3500 kw would not be in the failure portion of the fatigue curve for 3 times 10 to the 6th cycles -- that is, it would take some greater number of cycles

to cause fatigue at that load level, and for that reason we didn't credit your conclusion -- although you have told us time and again that it is still your conclusion that the endurance limit is somewhere at or above 3500 kw; but let's say we don't accept that for reasons of uncertainty as to whether you've got the requisite minimum number of cycles to support that -- and instead found that the endurance limit is at approximately the stress that would correspond to a load level of 3300 kw for infinite life -- that is, you would be below the horizontal line portion of the curve, of the fatigue curve. Are there any conclusions we could draw with respect to relatively short-term operation up to the load level of 3400 and 3500 kw, based on the proposition that you have established continuous life at 3300 kw?

A. (Witness Bush) One factor, of course, is that the band of stresses that we were talking of between 3300 and 3500 -- if one accepts the validity of the extrapolation -- the difference is about two to 2.5, three percent at most. That would say that we would have a postulated condition where the endurance limit would be sitting either precisely on or just barely above the 3300, and therefore the 3500 would be above this by a couple of ksi. If that were the case -- and, particularly if you assume also that we have rotated the line so it no longer intersects at 10 to the 6th but, perhaps, four or five times 10 to the 6th -- then I guess I could not

unequivocably establish that, under these conditions, the shaft would survive unlimited operation, say, at 3500.

I believe that was your question, was it not?

Q. Yes.

(The Board conferring.)

BY JUDGE BRENNER:

Q. Dr. Bush, if it is in your written testimony with respect to the crankshafts -- and forgive me if I don't remember it, but are you recommending any particular schedule of surveillance of the crankshafts if the diesels are permitted to operate under the load conditions being proposed by LILCO?

A. (Witness Bush) No, sir.

You're talking in terms of how many times they should be tested. I believe the Staff has such, but we haven't made it an explicit portion of the testimony, other than we suggest 3300. I believe the SER refers to it, but that's as far as I am aware.

Q. I've got procedural problems with the way the Staff approached what to put into evidence and what to not put in evidence; but they're not problems of your making, to be sure.

But, in your opinion, should there be particular surveillance or other examinations or inspections of the crankshaft, even if the engines are permitted to operate and, in fact, to operate within the limits of the 3300 qualified load?

A. (Witness Bush) I would assume that our testimony of October would apply, where, I believe, we established the caveats that at the first refueling outage they would be re-examined and then a decision would be made as to the schedule further than that. But, at this stage, between the cam gallery and the block tops and the crankshafts, I may be confused.

Q. I was just talking about the crankshafts, now.

A. (Witness Bush) I recognize that. But we certainly discussed this, and I believe the requirement was an examination at the refueling outage, a full examination. But I don't know if that has been changed by other testimony or not.

Q. You haven't changed it in your testimony?

A. (Witness Bush) No, sir.

Q. And if I gave you the opportunity now to change it, would you want to?

A. (Witness Bush) I am not a proponent of excessive testing of these, because I watched what happened to the others, where they literally wore them out. And so, whereas I think one needs to do some testing from a reliability point of view, perhaps every twelve or fourteen months do a 24-hour test, I guess I would be unwilling to see tests that were originally required, of every week or something of that nature. I think that's simply asking for trouble.

Q. What about inspections of the crankshaft after the normal 18 months, approximately months, 24-hour run? Do you think that's necessary?

A. (Witness Bush) I guess I would be lukewarm, in the sense I would like to see it inspected at the outage, which is, presumably, not too long thereafter -- I'm not sure where in contrast to that -- simply because if you take that action you have a crankshaft out of action for some period of time. But that's a personal opinion, and I guess it isn't backed up by much technical judgment on the thing.

Q. Well, my next question is going to be: if it only operated at 3300 kw or below, based on your testimony you wouldn't expect to find anything wrong with the crankshaft?

A. (Witness Bush) I would not expect to find anything wrong with it; that's true.

Q. Now, did you also testify -- maybe it was orally -- that you would expect to have some sort of inspection of the crankshaft if it operated at a higher load level?

A. (Witness Bush) That is in the testimony. It states that if, indeed, you are in an emergency condition, particularly if you run into the condition of an operator error, my testimony, in essence, says that I believe it would survive a period of time less than an hour; but I believe that it would be appropriate to re-examine the crankshaft

thereafter for any indication of degradation.

Q. Thank you. I apologize for my failing memory. You just reminded me: and then we walked you about a bit as to just what load you had in mind, and so on.

A. (Witness Bush) Right.

JUDGE BRENNER: That's all we have. Thank you both. We will go to the redirect.

Let me make the obvious point that if any party, along with their findings, as I said this generally earlier, wants to propose any conditions, be it surveillance conditions based on time, operation, load level, anything, for any of these components in controversy, we had better see it in the findings. And if you reach agreement on any such conditions, that, too, we should be informed of that; and it could be done along with the findings, also -- proposed findings. And the agreement could be provisional, too: that is, "Our position is A, but if you find B, then at least have the following conditions." That's one possibility.

Mr. Goddard?

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REDIRECT EXAMINATION

BY MR. GODDARD:

Q. Dr. Bush, would your conclusions regarding the endurance limit for these crankshafts have been affected in any way if you had considered operating time at loads below 3300 kw?

A. (Witness Bush) No, sir. I would have utilized the experimental evidence of runs of 10 to the 7th to establish that I should be above that -- namely, the values such as we suggest of in excess of 3430 -- and I would feel that loads that are well below that would not contribute.

Q. Dr. Bush, there were numerous questions asked with regard to the Manson approach. Would you state to what degree, if any, your conclusions on the endurance limit of the crankshafts were based upon the Manson calculations?

A. (Witness Bush) Essentially none, because they all came out the same way. We utilized the experimental evidence to establish the value, essentially at 3430, and then we went through a series of calculations utilizing the matrix that we discussed this morning to see if we would have any effect. And they essentially all came out negative, in the sense of showing anything which would indicate to us that, with our assumption of the sloping line at 10 to the 6th, that almost all of our stresses were grouped very close to or, more probably, below the endurance limit. So, as I say, all we did was get negative results because of that.

End AGB 14

15 AGB/wb11

Q. At the time you did your Manson calculations, you did not have knowledge of the sequencing of load application, did you?

A. (Witness Bush) None whatsoever; that's correct.

Q. Before the noon break--

A. (Witness Bush) Pardon me. I still do not have that, I might indicate, to clarify the record.

Q. Before the noon break, Dr. Bush, Mr. Dynner asked you a question with regard to the source of the figures that appear on page 22 of your prefiled testimony. This is the information in Answer 15.

A. (Witness Bush) Yes, sir.

Q. Are you aware at this time, or has your memory been refreshed as to the source of the figures which you set forth in that table?

A. (Witness Bush) Yes, we discussed this afterward which helped to refresh my memory. These numbers were generated by the Staff and approved by Dr. Berlinger and incorporated in the testimony on that basis, with the sole exception of the first line, which is the 1-minute value, which is the one that I had postulated and essentially we had removed from elsewhere.

Q. Just for clarification, that's the line that reads:

"Less than one minute at 3900 kilowatts."

Is that correct?

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A. (Witness Bush) That's correct.

Q. One last question for clarification, Dr. Bush.

Is it true that the references that you provided in Table 1 of your testimony all provide curves that are comparable to the schematic which you prepared as Figure 2?

A. (Witness Bush) Not all of them. Some of them do. Some of them simply state the results of tests; in other words, they would be in tabular form. And so I simply abstracted the tabular form therefrom.

In other words, the original curves were not necessarily incorporated in the references.

Q. But had the curves been incorporated in those references, is it your opinion they would have been comparable to the schematic which you prepared as Figure 2?

A. (Witness Bush) Certainly from the shape point of view, yes.

Q. Thank you, Dr. Bush .

MR. GODDARD: I have no further questions on redirect.

JUDGE BRENNER: Any follow-up by LILCO?

MR. STROUPE: Yes, Judge Brenner.

JUDGE BRENNER: How much do you have, roughly?

MR. STROUPE: No more than thirty minutes, and probably less than that.

If you want to take a break now I can probably

wb3

consolidate and reduce.

JUDGE BRENNER: All right. I was going to give you that opportunity, if you prefer; or if you prefer to go ahead and break in the middle, I'll give you that opportunity.

MR. STROUPE: Taking a break right now would be fine.

JUDGE BRENNER: All right.

If we broke until 3:35 would that give you the time you need?

All right, let's do that.

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(Recess.)

JUDGE BRENNER: Back on the record.

Mr. Stroupe, you may proceed.

RECROSS EXAMINATION

xzxzx

BY MR. STROUPE:

Q. Mr. Henriksen, you indicated yesterday and, I believe, again this afternoon in response to Judge Morris' questioning, that you would have blocked the governor on the Shoreham EDGs to perform the 10 to the 7th cycle test; is that correct?

A. (Witness Henriksen) I said yes, this would be my preferred method.

Q. It's true, isn't it, Mr. Henriksen, that if the governor on the Shoreham EDGs were blocked at a particular given load while the engine was operating on the grid, if that load was lost the engine would overspeed?

wb4

A. (Witness Henriksen) I think the engine would shut down on overspeed, yes.

Q. Are you aware, Mr. Henriksen, that the governor on the Shoreham EDG is for both synchronous and asynchronous operation?

A. (Witness Henriksen) As I testified earlier, I'm not familiar with the details of the governor.

Q. If, indeed, Mr. Henriksen, a loss of load with the governorblocked on a Shoreham EDG would result in an overspeed situation for that engine, would you recommend that testing be done with the governor blocked?

A. (Witness Henriksen) No, probably not.

Q. Do you have any knowledge, Mr. Henriksen, as to whether the fluctuation that has been testified about with regard to the kilowatt meter indication on the Shoreham EDGs when the engines are in fact on the grid, is caused by the dynamic interaction of the grid?

A. (Witness Henriksen) I have also testified before that I don't know exactly what causes the oscillation.

Q. Would it surprise you, Mr. Henriksen, if the oscillations were caused not by the governor but by the grid?

A. (Witness Henriksen) No.

Q. Dr. Bush, it's true, isn't it, that even if the onset of high cycle fatigue with regard to the Shoreham replacement crankshaft is not 1 x 10 to the 6th or, indeed,

wb5

3 x 10 to the 6th, but is 10 to the 7th, that the endurance test which has been run would still demonstrate an endurance limit of at least 3300 Kw?

A. (Witness Bush) Yes.

Q. And would it also be true, Dr. Bush, that loads above 3300 Kw that had been applied to the Shoreham EDG would add to this figure of 3300 Kw?

A. (Witness Bush) Yes.

I should perhaps clarify my previous one. I think I answered too rapidly.

If all of my cycles are to the left of the intersept, then obviously I can't say where I am under those circumstances. But presuming I am at, or to the right of it, then I can say that I have examined the situation, and I would say that it would be there.

JUDGE FERGUSON: While we have a pause:

Dr. Bush, clarify that last answer, would you, for the Board?

WITNESS BUSH: I believe he was citing the onset as being 10 to the 7th. And if I ran 10 to the 7th cycles at 3300, considering the points that we were discussing about the fact that it may not initiate precisely there, that you have a probability band, I can't unequivocally establish what is there.

Now, that represents coming right to a point. And

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that's the reason for my caveat.

I have run that number of cycles at 3300, and if my onset is at the same number of cycles I can't unequivocally establish what the situation is. That's all I can state.

BY MR. STROUPE:

Q. Dr. Bush, did you hear Dr. Pischinger's testimony that based on his cumulative damage analysis, using all hours, approximately 1323 hours, that he arrived at an endurance limit of approximately 3505 Kw?

MR. DYNNER: Asked and answered. In fact, of course, I had a number of questions dealing with that specific subject matter.

MR. STROUPE: Precisely. And that's why I wanted to ask the question.

JUDGE BRENNER: All right; we'll let you explore it, Mr. Stroupe, and see where you're going.

WITNESS BUSH: I heard that portion of the testimony, yes, sir.

BY MR. STROUPE:

Q. If you had utilized all the hours that we are talking about, Dr. Bush, would your endurance limit in terms of Kw been consistent with Dr. Pischinger's?

A. (Witness Bush) He approaches it from a different point of view, using that factor of safety.

I would say that our analysis and experimental

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evidence would indicate that we are within 50 or 60 kilowatts, and I recognize that testimony-- Well, I shouldn't say "testimony," a citation was given that the accuracy of measurement on the values at or above 3500 was better than was the case in 3300, which would have had an impact on the positioning of that. But that is still hearsay, I'm afraid, in the sense that we haven't examined those data.

Q. Would that accuracy have had an impact upwardly, in your opinion?

A. (Witness Bush) Yes.

Q. Dr. Bush, this morning I believe you testified, did you not, with regard to some cracks in the crankshaft that had been ground out; is that correct?

A. (Witness Bush) That's right, sir.

Q. You meant to refer, did you not, to the original crankshaft and not the replacement crankshaft?

A. (Witness Bush) I probably was ambiguous. This was one of the crankshafts which were examined after the initial failure. A crack was found in there. The crack was removed. I don't think it was recognized before-the-fact that it existed. And that it was strain-gaged to establish what the stress levels were.

Q. Dr. Bush, does your training and experience and expertise allow you to logically assume that stresses between 2800 Kw and 3300 Kw with regard to the Shoreham crankshafts

wb8

are going to be lower than stresses between 3300 Kw and 3500 Kw?

A. (Witness Bush) I would think so, sir.

Q. Dr. Bush, would I be correct in my interpretation of your testimony earlier today that as a result of the combination of load sequencing that you used in analyzing the cumulative damage under Manson's approach, you took a worst case situation with the higher load first and a best case situation with the lower load first? Is that correct, sir?

A. (Witness Bush) That was Dr. Pischinger's case, I believe, which you are discussing.

Q. Was that not one of your combinations?

A. (Witness Bush) But you added the words "worst" and "best," I think in there.

I gave the sequencing, and, in fact, I would have had another sequence probably in the 36, 35, 39, as high, simply because the stresses, as I have been able to determine on the basis of the strain gage data, are sufficiently close together that I think that the number of cycles tend to be more important than, perhaps, another ksi in stress. That was the only reason for that.

I do not disagree with Dr. Pischinger's statement in the generic sense. If I test at a substantial level, such as the example we were using of 60 ksi, then I don't think there's any doubt that that represents a more severe condition

wb9

than the other one. But these are very close together.

Q. So would I be correct in interpreting your answer to be that, assuming the higher loads first would result in the worst case situation?

A. (Witness Bush) If the higher load is substantially above the others, then I would say that's the case. If they're very close together, then in my estimation one has to look at the number of cycles that go with that load and at the time that goes with it, and if it's a few higher for the higher load, where it is only a couple of ksi, then I don't consider that as significant as perhaps 100 or more hours. That's the only difference.

E 15

Q. Dr. Bush, is it your opinion, and based on your calculations and analysis, that the endurance limits of the Shoreham replacement crankshafts are approximately 3500 Kw and possibly greater?

MR. DYNNER: Asked and answered.

MR. STROUPE: Judge Brenner, I believe that this is a question that you phrased, assuming 3500 rather than 3430, and I am just following up on that.

JUDGE BRENNER: I really think it has been asked and answered a lot. Can you put a new point --

MR. STROUPE: I am just not as confident that the 3500 Kw figure has been asked and answered. It may have been asked, I am not confident it has been answered.

(The Board conferring.)

JUDGE BRENNER: All right. I'll give you this one, Mr. Stroupe, but not too many more, okay, because --

MR. STROUPE: Thank you, Judge Brenner.

WITNESS BUSH: I believe I stated that I would expect it to be at least 3430 and possibly it could be higher than that.

I stated in an earlier question that it's a function of what the real values were versus the assumed values, and I still have only hearsay evidence on those.

BY MR. STROUPE:

Q. Do you indeed have a degree of confidence in your

opinion, Dr. Bush?

A. (Witness Bush) Yes.

Q. Is it a high degree of confidence?

A. (Witness Bush) Within engineering limits I guess I would say yes, it's a high degree of confidence.

Q. Now you said I believe yesterday, Dr. Bush, in response to a question from Mr. Dynner as a preface that engineering judgment, for what it's worth.

You didn't mean by that to infer that your engineering judgment is not worth anything, did you?

A. (Witness Bush) I hope not, I get paid for it....

No, not facetiously, I think in many instance you must apply engineering judgment, that you can come up with totally anomalous results if you do not use it.

Q. Dr. Bush, if I may, let me direct your attention to page 22 of your testimony, specifically the table that is set out thereon.

A. (Witness Bush) Yes.

Q. Did I understand you correctly earlier to indicate that the first entry in that table that says: "Less than one minute at 3900 Kw," should not be in the testimony either, that that was part of the same matter that was taken out of the testimony earlier this morning?

A. (Witness Bush) We discussed this last night and decided that since this was a generalized assumption on a

LOOP/LOCA that we would not do so, I presume to be consistent with the further deletion of other matters that came up, that this fits generally in that same category.

Our feeling was that it was kind of generalized coverage of the thing, but I guess I would have to confess that that particular item certainly was not generated as a result of the FSAR and it does indeed related back to the preceding pages.

Q. And it was based upon a hypothetical situation, wasn't it?

A. (Witness Bush) One reason we left it in was that we generated the words for the hypothetical situation which were then after the fact taken out.

Q. Dr. Bush, in response to some questioning from the Board with regard to your recommendations as to any inspections and/or tests that need to be performed on any sort of a periodic basis to the crankshafts, you, I believe, indicated that you had some testimony on that and the testimony was given in the fall of 1984 in this proceeding, did you not?

A. (Witness Bush) Yes. Well there was testimony in the fall of 1984, yes.

Q. Wasn't that testimony, Dr. Bush, with regard to recommended inspections at the refueling outage formulated at a time when no endurance run had been conducted and no subsequent non-destructive examination of the crankshafts

had been conducted?

A. (Witness Bush) That's correct.

Q. Does that 10 to the 7 cycle endurance run and the inspections that followed thereafter have an effect upon your opinion as to any tests or inspections that should be done to the crankshaft at the first refueling outage?

A. (Witness Bush) It undoubtedly would tend to lessen that. But you realize this was a joint decision and that I was only a minor contributor to that so I could only express a personal opinion and nothing beyond that.

Q. I'm only asking you for your personal opinion.

A. (Witness Bush) Certainly the test and the fact that examination was done would lessen the urgency for such an examination. That is a personal judgment on my part.

Q. Dr. Bush, looking again at page 22, regardless of whether the figures are correct or incorrect in terms of either their Kw load or their duration, is it your opinion that the Shoreham replacement crankshafts can sustain the loads postulated for the periods specified?

A. (Witness Bush) I'm sorry, sir, you asked me an open-ended question because you both permitted the times to change and the kilowatts to change and I don't know how to answer that question.

Q. No, I'm asking based on the times and the kilowatts that are listed on that chart.

A. (Witness Bush) Okay. I'm sorry, your "regardless" confused me in that respect.

If you presume the time and the kilowatt levels that are shown here, I would anticipate no problem.

MR. STROUPE: That's all the questions I have, Judge Brenner.

JUDGE BRENNER: Mr. Dynner, any follow-up?

MR. DYNNER: Yes, I have a few follow-up questions.

RECROSS-EXAMINATION

BY MR. DYNNER:

Q. Dr. Bush, we have been discussing your answer 16 on page 23.

I'm curious. The sentence in the last paragraph of answer 16, which begins "in view of the fact," is that sentence written by you, yourself, or was it written by Professor Sarsten or Mr. Henriksen or somebody else?

A. (Witness Bush) We certainly collaborated on it, all three of our names were on it initially. Since it deals with endurance limit, I would certainly have been the major contributor and anyone else would have simply been looking at the words rather than generating the words.

Q. So you think you wrote it yourself, as far as you can recall?

A. (Witness Bush) Yes.

Q. Now did I understand you to say in answer to one of

Judge Brenner's questions that now, on reflection, you would change the value of 3300 Kw that appears in that sentence to read, I think you said --

A. (Witness Bush) 3430.

Q. -- 3430, is that correct?

A. (Witness Bush) Yes, sir.

Q. And does that mean now that you feel it would be prudent to limit surveillance testing to 3430 rather than 3300?

A. (Witness Bush) I guess I mousetrapped myself, didn't I?

No, I believe in my comment to this question and response that I felt that it still would be appropriate to do the surveillance testing at 3300.

Q. If I understand your testimony if the endurance limit is 3430, that would mean that at loads below 3430 you would have no doubt that the crankshaft would have infinite life, isn't that right?

A. (Witness Bush) That's right.

Q. Well if you have no doubt that the crankshaft has infinite life at below 3430, then why would you have any hesitation whatsoever at testing the crankshaft during surveillance testing at 3400 Kw?

A. (Witness Bush) Well I think the basis is the word "prudent." I don't see anything to be accomplished by

going to a higher value.

Q. You don't think that, for example, by testing at 3400 that you would be assured of testing a level that not only included cyclic loads but also included part, if not all, of instrument error or oscillation of the watt meter, is that your testimony?

MR. STROUPE: I am going to object to that question on the basis I don't think that was raised on direct testimony and thus would not be the subject of recross.

JUDGE BRENNER: Well Mr. Dynner has taken it beyond the particular point raised but he is entitled to build on that, as he is building on the question I asked among other things, I suppose, as to the possible apparent discrepancy between the paragraph on page 23 and the other sentence, which I think was on page 17. So I think he is entitled to ask.

For Dr. Bush's benefit, I did not have in mind the limit on the surveillance testing so much as the other facet as to his belief of where the endurance limit was. But nevertheless it is, I think, fair for Mr. Dynner to pursue the point.

WITNESS BUSH: Expressing a personal opinion, I see very little to be accomplished by increasing the kilowatt level under these circumstances.

The units essentially were given a 7 times 10 to the

6 test at 3300 and I feel that raising the surveillance testing value does not accomplish anything of particular worth under these circumstances. Now that's a subjective judgment on my part.

BY MR. DYNNER:

Q. Well you also said in answer to Judge Brenner's question -- I believe it was Judge Brenner's question -- about the 3 times 10 to the 7 cycles during the 40-year life of the plant that you didn't want to test the crankshafts so much as to wear them out and you made some statement about that's what you thought had been done with the original crankshafts.

A. (Witness Bush) If I said that I said it incorrectly. I was concerned with the diesels. The experience has been not that you wear out the crankshafts but that you wear out other components by excessive testing.

I participated when the decisions were made to test on a weekly basis and the results of that became very apparent about three years ago. So I am not just concerned about the crankshafts, I am concerned about what I would call the overall reliability or essentially the literal wearing out of the diesels if you test them to an excessive period.

JUDGE BRENNER: Dr. Bush, help me out. What weekly testing three years ago are you talking about?

WITNESS BUSH: Did I say three years ago? I didn't think I did.

JUDGE BRENNER: What weekly testing are you talking about?

WITNESS BUSH: I'm talking about a report --

JUDGE BRENNER: Are you talking about the Shoreham diesels?

WITNESS BUSH: No, not at all. Let me clarify that.

About 15 years ago the issue came up --

JUDGE BRENNER: Just tell me if you can, it will help me -- if you have to expand, I'll let you but consider whether you have to -- what weekly testing are you talking about?

WITNESS BUSH: That's the testing I'm talking about.

A decision was made some 15 years ago that there would be weekly testing of diesels. There is a NUREG report out that is available and I was reviewing a while ago that clearly indicates that excessive testing of diesels simply results in wear out -- not of crankshafts, things of that nature. And so there has been a tendency to go for lesser time, so that's the reason.

So I am not so much concerned with crankshafts--I don't consider this excessive, incidentally, 1 to 3 times 10 to the 7th is far below what it was when we discussed this in the late-1960's and early-1970's.

BY MR. DYNNER:

Q. Well am I correct then that given your calculation concerning the -- or your analysis concerning the endurance limit being 3430 for the crankshafts that you wouldn't have any concern as to an accumulation of 3 times 10 to the 7 cycles at any level below 3430 Kw with respect to the crankshafts, isn't that right?

A. (Witness Bush) I would simply prefer not to do that.

Q. Why?

A. (Witness Bush) Well that's why there is a fuzzy band around such tests; I wouldn't expect anything to happen but I would see no reason to, shall I say, push one's luck on it.

I could not make a strong case why I would have to do it at 3430, for example, versus 3300 is the only reason.

Q. Is it fair to say that as a conservative scientist that you would prefer to rely as to the certainty of the safety of the crankshafts at 3300 because they have been tested 10 to the 7th at 3300 for sure?

MR. STROUPE: Objection. I think that goes a little far, Judge Brenner, I think that's really leading the witness around pretty badly.

JUDGE BRENNER: Well it's cross-examination, that's your problem --

MR. STROUPE: I understand that.

JUDGE BRENNER: -- that's your problem.

I'll overrule the objection.

WITNESS BUSH: I guess all I could say is I don't see much that could be accomplished by it. Hypothetically one could say you would run into no problems but the closer one comes to the line the more the difficulty is; that's like running a car when you're in the red zone and saying it won't fail, but it might fail tomorrow, too.

BY MR. DYNNER:

Q. So you would prefer to rely on the actual 10 to the 7th testing with respect to the 3300 load, is that right?

A. (Witness Bush) To a major degree, yes. I would accept the experimental evidence. Obviously the combination of the loads--since only 7 times 10 to the 6th is the margin that we have in there but it's a margin that I would just as soon not infringe on too excessively, I guess is a way of looking at it.

Q. Dr. Bush, you were asked by Professor Ferguson a number of questions concerning Figure 2 in Table 1.

A. (Witness Bush) Yes, sir.

Q. And as I understand it -- please correct me if I'm wrong -- Figure 2 is set forth there really to give the shape of the curve for ferritic steels, isn't that correct?

A. (Witness Bush) That's correct.

Q. And it's not supposed to show any particular stress values or cycle values with respect specifically to the Shoreham crankshafts, isn't that right?

A. (Witness Bush) You're quite right. It would have been best to just have a stress scale on there with no values on it.

Q. Now with respect to the Table 1 data, am I correct that it might have been possible if you had, for example, a test bar from the ABS Grade 4-S steel from the 103 crankshaft to conduct a test of that particular material which would give you the actual benchmark for the fatigue limit beginnings as to that particular material, isn't that right?

MR. STROUPE: Objection. I believe, Judge Brenner, that recross goes beyond the scope of any direct examination.

JUDGE BRENNER: No, the Board asked questions about that Table 1 and I think that's what he's probing.

MR. STROUPE: I understand about the table, what he's asking now though I thought was a specific question relating to the test bar of the Shoreham crankshaft which has not been talked about at all.

JUDGE BRENNER: I think it is relevant to the subject I just mentioned.

WITNESS BUSH: I believe I can answer it.

If I could select materials from the appropriate

locations -- which tends to be near the surface and not near the center, because there will be a gradient -- and if I were able to develop rotating beam specimens, in this instance, I could certainly generate a curve -- recognizing that one has to apply considerable discretion in the conversion of that curve to a full structure. But certainly if I could generate 100 or so samples as, for example, I would be able to generate the shape of the curve and, recognizing that because of the size effect I may not get the precise endurance limit, then I would certainly locate it otherwise.

BY MR. DYNNER:

Q And am I correct that by "the size effect" that you are referring to the fact that with respect particularly to shafts that there is a relationship between the fatigue strength and the size of the shafts, isn't that right?

MR. STROUPE: Objection. That was asked and answered with relation to the geometry of the shaft earlier today.

JUDGE BRENNER: I think this may be a different question. We will overrule the objection.

WITNESS BUSH: Size is certainly a factor. We have to recognize that the samples we would use are highly specialized, they tend to be hourglass in shape and they tend to be highly polished, et cetera, and so one has to consider the smaller size and make an appropriate correction

for such conditions as surface and size and stress concentration factors in order to interpret it.

It is possible to do so, it is done in fact.

BY MR. DYNNER:

Q. So that in coming up with this data then, as I understand it, you would have to consider such factors as size, surface condition, stress concentrations as well as things such as the static and alternating loads, isn't that right?

A. (Witness Bush) Yes, that's correct.

Q. And is it also true that there is often considerable variation between different samples of material to one specification, so that in comparing two materials a difference of 10 percent or even 20 percent between the quoted values of fatigue strength may not be significant?

MR. STROUPE: I would object to that question. I don't see the relevancy of that question, frankly.

JUDGE BRENNER: I see the relevancy in going to use of the Table 1 but I think you said something wrong in there, Mr. Dynner, or else maybe I lost the thread. I think you had a "not" at the end and maybe you meant something else.

MR. DYNNER: No, it was supposed to be there.

JUDGE BRENNER: Okay.

WITNESS BUSH: If you could rephrase it, I could at least listen. I was having difficulty there in following

it so maybe I missed something.

MR. DYNNER: Yes.

BY MR. DYNNER:

Q. There is often considerable variation between samples of material to one specification, so that in comparing two materials a difference of 10 percent or even 20 percent between the quoted values of fatigue strength may not be significant.

A. (Witness Bush) I'm not sure that I would say that it wasn't significant. If you are phrasing it in the sense that can it occur, the answer is yes, it can occur.

For example, I could take nominally the same composition of an ABS 4 steel such as we are discussing here and depending on how I did the heat treatment, I could vary the ultimate tensile strength from below 90,000 and probably as high as 110,000 and when I convert that in the context of what the relative endurance limit would be or fatigue strength, that would be mirrored probably in a shift of the range you're talking about; because at 40,000, for example, 10 percent is a difference of 4,000, which would not surprise me under those circumstances.

Q. When you put together Table 1, am I correct that you were just unable to find the relevant kind of information with respect to ABS Grade 4-S steel objects and that's why there's no item on that table that shows the material of

ABS Grade 4-S steel?

A. (Witness Bush) That's true. I picked sources of information that were reasonably available to me. I suspect in order to find the information we are discussing I would have had to go to the Society of Marine Engineers' documents, transactions, which unfortunately is not one of the documents that we carry in our library and, based on the turnaround time -- assuming I even knew where to look in it, which I didn't -- I couldn't have done it.

Now perhaps by going to Crerar I could have done so, but since the purpose of this table was not really to try to tie down ABS 4, I didn't.

I quite frankly didn't even consider that aspect of it, other than I did, indeed, ask my wife to check to see if they had the Society of Marine Engineers' transactions and the answer as I expected was no.

Q. Well in estimating these endurance limits with respect to their effect on the crankshafts, do you agree that in plain carbon steels that the endurance limit usually occurs between 10 to the 5th and 10 to the 7th cycles?

A. (Witness Bush) I would say with that range the answer is yes, I could agree quite unequivocally.

Q. Would you agree that with respect to alloy steels on the other hand, the fatigue limit is less distinct and it may be necessary to continue fatigue tests for longer

endurances?

MR. STROUPE: I am going to object to this, Judge Brenner, unless Mr. Dynner can equate the relevancy of this to the grade steel that is in the Shoreham replacement crankshafts.

JUDGE BRENNER: What's the relevancy?

MR. DYNNER: The relevancy is that what we're talking about is, as I understand it, particular grades of particular steels in Table 1, from which estimates have been made as to the beginning of the fatigue limit using 1 to the 10 to the 6th cycles.

JUDGE BRENNER: But he has testified they are all ferritic steels, if you want to ask him whether that's the case, go ahead, but I thought he already testified to that earlier.

MR. DYNNER: Right. I am getting to this point.

JUDGE BRENNER: Well you see your question is going to be irrelevant unless he is using alloy steels for any bases. If you establish that, then your question would become relevant.

MR. DYNNER: Yes, I am about to try.

JUDGE BRENNER: All right. I guess you have to switch the order then.

We'll sustain the objection.

BY MR. DYNNER:

Q. The information you have given here on Table 1 is with respect to ferritic steels, is that right, ferrite steels?

A. (Witness Bush) Yes, sir.

Q. Isn't ferrite steel an alloy?

A. (Witness Bush) A ferritic steel covers the whole class from plain carbons to very exotic alloy combinations. These represent a very -- an infinitesimally small fraction of such steels.

Q. Yes.

Is the ABS Grade 4-S steel of which the crankshaft is manufactured an alloy steel?

A. (Witness Bush) It has alloy in it. I can probably give you the specific composition.

The answer is it has some alloy in it and so it is a little more than a 10/50 steel and a little less than a 50/50 steel is about what it comes down to.

Q. Would it be generally considered in the profession to be an alloy steel --

A. (Witness Bush) A low alloy steel. There is enough in there that I would consider it in that category, as contrasted to a pure plate in carbon steel.

Q. All right.

And do you agree that with alloy steels the fatigue limit is less distinct and it may be necessary to

continue fatigue tests with longer endurances than the 10 to the 5th and 10 to the 7th that we discussed with respect to the plain carbon steels, as a general proposition?

A. (Witness Bush) I guess I can't interpret that from what I've put in the table because if I take the carbon steels out, I will have some at 1 and 2 and 2-1/2 and .2 and 1 and probably a 1-1/2, and if I look at the range on the alloy steels, I will find a range that will go from about .7 or .6 up to about 2-1/2, so as far as I am concerned there isn't any significant difference in this very small sample.

Q. Yes.

And my question to you was as a general proposition and not confined to this very small sample, is it fair to say that with alloy steels the fatigue limit is less distinct and it may be necessary to continue fatigue tests to longer endurances than for plain carbon steels?

Do you know whether or not that is an accurate general statement?

A. (Witness Bush) No, I wouldn't agree with that.

Now --

Q. Are you familiar -- Go ahead, sorry.

You wanted to add something?

A. (Witness Bush) I was simply going to say that by "less distinct," I would have to interpret that as

the fact that they might be shifted further and therefore that the location as such.

But so far as I am concerned whether I have an alloy steel or whether I have a plain carbon steel, I would expect to see pretty much similar behavior with regard to the S-N portion, the slanted portion, and the endurance limit.

Q. Are you familiar with Forrest's work entitled "Fatigue of Metals?"

A. (Witness Bush) I don't recognize it as such.

Q. You don't recognize that?

A. (Witness Bush) No, not that particular reference.

Q. Do you recognize Professor Forrest's name, P.G. Forrest?

A. (Witness Bush) No.

Q. Aside from the work that you have done in compiling Table 1, have you done any other analysis of the fatigue limits of alloy steels or are you just relying on the cumulation of data in Table 1 for your conclusions?

A. (Witness Bush) Let me try to answer as I interpret your question.

Now you're asking have I actually conducted fatigue tests, is that what you're --

Q. No. I'm just asking whether your conclusions in this testimony are based solely upon the data that you have accumulated in Table 1 or whether there are other endurance

limits that you are aware of for alloy steels that you have not referred to --

A. (Witness Bush) Oh yes, I misunderstood.

These are something that I was able to collect in about 30 minutes. I simply took this off the shelf of my own personal library and simply by leafing through the pages came up with these values and after I got so many I decided to stop and then that was the basis.

I could find many more, for example, I know if I went to the British Welding Institute, for example, I could find a lot of data but I was only trying to make one point and that's why I stopped.

Q. But you are relying for your testimony only on these particular data, is that correct?

A. (Witness Bush) I used these data basically to indicate that the values tended to hover around 1 times 10 to the 6th, that's true.

Q. And range in fact from, as I read your table, a low of .2 times 10 to the 6th to a high of about 3 times 10 to the 6th, isn't that right?

A. (Witness Bush) That's right.

MR. DYNNER: No further questions.

JUDGE MORRIS: Dr. Bush, I think you mentioned you could give the content of the ABS steel. Do you have it handy?

WITNESS BUSH: I have it and I can indeed get it,

but I would have to look through a few pieces of paper in the process. If you wouldn't mind my doing that, I'll do it and if you have other questions I will try to find it.

JUDGE MORRIS: Thank you.

JUDGE BRENNER: All right. We do want to get that for the record. Let's see if we have other questions meanwhile. The Board has nothing further.

Staff?

(Counsel conferring.)

JUDGE BRENNER: Do you have questions?

MR. GODDARD: Yes, I do.

JUDGE BRENNER: How much do you have?

MR. GODDARD: About two questions. I am just waiting for Dr. Bush to finish what he is doing.

JUDGE BRENNER: Well that's going to be my next --

FURTHER REDIRECT EXAMINATION

BY MR. GODDARD:

Q. Dr. Bush.

A. (Witness Bush) Yes, sir.

JUDGE BRENNER: Wait a minute.

If we give you another minute or two would you find it now or would you prefer we gave you more --

WITNESS BUSH: If you wouldn't mind I know I can find it but it may take me a little longer than just sitting up here.

JUDGE BRENNER: All right.

Maybe we could get it first thing in the morning.

WITNESS BUSH: Certainly in the morning I can have it. I don't think I can put my hands on it immediately.

JUDGE BRENNER: All right. We'll get that first thing in the morning.

Mr. Goddard.

MR. GODDARD: Thank you, Judge Brenner.

BY MR. GODDARD:

Q. Dr. Bush, following up on a question which Mr. Dynner asked and based upon your experience, do you believe that using a large sampling of ferrite steels than that contained in Table 1 would affect your conclusion regarding the location of the endurance limits for ferrite steels?

A. (Witness Bush) No, sir, I think they will tend to cluster around 1 times 10 to the 6th. That has been cited in a number of texts and I was simply trying to validate that by going on a random basis, picking out some samples -- or not quite random, going to what I had available.

Obviously one factor is that the band might become a little wider but I don't think it would become much wider.

MR. GODDARD: Staff has no further questions.

JUDGE BRENNER: Mr. Stroupe?

MR. STROUPE: I have no further questions, Judge Brenner.

I do have a proposal I would like to present to the Board at the appropriate time.

JUDGE BRENNER: All right. It depends on what the proposal is. Maybe the time would never be appropriate.

(Laughter.)

JUDGE BRENNER: No, I'll give you the chance.

Mr. Dynner, do you have anything based on those two questions?

MR. DYNNER: Nothing further, sir.

JUDGE BRENNER: All right.

Let us dismiss the panel in their present capacity as the witnesses on the crankshaft. You will be reincarnated soon as the panel on the blocks.

We will get the content of the ABS -- I guess it is .4S steel, I guess more particularly the content of the steel that is actually used in the crankshaft--

(The Board conferring.)

JUDGE BRENNER: We will get that tomorrow morning, and we can take it from Dr. Bush from wherever he happens to be seated in the courtroom. I don't think there would be follow-up questions based on that. We just want to establish

it for the record.

And when he gives it, you know, specify whether you're talking about the content of general ABS Grade 4S steel or the particular content of the steel for this crankshaft, of if they are wholly the same, tell us that, too.

All right. And the witnesses can be excused for now. Thank you for your time on this subject, and we look forward to your time on the other subject.

MR. GODDARD: Judge Brenner, excuse me. Mr. Henriksen is in fact not a sponsor of any of our testimony on the blocks. Accordingly, if there is any party that sees any reason that Mr. Henriksen should not be permanently excused at this point, assuming the Board has no objection--

JUDGE BRENNER: I'm sorry, I just thought he was involved on the block. I didn't draw the distinction because his name is on the testimony.

Everything in the testimony relating to the blocks is now solely sponsored by Dr. Bush?

MR. GODDARD: That's correct.

JUDGE BRENNER: Well, Mr. Henriksen, you get away qhicker than I thought you were going to get away. Thank you a gain for being here. I am sure you will enjoy flying back to the lovely spring snows in your part of the country.

(Witness Henriksen excused; Dr. Bush

temporarily excused.)

JUDGE BRENNER: All right, you had a proposal.

MR. STROUPE: Judge Brenner, what I was going to propose is-- I have mentioned this already to Mr. Dynner and to the Staff. There seems to be some confusion and some concern as I interpreted what has transpired today about the stresses between 3800 kw and 3300 kw as opposed to 3300 and 3500 kw.

We have in the courtroom, seated to my right, Dr. Paul Johnston who is intimately familiar with these stresses and I would offer him up for purposes of providing testimony on that very subject, and in addition to that subject, on the subject of the tensile stresses which Dr. Bush referred to in response to a question of Judge Ferguson from the Stone and Webster report which he is also intimately familiar with.

JUDGE BRENNER: Have you discussed with with the parties?

MR. STROUPE: I indicated to the parties that I was going to make that proposal. I was told by Mr. Dynner he would oppose it. I was told by the Staff that they would I believe not oppose it.

JUDGE BRENNER: Mr. Dynner?

MR. DYNNER: Yes, I would strongly object to the introduction of a new witness on a new topic. The reason why we have prefiled testimony is to give the parties a chance to

read what a witness has to say and prepare adequately for cross-examination.

The crankshafts have been known to be at issue for a long time. LILCO had its panel. They chose not to put Dr. Johnston on their panel which Dr. Pischinger was on. And I think at this late date to come out, hopefully when we are at the end of the day and at the end of the crankshafts, with a new and unknown -- some new and unknown testimony would radically depart from the regulations and the Board procedures.

For that reason I would strongly oppose it.

JUDGE BRENNER: All right.

Staff, why don't you tell us your position, and then explain, if it is what Mr. Stroupe said it is, why it is valid in light of Mr. Dynner's objection.

MR. GODDARD: Inasmuch as Dr. Bush did not deal in any degree with the tensile strengths which were here involved, Staff has no objection to Dr. Johnston taking the stand for the purpose of discussing this aspect of the stresses in the FaAA report.

The Staff, as the Board and all parties know, would have been able to fill in a few of the gaps in the Staff testimony had Professor Sarsten been able to testify here. Accordingly, this is data which might have been covered.

Mr. Dynner appeared to be focusing on this point, and I think some of the Board questions dealt with it.

Dr. Bush was perhaps not the most appropriate witness to deal with this matter, and to the extent that Dr. Johnston is here and that his testimony would not unduly expand this record, the Staff would not oppose its introduction at this time.

JUDGE BRENNER: What about Mr. Dynner's objection?

MR. GODDARD: On the basis of it not being prefiled?

JUDGE BRENNER: It is new testimony this late in the day, not being prefiled or known to him prior to close to this time.

MR. GODDARD: Tbe Staff is not of the position that it is new testimony. There has been ample discussion of these stresses in the testimony previously given, albeit at different power levels. To the extent that it is complementary to the testimony of Dr. Bush and the cross-examination today, the Staff would not oppose it.

JUDGE BRENNER: You are talking about the stresses measured during this endurance run. Correct?

MR. STROUPE: No, that is not correct, Judge Brenner. Basically what I'm talking about is the nominal stresses and the measured stresses, both of which have been talked about in previous testimony in terms of perhaps some figures.

I know we have testimony with regard to 33 and 35. I don't think there is any testimony on the 28 because, frankly, no one anticipated, at least for LILCO's purposes, that that would be the subject of any discussion.

I don't believe to call this testimony new testimony is really accurate.

MR. DYNNER: I've got two more objections, that being the clarification, and I won't make them unless you feel it's necessary for me to.

JUDGE BRENNER: I wanted to confer with my colleagues so maybe you had better make them, and keep it short.

MR. DYNNER: Short.

Well, given what Mr. Stroupe has said, there are two additional objections. One is that that material is now outside of the scope. If what he is talking about is measurements that were made previously, it is not within the scope of this hearing which was supposed to have dealt with the newly developed information from the endurance run and the testing.

And the second point and objection I want to make is that the only issue in which this matter came up was in an examination of the bases for Dr. Bush's calculations. What I was exploring was what Dr. Bush thought and what Dr. Bush based his analysis on. And it is not really relevant as to whether Dr. Johnston thinks that those numbers are different or not.

We would be merely exploring the bases for Dr. Bush's analysis. So that's an objection as to relevancy

as well.

MR. STROUPE: Judge Brenner, if I may?

JUDGE BRENNER: All right.

Let me get one or two facts because I am confused on one or two things. I don't know if they will be material to the ruling or not.

One of the things Dr. Bush referred to was the report of the endurance run which I thought he said contained some of the measured stress values. That's a document that we've had in our possession, although it is not in evidence, for quite a while. I think it is dated December or January.

That is not what you are talking about, Mr. Stroupe?

MR. STROUPE: Judge Brenner, that is not what we are talking about.

JUDGE BRENNER: All right.

MR. STROUPE: Actually it is test data from January of 1984, and frankly, I don't think that we could have anticipated that it was going to become a question until Mr. Dynner's cross-examination of Dr. Bush.

JUDGE BRENNER: When you say it is test data from 1984, what you want to put on as evidence now is test data from 1984?

MR. STROUPE: Yes. I would like to have Dr. Johnston testify as to whether or not the stresses from 2800 kw really to 3900 kw are indeed linear as was postulated

today.

JUDGE BRENNER: Mr. Dynner, let me ask you a question. I don't know if it has been raised by the parties but it's been on my mind. I guess Mr. Goddard did allude to it.

What about the potential argument that if Professor Sarsten had been here as everyone expected up until his death -- and we learned about it on Thursday; I'm not sure when it occurred, but obviously of course in that timeframe -- that at least potentially there would have been a witness on the Staff panel with Dr. Bush who could have told us a little more about some of those things Dr. Bush was relying on?

From time to time Dr. Bush did try to say he had certain impressions as to what Professor Sarsten would think were he here, and of course we couldn't accept that testimony, and that adds to the potential problem.

MR. DYNNER: I think it is sheer folly to try to speculate on what Professor Sarsten may or may not have said.

JUDGE BRENNER: We are not going to do that.

MR. DYNNER: I think in terms of information that he might have furnished, he might have also furnished information and opinions that differed markedly with what Dr. Bush's opinions are and what his analyses were because I noted, and I am sure everyone noted that Dr. Bush's testimony

was not always supported by Professor Sarsten as a co-author. And they were only in discrete places.

And unfortunately we were all deprived of the ability to hear what Professor Sarsten might have said. But I certainly don't think it is fair to allow a completely different witness from a different party to come on now with new testimony that I don't have any idea what he is going to say--

JUDGE BRENNER: Well, what if we didn't let him come on now, but let them put together some proposed rebuttal very quickly for us to look at, and then make the decision?

MR. DYNNER: Well, for the two other reasons I've stated, I can't imagine that it has any relevancy. As I said, the only way that this issue came up was in exploring what the bases were for Dr. Bush's analysis. And somebody now is presumably going to come on and put in stuff that is either going to say that Dr. Bush was right or wrong or mistaken or he should have looked at this or he should have looked at that. And I just don't think that's relevant.

The record stands with what Dr. Bush relied upon, and I think it is pretty clear.

MR. STROUPE: Judge Brenner, it is not our intent to say what Dr. Bush should have looked at or should not have looked at. All we wish to do in a very short period of time, two or three questions, which I think we could certainly put

together tonight and have ready tomorrow morning in written form which would clear up this problem that the Board has raised about what happens between 3300 kw and 3500 kw, if anything, that would affect whether the crankshaft is good at 3500 since the parties in effect have agreed it is good at 33.

I think we can do that succinctly and quickly, and frankly I believe it would be in the public interest to allow that testimony.

end 19

MR. DYNNER: I would object more strongly if that's the purpose, because he has already --

JUDGE BRENNER: Mr. Dynner, I think we've got the drift of the parties' positions and the bases for it.

(The Board conferring.)

JUDGE BRENNER: We are going to sustain the objection to your proposal, Mr. Stroupe. We cannot consider it legitimate rebuttal, because it does not rebut any points. We agree with Mr. Dynner that the context of the evidence given by the Staff in the questions asked of Dr. Bush is: just what did he use to reach his conclusions? And we have got ample testimony on that. To the extent that he pointed to other things that he used, it is his understanding of what he used, and why, that is important.

It is also not legitimate for LILCO to suggest that it could not have anticipated that the sensitivity of actual stress measurements at different points, to the extent they are not already in the record, wouldn't have been pertinent. We emphasized that we were interested in the sensitivity over the range of load values that might be pertinent in the qualified load context should be put in. I've said this before, in other contexts. We were careful not to specify 3300, both in our written order reopening the record and in our oral ruling which preceded that written order.

And we expected to see the sensitivity. Frankly,

speaking for myself, I was a little surprised that we did not get testimony from LILCO that matched up all the calculations and measured values we had seen at 3500 with the lower values to show us what the sensitivity might have been.

So it would have been reasonable and appropriate to include any values not already in the record at loads of interest, in the testimony. If it's already in the record, you've got it to cite to us in findings, as I've also indicated. And if it's not in the record, you could have put it there. You can't legitimately tie it to any need for rebuttal based on testimony we've now had.

To the extent you mentioned the values at 2800, we have doubts as to the relevance or materiality down at that load level, although I'm not ruling that if you have chosen to put that into your prefiled testimony we would have found it irrelevant. I don't know.

So that's where we stand. If you want to put testimony together and submit it as an offer of proof, you can do that. But you don't have to. But you have that right. Or you could stand on your comments already indicating what you would have put in, which I think is probably already well described in the record.

MR. STROUPE: We'll stand on our comments.

JUDGE BRENNER: I'm sorry; you two could have left any time you wanted to. Of course, you don't have to. But I

meant to excuse you.

Is there any point in swearing witnesses in now?

MR. STROUPE: Judge Brenner, I wonder if we might take up two other things?

JUDGE BRENNER: All right. Let's decide first that we will swear in LILCO's block witnesses first thing tomorrow morning rather than at ten to five today.

MR. STROUPE: All right.

JUDGE BRENNER: Fine.

MR. STROUPE: You inquired of the parties as to a findings schedule, I believe, last week or two weeks ago and again this week --

JUDGE BRENNER: The parties told me they were going to give us a proposal during the interim week, but they did not.

MR. STROUPE: We have, indeed -- at least, the County and LILCO has spoken, and the Staff, too, I believe. And I think we are in agreement that we would be perfectly content with LILCO's findings due on April 4, and the County's findings due, I guess, ten days thereafter, is what the requirement is, with the Staff's findings due within the period of whatever is prescribed thereafter. I think that's probably a week, seven days more than you indicated in Bethesda that you were thinking about. But I'm not sure we all contemplated we would be going this long, either.

JUDGE BRENNER: Well, that's reasonably consistent with the schedule we were thinking about then. I said there would be some variability. It happens I have several alternatives written down here because I thought the parties were going to have a dispute, since we didn't have an agreement. I can tell you that the scatter in the data between your agreement and my variations is very slight; and so, by whatever method, we ended up with just about the same schedule.

I'll lay out the rest of the schedule, if that's what you're asking me to do. I'll take a look at whether they fall on weekends or not.

MR. STROUPE: The second thing, I think --

JUDGE BRENNER: Think about page limitations, if you haven't already.

MR. STROUPE: The last time I thought about page limitations, I think I was substantially off. I think I can give you a better estimate this time.

JUDGE BRENNER: Think about two digits; and, in fact, not even terribly close to exceeding two digits.

MR. STROUPE: I think Mr. Ellis is now ready to address to the Board the question of the cam gallery settlement.

MR. ELLIS: Judge, there is a resolution, of course, as we have discussed. I think what remains that there isn't

entire agreement on is language.

I don't think the lack of agreement is anything of substance, and I don't quite understand why there is a lack of agreement. But I think all that matters to me -- and I'm going to show you what the language is that the parties have discussed --

JUDGE BRENNER: But wait. You haven't agreed on it?

MR. ELLIS: We have agreed on it. It is the legal effect that we have not agreed upon.

We have agreed on the technical aspects. And, essentially, what I have put down here is this resolves the cam gallery aspects of the diesel generator block contention. And Mr. Dynner would prefer not to say that, and instead to say that it resolves the issue of monitoring the cam gallery cracks, and that no findings will be made regarding the cam gallery cracks.

JUDGE BRENNER: All right.

I'll tell you what. We will accept both of those descriptions.

MR. ELLIS: That's exactly what we've got, Judge.

JUDGE BRENNER: And when all this is over, or when I'm less tired, Mr. Dynner will explain the significance of that difference to me. And he can also explain the significance of one of the County's motions to strike, which arguably was related to that, too.

(Documents handed to the Board.)

MR. ELLIS: What I have handed the Board is a single sheet, and it is entitled "Resolution of Cam Gallery Monitoring Issue". The material that appears in parentheses is the material that I had proposed. The material that is underscored is the material that Mr. Dynner believes is appropriate in lieu of the material in parentheses.

We have no objection to the material that is underscored. However, we do think that it ought to be clear that the cam gallery aspect of the diesel generator block litigation is resolved and effectively withdrawn. And we do think that it is a resolution of the cam gallery monitoring issue --

JUDGE BRENNER: Just to show you how important the rest of it is, I am only going to read the essential paragraphs and decide whether that's acceptable or not and, without reading, on blind faith, based on what you've told me, accept the rest of it in the record as the parties' own individual explanations of what they think they're doing -- what they think the legal effect is of what they're doing.

End AGB20
AGB21

I hate to ask a question, now that you all have this fine agreement. What about covering the point that if the 30 hours trigger -- maybe I'm tired, maybe it's already in the language. If the 30 hours triggers the inspection, did you cover the point that the three months then begins to

run again?

MR. ELLIS: No, sir. We did not cover that explicitly. We believe that is clearly understood by the parties, and we just assumed that the more language we insert, the more opportunities for dispute. And we do understand that if there is an inspection triggered by the 30 hours, the three months would begin to run from that inspection rather than the previous calendar inspection.

JUDGE BRENNER: All right.

Mr. Dynner, do you have any problem with what Mr. Ellis has said, the last part?

MR. DYNNER: No. It's on the record, I think, and I agree with it.

JUDGE BRENNER: All right. Fine.

Notwithstanding the parties' zeal, we will commend them for the substance of their agreement, and bind it into the -- let's just bind into the transcript at this point; and that way it'll be easily accessible. And nothing further need be done on it with respect to the proposed findings, including the actual language of the inspection requirements. And, obviously, the parties will see to it that it is given proper effect wherever it should be, be it in the tech specs or somewhere else, so that any license that may ever hereafter issue based on this...

(The document follows.)

(RESOLUTION OF CAM GALLERY MONITORING ISSUE)

(Pursuant to the resolution of the cam gallery aspect of the diesel generator block contention, the following is agreed to by and between the parties:)

The parties have resolved the issue of monitoring the cam gallery cracks in the blocks as follows:

Cam gallery saddle locations nos. 2 and 8 on the EDG 101 and 102 blocks will be inspected by LILCO every three months, or after 30 hours of operation at or above a load of 1800 KW, whichever comes first. These inspections will be performed from the time the EDGs are initially placed in operation for emergency standby service until the first refueling outage. Liquid penetrant examinations of the nos. 2 and 8 saddle locations will be performed to monitor the length of the cracks, followed by TSI depth gauge measurements of the cracks to monitor their depth.

The parties confirm that no findings will be made regarding the cam gallery cracks in the blocks, given the Stipulation of January 14, 1985, and the foregoing resolution of the monitoring issue.

(As a result of this inspection commitment by LILCO, Suffolk County, New York State and the NRC Staff agree that the cam gallery aspect of the diesel generator block contention is resolved and therefore withdrawn.)

All right. Why is it on important subjects you're able to get over the problems of language, and on relatively unimportant disputes you stand by problems in language? I don't know. I suppose that --

MR. DYNNER: Better than the reverse.

JUDGE BRENNER: Yes. I was just going to say the former more than makes up for the latter, and that's why I'm able to smile about this, because this has not been typical behavior of the parties.

Can we adjourn for the day, now?

MR. ELLIS: Yes, sir.

JUDGE BRENNER: All right. Let's do that, and resume at nine o'clock tomorrow. We will adjourn at approximately noon tomorrow.

(Whereupon, at 4:57 p.m., the hearing in the above-entitled matter was adjourned, to reconvene at 9:00 a.m. the following day.)

End AGB21

CERTIFICATE OF OFFICIAL REPORTER

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

NAME OF PROCEEDING: LONG ISLAND LIGHTING COMPANY

(Shoreham Nuclear Power Station)

DOCKET NO.: 50-322-OL

PLACE: HAUPPAUGE, NEW YORK

DATE: THURSDAY, MARCH 7, 1985

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(sigt) William R. Bloom

(TYPED)

WILLIAM R. BLOOM

Official Reporter

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(sigt) Anne G. Bloom

(TYPED)

ANNE G. BLOOM

Official Reporter

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