ORIGINAL

UNITED STATES
NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF:

LONG ISLAND LIGHTING COMPANY

(Shoreham Nuclear Power Station)

DOCKET NO: 50-322-1 (OL)

LOCATION: HAUPPAUGE, NEW YORK

PAGES: 26273 - 26443

DATE: TUESDAY, NOVEMBER 13, 1984

TR-01/01
Additional 2 copies to ASLAB, E/W-439

ACE-FEDERAL REPORTERS, INC.

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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In the matter of: :

LONG ISLAND LIGHTING COMPANY : Docket No. 50-322-1 (OL)

(Shoreham Nuclear Power Station): :

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State Office Building,

Veterans Memorial Highway,

Hauppauge, New York.

Tuesday, November 13, 1984

The hearing in the above-entitled matter was reconvened, pursuant to adjournment, at 10:30 a.m.

BEFORE:

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

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

JUDGE GEORGE A. FERGUSON, Member,
Atomic Safety and Licensing Board.
(Not present.)

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APPEARANCES:

On behalf of the Applicant:

TIM ELLIS, Esq.
Hunton and Williams
700 East Main Street,
Richmond, Virginia 23219

On behalf of the Nuclear Regulatory Commission Staff:

ROBERT G. PERLIS, Esq.
Office of the Executive Legal Director

On behalf of Intervenor Suffolk County:

ALAN ROY DYNNER, Esq.
JOSEPH J. BRIGATI, Esq.,
Kirkpatrick, Lockhart, Hill, Christopher and Phillips,
1900 M Street, N. W.,
Washington, D. C. 20036

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C O N T E N T S

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		Id.	Evd.
1	EXHIBITS		
2	Suffolk County Exhibit 7:	26328	
3	Design Review of TDI R-4 and RV-4 Series		
4	Emergency Diesel Generator Cylinder		
5	Blocks and Liners, by FaAA		
6			
7	Lilco Diesel Exhibit B-60	26336	
8	"Preliminary Cam Gallery Strain		
9	Gage Data"		
10			
11	DOCUMENTS INSERTED:		
12	Rebuttal Testimony of Dr. Robert N. Anderson,		26326
13	Professor Stanley G. Christensen and		
14	G. Dennis Eley		
15			
16	Volume 4, Cylinder Block Exhibits		26328
17			
18			
19			
20			
21			
22			
23			
24	Luncheon Recess - 26320		
25	Afternoon Recess - 26379; 26426		

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PROCEEDINGS

JUDGE BRENNER: Good morning.

We have come to the point of follow-up examination of the Staff's Witness Panel on Blocks. As we stated at the time of recess last Friday, we expect such follow-up to be just that, not a rehash of all the testimony we have heard. And we expect it to move expeditiously in light of that goal.

Mr. Ellis, you may begin.

MR. ELLIS: I take it you don't want any preliminary matters.

JUDGE BRENNER: That's right.

MR. ELLIS: When will we get an opportunity for that?

JUDGE BRENNER: After the lunch break, or perhaps before the lunch break, if you think it is something we will need to deliberate. But let's proceed with the witnesses for now.

Whereupon,

SPENCER H. BUSH,

ADAM J. HENRIKSEN,

and

CARL H. BERLINGER

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

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RECROSS-EXAMINATION (Continued)

BY MR. ELLIS:

Q Dr. Berlinger, you were asked about inspections for circumferential cracks in the 101 and the 102 blocks.

You are aware, are you not, that a UT inspection method that was shown to be effective in detecting circumferential cracks in the old 103 was applied to the 101 block? Are you aware of that?

A (Witness Berlinger) Yes, Mr. Ellis, I am.

Q And that no cracks or indications were found. Is that correct?

A That's correct.

Q And on the issue of circumferential cracks, Dr. Bush, you told Judge Morris that you were not aware of any finite element analysis.

In your review of the transcript, particularly of pages 25,341 to 345, did you refresh your recollection that in fact there was two-dimensional and three-dimensional finite element analysis performed with respect to the circumferential cracks?

A (Witness Bush) Will you give me those pages again?

Q Yes, sir. 25,341 through 345.

A Well, if I have it I'm not aware of it, to tell the truth. I remember the oral discussion of it, but-- Are

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you citing that there was an actual physical write-up of this?

Q I'm asking you j st whether you were aware that such an analysis was performed.

A I have not seen the analysis.

Q And I take it you have not felt the need to see it because of your opinion that it is not necessary, as you testified in your supplemental testimony?

A I do not consider that as a major item of concern; that's correct.

Q Dr. Bush, you were asked a number of questions by Judge Morris concerning the origin of the cam gallery cracks.

It is still your opinion, isn't it, that the cam gallery cracks are process or hot tear cracks?

A That's correct.

Q And you would disagree with Dr. Anderson's opinion that the cracks propagated as a result of operation, wouldn't you?

A Yes.

Q So when you indicated to Dr. Morris that you could not agree or disagree on that in that area, you were referring only to whether the repair weld cracks were surface or subsurface defects. Is that correct?

A I have a semantic problem with that question.

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Could you rephrase it for me, please?

Q Yes, sir.

I take it that when you indicated you could not disagree or agree with Dr. Anderson, you were referring only to whether the repair weld cracks were surface or subsurface defects in the cam gallery area?

A That question to me means we are talking exclusively of the cracks that are related to the repair weld I'm not quite sure that's what you mean. That's why I have a semantic problem. I will answer it in that context.

That is that I am convinced that the cracks on the heat side of the repair weld are undoubtedly related to the fabrication of the weld per se. If you are considering the possibility that there is a crack below the repair weld that had not been removed completely prior to the welding, I feel that that exists -- that that condition existed also.

Q Am I correct, Dr. Bush, that in the pieces in the photomicrographs you examined there was no evidence of subsurface crack initiation in the cam gallery area?

A I was unable to detect any. However, I recognize that those photomicrographs might not be the most definitive in that respect. You might require another set.

Q In response to Judge Morris' questions, you indicated that high tensile stresses would develop even in

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iron-nickel weld rods -- if iron-nickel weld rods were used.

A That's correct.

Q Isn't it also true that there would be balancing compressive residual stresses beneath the weld which would prevent crack growth of a process crack even if it extended to that depth?

A So long as the region around the weld doesn't crack, that would be the case.

Q Even if the weld cracks, won't the stresses below the welds still be compressive?

A The answer is not necessarily. If I get complete cracking along one side of the weld, I can get a relief in that circumstance, and unless I am partly pinned, in other words, if the crack is not-- If the crack approximates 180 degrees, so to speak, then I'd say no.

Otherwise, I would say yes, there would probably be residual compressive stresses remaining.

Q Dr. Bush, given your view that the cam gallery cracks are process or hot tear cracks, I take it it is also your opinion that the 15 mill indications found in the new 103 cam gallery block are also of that nature.

A That may not be the case. There might be sufficient residual stress from the casting process that they could have cracked. Since I have seen no cross-sections of them so that I could identify the presence

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or absence of any films, I could not unequivocally establish whether these are hot tears or they might have been delayed cracking due to residual stresses. I simply don't know.

Q Is it your opinion that it is more probable than not, however, that they are process?

A I would say they are process-related. I simply don't have enough evidence to indicate whether they are hot tears. That's my only comment in that respect.

Q In response to Judge Morris' question that if graphitic corrosion were occurring in the cam gallery it would occur all over, you said you could not say whether that occurred in the painted areas.

It is true, isn't it, that there are many unpainted areas on the cam shaft and cam shaft bearings which were bright and shiny and showed no corrosion?

A You're talking about the cam shaft and that's not the same material, as I recall.

Now if you want to discuss the top of the block or something of that nature which I know is not painted, that would be a more significant type of thing because if one assumes that oxygen as such as responsible for the graphitic corrosion which can occur but usually doesn't, then one would have to argue that under those circumstances machined areas exposed to oxygen and some degree of

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temperature should display the same type of graphitic corrosion. To my knowledge this has not been the case.

Q If you had graphitic corrosion here you would expect the corrosion product to be a sulfide rather than an oxide, wouldn't you?

A Not necessarily. Graphitic corrosion, when tied to underground material, is usually a sulfide-related product. That's because of anaerobic material.

You can generate graphitic corrosion in certain acidic solutions, hydrochloric, certain concentrations of sulfuric acids, possibly nitric acids. I don't know of the presence of any of these. What you do with any of these solutions is selectively leach out the metal leaving the graphite behind.

If one argues that the environment is the same in a variety of locations in the block then one must understand why it occurs in one location and not in another, and I have not been able to figure that one out.

JUDGE BRENNER: I'm sorry, I just lost the train of that answer, Dr. Bush. It is probably my fault.

Can graphitic corrosion be an oxide in the circumstances we have here?

WITNESS BUSH: Well, graphitic corrosion is selective removal of the material leaving the graphite behind. The product itself might well be an oxide -- that's

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correct -- of the metal under these circumstances. But generally it would be some other kind of a compound if you are going to leach away or remove the material.

But you cannot rule out the possibility of an oxide. That is true.

BY MR. ELLIS:

Q But it would be more likely that it would be a sulfide. Is that your view?

A (Witness Bush) I'm sorry, I used an analogy of areas where I am most familiar with it, and I am sure we do not have anaerobic bacteria in these locations which is normally how you would chew this one up.

When you have the sulfide product, it is usually when you bury a pipe in very heavy clays, moist clays, and the anaerobic bacteria literally eat away all of the metal, leaving the graphite behind. That is a very specialized case that has occurred and is cited in Fontana's book as a for-instance. I do not think we have that condition here.

I was using the analogy of that's where you most commonly run into it, or one of the more common methods of running into it.

Q I take it you are aware that FaAA did a microprobe analysis to confirm that the layer was an oxide layer.

A I have heard that in there. I have not seen the

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specific run that identifies the constituents.

Q Would you consider that generally supportive of your conclusion that graphitic corrosion did not occur in this instance?

A Well, from a somewhat different point of view. I would have expected there to be oxides present, so I am answering your question indirectly.

Q Dr. Bush, my notes indicate that Mr. Dynner asked you a question in which he suggested there were two specimens and replicas relating to the cam gallery.

Did you have an opportunity to review transcript pages 24,738 and 39 which reflect the samples that were taken from the block top?

A If there were the ones that I believe they are, this was a statement by Dr. Wachob with regard to samples taken from each of the blocks at the locations, and as I understand there were four sites, one of which was a replica.

I have also read that there were several replicas. That was another source. So I can only go on the basis of what I read on these particular pages as to what is correct. So I presume this is the case.

Q Are those the samples and the locations that you had in mind in connection with your testimony that the samples were sufficient to enable you to reach the opinion

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that the 101 and 102 blocks had superior physical properties to those of the original 103 block?

MR. BRIGATI: Objection to the characterization of the witness' testimony.

JUDGE BRENNER: Overruled.

WITNESS BUSH: I had thought that there were a few more replicas, quite frankly, than are here. I would say that we have what amounts to six samples from two blocks compared to a large number from the third block.

The microstructures certainly were definitely different in the six samples contrasted to the ones from the old 103 block.

BY MR. ELLIS:

Q And you are aware there were ten replicas from each?

A (Witness Bush) That is a confusing issue. I have read the number ten replicas. I have also read the number one replica per block. And quite frankly, since I haven't seen all of the various runs, I do not know which number is correct.

Q Have you seen enough to satisfy you on the opinion that you reached and testified to earlier concerning the 101 and 102 blocks having superior physical properties to those of the original 103 block?

A I consider that there is a very definite

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difference in there, and whereas the sample is less significant statistically than I thought, I would still abide by my original statement.

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Q Do you know how far away the circumferential area is from the block top? About an inch and a half: does that sound right to you?

A Would you mind defining what you mean by "circumferential area" in this circumstance?

Q Yes, sir, I'm sorry: the area in which the circumferential cracking was found in the old 103 block.

Maybe, Dr. Berlinger, can you help? Is that about an inch and a half away from where these samples were taken?

A (Witness Berlinger) Yes. I believe it's an inch and a half from the block top surface.

Q Given that, Dr. Bush, would you also agree that the samples would also be representative of the regions where the circumferential cracks were detected in the old 103 block?

A (Witness Bush) I would assume so, yes. The difference, under the circumstances, and in the lack of positive evidence as to how they placed the cores, I would not expect to see that much difference from one location to the other, recognizing that we don't have very much information about that aspect.

Q Dr. Bush, you were asked a number of questions by Mr. Dynner concerning the length of time it might take a stud-to-stud crack initiating at the counterbore to

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propagate to the surface. I take it you took that possibility into account in reaching your conclusion that the 101, 102 and new 103 blocks are suitable for nuclear service with respect to ligament or stud-to-stud cracks, provided that eddy current inspection is performed after operation to confirm the absence of stud-to-stud cracks?

A If I said that, I didn't mean to, and I thought the record was clear. I indicated that I considered the possibility of ligament cracks initiating in the counterbore region couldn't be ruled out. I didn't say unequivocally that's where it occurred. I thought that I indicated that with regard to the stud-to-stud situation it is not the same at all, and it might well have initiated at the upper corner, as contrasted to the counterbore. That's what I believe I testified to.

Q So that you consider that the stud-to-stud crack initiation is far more likely at the block top?

A I would think so, yes.

Q Dr. Bush, you were asked a number of questions by Mr. Dynner about the Goodman diagrams, B-49 and B-50.

A Yes, sir.

Q You're aware, aren't you, that the inspections of the cam gallery area -- I beg your pardon, of the block top area indicate that there are not ligament cracks at every stud hole?

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A Yes, I'm aware of that.

Q And, in addition, that these inspections, as you know, reflect that there is no stud-to-stud cracks reported on either the 101 or 102 despite operation with ligament cracks; is that correct?

A Yes.

Q Would you agree that this confirms that the analysis reflected in the Goodman diagrams is based on conservatisms in both scale factors and materials properties?

A That could account for the fact of the -- or, the absence of the cracks.

Q And you're aware that FaAA did testify to these conservatisms at transcript 24,648 through 52?

A I have read that testimony, and I'm aware that they did, yes.

Q Based on your review of that, and on your knowledge of the physical evidence, then would you agree that the Goodman diagrams do, in fact, reflect a conservative analysis?

A I have considerable difficulty with the Goodman diagrams, because even if the properties are conservative, namely, that the ultimate tensile strengths, for example, are higher, the impact of that in the shifting of the line positions on the Goodman diagram is second order because

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the lines are quite close to the horizontal axis; and, whereas I could understand it clearly with regard to the Goodman diagrams that were presented initially in the June report by failure analysis, and I think I understood it to a degree with the second set, I must confess I still do not understand the values on the official attachments to the transcript.

Q You would agree, though, wouldn't you, that the Goodman diagrams reflect a conservative or very pessimistic view, because what they predict has certainly not occurred?

A You are most certainly correct there. I would, by looking at those values and their position, I would have to infer cracking in almost no cycles, because I am well above the mean stress level for this material. Therefore, it indicates that the Goodman diagram is not necessarily representing the actual condition in the block.

Q Dr. Bush, Mr. Dynner asked you a number of questions. He asked you to identify the stationary diesels that you included in the empirical evidence to support your conclusion that the ligament cracks grow to size sited and then arrest. Included in this empirical evidence are -- is the experience with the 101, the 102 and the old 103 blocks; isn't that correct?

A That's correct.

Q Dr. Berlinger, you indicated in your testimony

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at transcript 26,238 that the Staff has not been able to determine -- to make a determination at 3500 and 3900 and therefore recommended the testing. The endurance testing was chiefly for the purpose of the crankshaft; am I correct in that regard?

A (Witness Berlinger) Yes, that's correct.

Q And the Staff's conclusions about the adequacy of the blocks for nuclear service with the conditions that the Staff has stated in its testimony are based on the loop LOCA as defined in the current FSAR; isn't that correct?

A Would you repeat that, please?

Q Yes.

The conclusions that the Staff reached concerning the adequacy of the 101, the 102 and the new 103 blocks for nuclear service subject to the conditions stated was based on the load profiles as the currently exist for the loop LOCA?

A As they currently exist in the FSAR for the loop LOCA, that is correct, which would be a 3500 to 3900 kilowatt load range.

Q Dr. Berlinger, there was some testimony, also, on Friday concerning stresses experienced during fast starts. Are you aware that -- I take it you are aware that FaAA strain gauged the 103 engine and showed that in the stud-to-stud area the stresses attributable to fast starts

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were no greater those at steady-state operation?

A I believe that is what FaAA concluded, but that is not directly related to the statement that I made on Friday that is in the transcript.

Q The statement, then, that you made on Friday relates to the ligament cracks or to some other portion of the engine?

A No. The placement of the strain gauges on the block top, as I recall, were primarily in the stud-to-stud area, and the conclusions that we had reached, as stated in our written testimony, were that the existence or the occurrence of ligament cracks in the counterbore-to-stud region were not ruled out -- were expected, as Dr. Bush had said, or could be expected to occur.

The question that we had was with regard to stud-to-stud cracks, once a ligament crack had changed the stress field such that there would be, possibly, a higher stress in the stud-to-stud region.

JUDGE BRENNER: A higher stress for fast starts as compared to steady-state operation? That is Mr. Ellis' basic question.

WITNESS BERLINGER: The comments that I had made last week with regard to rapid starts and loading the engine were meant to indicate that we have felt, based on an assessment of the data, that that is the most stressful

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condition that is placed on the engines themselves -- that's during starting and loading. And it was not directed to a specific location, those comments; it was not restricted to a particular crack location.

BY MR. ELLIS:

Q With respect, though, to the stud-to-stud region, I take it you would agree that the data indicates that fast starts do not create greater stresses even in the presence of ligament cracks?

MR. BRIGATI: Objection: Asked and answered.

JUDGE BRENNER: No. Overruled.

WITNESS BERLINGER: No. The evidence that has been provided by FaAA from the strain gauge data would indicate that the stresses would not be any larger during a start. And I have not performed independent analyses to confirm or deny that conclusion presented by FaAA.

JUDGE BRENNER: How many more do you have, Mr. Ellis?

MR. ELLIS: That's it, Judge Brenner.

JUDGE BRENNER: Good timing.

Followed by the County, which we expect to be even briefer than LILCO's, since LILCO had to ask questions after the County's examination.

MR. BRIGATI: I'll try to make it briefer, Judge, but I'm not sure that it's going to be.

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JUDGE BRENNER: It will be. We have a maximum of about a half-hour in mind, and we expect you to to easily beat that.

MR. BRIGATI: Okay.

RECROSS EXAMINATION

BY MR. BRIGATI:

Q Dr. Berlinger, you testified that operation of the engines with water in the oil could lead to overheating in the bearings and bearing failure. Do you recall that testimony?

A (Witness Berlinger) Yes. And the basic reason for that is that the ability of the oil to provide lubrication, depending on its particular service needs would be affected by the presence of water.

Q Okay. Operation over what period of time, Dr. Berlinger?

A Are you asking me how long the engine could run with water in it before it would go to failure?

Q Yes.

A There is no way that I can give you a firm number. It depends on how much water there is and how good the oil is, what type of oil it is, what the bearing film pressures would be, what the oil pressure in the lubrication system would be that is supplying oil throughout the engine. There are just too many variables for me to try and

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estimate how long it would take.

If you want to give me a specific scenario, I'll give you my best guess, but I think you're asking for an impossible thing.

Q Are you familiar with the type of oil that is being used by LILCO in the EDGs at this point in time?

A I'm not overly familiar with it. I do know that the type of oil that's being used is different than was used in the past. There's been a recent change -- I think as far back as late spring or early summer, in that time frame, they went to a better grade of oil. I think it's a Mobil oil.

Q Do you know anything about --

JUDGE BRENNER: Excuse me, Mr. Brigati.

For what it's worth, it's my opinion that you're not asking the person with credentials in this area, the questions about diesel operability.

MR. BRIGATI: I'm following up on Dr. Berlinger's testimony, Judge.

JUDGE BRENNER: I just made my statement.

MR. BRIGATI: And if Mr. Henriksen has anything to add, I'll be happy to hear from him. If he has anything to add to clarify what Dr. Berlinger is saying, or he has anything to add in disagreement with Dr. Berlinger, I'd be happy to hear from him.

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JUDGE MORRIS: Just so I'm clear, Dr. Berlinger, you're still talking about lubricating oil. Is that correct?

WITNESS BERLINGER: Lubricating oil, as opposed to diesel fuel oil.

MR. BRIGATI: That was the context of my questions, Judge Morris.

BY MR. BRIGATI:

Q Are you sufficiently familiar with the properties of the new oil being used by LILCO to estimate how long a bearing failure might occur if there were twenty gallons of water in the lube oil?

A (Witness Berlinger) No.

Q How about you, Mr. Henricksen?

A (Witness Henricksen) I have already testified to the effect that I don't know.

Q I have a general question for the panel: has the NRC Staff looked into the incident described by Dr. McCarthy concerning a tugboat operating for about two weeks with a high quantity of water in its lube oil?

A (Witness Berlinger) I have not.

A (Witness Henricksen) I have been asked the question whether I believed it. Judge Morris asked me and I said I did not believe an engine could run there; and I think hearsay says that the engine in particular has lost

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all bearings and has got a broken crankshaft.

Q You say "hearsay says that": what do you mean, Mr. Hendricksen?

A Well, one of my colleagues at PNL, a consulting engineer, knows about this engine.

Q A consultant to the NRC Staff has investigated the matter?

A He has not investigated it. He has heard that this is the case.

Q So that, according to that information, the engine did not survive the operation?

A That's the information I have, yes.

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Q Mr. Henriksen, you testified that in your opinion the loss of 20 gallons of water from the cooling system would not represent any immediate danger. Am I accurately characterizing your testimony?

A In that context I think I was referring to the jacket water system. We are not talking about water in the lube oil any longer, I take it?

Q Correct, just loss of water.

A Yes, I do not see that would be a problem.

Q Wouldn't that depend on the rate of loss, the rate of leakage?

A The 20 gallons in itself would not be a problem. If this happens in one minute obviously it's a different story. We're talking about the seepage through a crack, I think -- and I was asked this earlier.

Q Or possibly seepage through several cracks? That would create a bigger problem, wouldn't it?

A Well the faster the flow the closer you could get to a problem, there's no question about that.

Q Do you know whether the loss of 20 gallons of water from the jacket water system is automatically made up?

A As far as I know it is not automatic, it is manual.

Q It's manual.

So someone has to come and activate a system to

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replace the 20 gallons, is that correct?

A I think that was previously stated by LILCO.

Q Do you know whether the operator who would be undertaking that action would be located in the event of a loop LOCA?

A As I recall a previous statement by LILCO the operator would be in the operating room.

Q How far is that from the engine?

A I have not been to the operating room, I do not know the location relative to the engine room.

A (Witness Berlinger) Can I add something? It's more a question than an answer.

I was under the impression, based on the prior questions asked last week and those you asked just a few minutes ago that the reference to 20 gallons of water was a total amount of water. It was not 20 gallons a minute but it was a loss of 20 gallons and the rate wouldn't make a darn bit of difference from the comments that were made previously. I don't think we were talking rate, it's the total amount of water.

Q You don't think the rate of loss of water would make a difference, Dr. Berlinger?

A No, I think that if you are talking about a loss of 20 gallons of water, that's a total loss of 20 gallons of water. If you wanted to ask the question differently as to

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20 gallons a minute or 20 gallons an hour or 20 gallons a week, that would be different and then I think it would be consistent with the question that was asked before.

Q You let your counsel correct the record insofar as that's concerned.

A I don't understand the question, that's what I'm trying to say to you.

JUDGE BRENNER: He wants to ask another question, Mr. Berlinger, and that's okay with me.

BY MR. BRIGATI:

Q Dr. Berlinger, you testified that you did not think it was likely that the stud-to-stud crack would open sufficiently to loosen the stud bolts.

Am I correctly characterizing your testimony?

A (Witness Berlinger) Yes, I did state that.

Q Do you believe that it is possible that such a crack could cause loosening of the stud bolts?

A If a crack was sufficient to loosen the stud bolts, then loosening the stud bolts would be a secondary problem. I believe that you have a much more massive problem on your hands, including a very large rate of water leakage. In other words, you have to have one heck of a crack in order to loosen up those stud bolts to the point where the heads themselves would be loosened.

Q How deep would the crack have to be, in your

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opinion?

A They would basically have to be through-wall. You would have to loosen up that entire section of the block.

Q So the entire stud hole, is that your opinion?

A You would have to go clear through the block, not the stud hole necessarily. And if you went through the entire block you would have already propagated through the stud hole. It would be a crack coming in from the ligament and a crack going over to another stud and most likely the crack would go quite a ways across the block top. It would probably go across several cylinders.

Q So in your view the concern about a stud-to-stud crack in that area would be not that you would lose the studs but that you would have a massive water leakage?

A That would be the immediate problem, and I think that would be the one I would be more concerned about.

I might add that I guess I cannot envision how that would happen based on what I've seen in these engines in the past.

Q You don't believe it's possible that a stud-to-stud crack could weaken the integrity of the block sufficiently so that there would be a loosening of the stud bolts?

A That is correct. I think that loosening stud

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bolts would be very unlikely as a cause for engine failure.

Q What is the basis for that opinion? Have you done any analysis?

A No, I have not done any analysis other than analyzing the available data based on the inspections that have been performed on the Shoreham engines which indicate to me that even after the engine has been operated at at least 3900 kilowatts and sizable cracks from the standpoint of depth have occurred, there has been no evidence of studs loosening.

In addition, by reviewing the blueprints of the engine block it is fairly -- and by realizing the massiveness of the engine block, I think it is easy to envision the difficulty of these blocks going to catastrophic failure. I think if cracks would start to propagate they would -- they would give you some warning, whether it be a water leak or whatever.

JUDGE BRENNER: Mr. Henriksen, can you tell me whether you agree or disagree with Dr. Berlinger's answer, the last two answers?

WITNESS HENRIKSEN: Well I have not made an analysis of the problem as presented. All I can say is I don't think it is very likely that the cracks can develop to the point where the studs can come loose.

JUDGE BRENNER: What kind of crack or cracks do

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you believe would have to develop for the studs to loosen?

WITNESS HENRIKSEN: It would almost have to go down to the root of the threads on both sides.

JUDGE BRENNER: Down to the top of the threads?

WITNESS HENRIKSEN: From the top and all the way down.

BY MR. BRIGATI:

Q Dr. Bush, you testified about a meeting in September that you attended and from which you came away with the feeling that there was no evidence of cracking in the cam gallery area of the new 103 block.

Do you recall that testimony?

A (Witness Bush) Yes.

Q What was said in that meeting that led you to believe there was no evidence of cracking?

A That particular meeting actually had four subsets in it, one of which we addressed in previous testimony, namely, looking at photomicrographs; another one had to do with establishing the conditions for operation which interrelates to this. We also were provided with other information.

At that time we were informed that there was no evidence of cracking in the 103 -- which was one of the reasons for making the decision on selecting the 103, the new 103 block for instrumentation and conducting of the run

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to 10 to the 7 cycles.

Q Who made that representation to you, Dr. Bush?

A There were several people in the room. I think probably Dr. Berlinger could better answer that question than I.

Q Dr. Berlinger?

A (Witness Berlinger) The information was passed on from the LILCO operations people, I think it included -- people at the meeting -- Craig Seaman, Ed Youngling, Brian McCaffrey, also there were people from FaAA at the meeting such as Dr. Rau, Dr. Wachob. The information is as characterized by Dr. Bush.

The only thing I can add to his previous answer was the fact that the information that there were no existing cracks in the 103 block was based on visual inspections that were done both at TDI during the manufacture of the block and inspections that had been done at Shoreham prior to operation of the engine.

Q And when you use the term no evidence of cracking, you include the term indications in cracking, don't you?

A That's correct. There were no indications of -- call them linear indications or cracks identified based on visual inspection and that's the information that we had been given at that meeting on September 21st.

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Q Okay.

Dr. Bush, you haven't personally examined the cam gallery indications that have been discovered on the new 103 block, have you?

A (Witness Bush) No, I have not.

Q Dr. Berlinger, I think you testified that you had and you didn't see the indications visually, am I correct?

A (Witness Berlinger) That's correct. I think I testified to that on Friday.

Q Were you looking at the cam gallery regions that indications have been discovered in in that time --

A Yes -- excuse me.

Q -- at that time.

A I'm sorry.

Q I'm sorry -- at that time.

A Yes, the cam gallery --

JUDGE BRENNER: Excuse me. We are repeating testimony here. He talked about what he looked at and they were circled and so on --

MR. BRIGATI: Thank you, Judge.

BY MR. BRIGATI:

Q Did you use any kind of a magnifying glass in your inspection of that area at that time?

A (Witness Berlinger) No, I didn't use a magnifying glass. I just tried to use good light which

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would allow me to identify any cracks if they were obvious.

Q Dr. Bush, on Friday you were asked about Dr. Anderson's supplemental testimony, question seven, page five, concerning whether air could be present in the environment of the hot casting and I believe you testified that you agreed with Dr. Anderson that no air would be present during the early phases of the cooling process but you expressed the view that you would expect air to enter some time during the later casting-cooling period.

Do you recall that testimony?

A (Witness Bush) Yes, I do.

Q Later in your testimony you said that you expect cam gallery cracks to occur reasonably early in the life of the cooling process.

A That's correct.

Q -- and that the movement of air would be later.

But you also indicated that you would want to talk to an individual who was an expert in casting to cover that possibility.

Do you recall that?

A I do not profess to be an expert in the casting process, so I said that I would not be the appropriate witness under these circumstances.

Q So you really don't have the expertise to comment on whether Dr. Anderson's testimony was valid or invalid,

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am I correct?

A I think I can respond to portions thereof. But if you want the explicit aspects of the casting process, I am not going to be able to do that.

Q What do you mean you can respond to explicit portions thereof?

A Well there are certain processes I think that are fairly apparent. I have worked in a foundry. That doesn't make me an expert in the cast iron or other things. I am reasonably aware of what procedure is used and what type of bonding material is used. And in the early stages when you pour very hot metal you do indeed burn off and you end up with a reducing atmosphere. But once you have burned that material off that is in the core sands you now have a semipermeable or permeable material, and if it sits there there is no particular reason why air will not move into it and that is the only point I was attempting to make. That's something that one would derive, say, from physical principles, if nothing else.

Q So you think it is possible for air to get in there?

A Oh yes.

Q But you were not necessarily commenting on the probability of the oxidation process hypothesized by FaAA, am I correct?

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A I wasn't stating that the oxidation necessarily had to be concurrent with the formation of a hot tear. It could occur somewhat later in time.

You want to recall that this metal sits there for a matter of many hours or days, and admittedly at any one time, one would have to have a feel for a temperature. But the doubling time on oxidation you could pretty well establish and so even though you might be four or five hundred degrees or six hundred degrees below the melting point, you could still have extensive oxidation.

I think those are the type of temperatures we are probably talking about whereas I would anticipate that the cracks would have formed at a substantially higher temperature.

Q You don't know the cooling rate for this particular block?

A The only way I would know that would be if it had been instrumented because these are extremely complex geometries, and any one particular location is a function of the gating and the riser and the thickness of the material, and so forth. So you have a multiparametric problem.

So the only thing I could say is to know that and to trust it, I would almost have to say that they would have to have embedded thermocouples or something of that nature.

Q Would you agree, Dr. Bush, that if the

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oxidation process hypothesized by FaAA took place in the cam gallery cracks you would expect to see that kind of oxide in a lot of other places in the block?

A That would be quite possible, yes.

You have to recall that most surfaces are sandblasted and many surfaces are machined, so that doesn't say what the block looked like. It simply says that at one time in life before the other process, after the shakeout was done, the situation might be totally different than when you look at it now.

Q But you don't know whether this particular block was sandblasted to remove any oxide from the surface, do you?

A It's standard procedure. That's about all I can say. And obviously I do not know because I wasn't there.

I do know by evidence that one would look at that there obviously had to have been a machining of the upper surface, but that's about as far as I can go.

JUDGE BRENNER: Are you coming to a close, Mr. Brigati? You've got about five more minutes.

MR. BRIGATI: I'm getting there, Judge.

JUDGE BRENNER: Well, you had better ask your most important remaining questions now, if there are any such questions.

BY MR. BRIGATI:

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Q Dr. Bush, --

A (Witness Bush) Yes, sir?

Q -- you testified that you thought that a leak in the cam gallery area would start out by leaking at the rate of about .0005 gallons per minute, by analogy to some other crack analysis that you have done.

A That's correct. I would expect just a few drops initially that would increase.

We have two situations. We have finite thickness. We have no obvious driving forces to open the crack up, and we don't have much driving force from the water pressure. My experience is more at 1,000 or 2200 pounds per square inch, and even under those circumstances at those pressures when you have a crack through a half-inch wall, that's about what you get, is a drip.

Q How big a crack are you assuming in that estimated rate of leakage?

A Oh, that might be a crack that would be two to three inches long, obviously fairly tight under those circumstances to get five gallons a minute.

As I recall the pressures, I would have to have a stream of water coming out that would be probably in excess of the diameter of my thumb, something like a half to three-quarters of an inch. There isn't that much driving force at these pressures.

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Q How big a crack would you have to have to leak, say, a gallon every 12 hours into the cam gallery area, given the pressures in the system?

A Well, that would be hard to say. I would think we were now getting-- If I convert it to equivalent diameter, we're probably getting it down to something larger than maybe perhaps twice the size of the lead in a lead pencil, something of that nature, let me say roughly in the vicinity of a sixteenth of an inch or so in diameter. That's a very approximate type thing.

Q Well, how long would such a crack have to be?

A I converted it to equivalent diameter. In other words what I did was I took a crack and I made it into one. I cannot tell you how long the crack is.

The critical thing is not the length, it is how much it's open. That's the factor that controls under these circumstances as much as anything.

Q In response to a question by Judge Morris, Dr. Bush, you testified that you generally agreed with the methodology that FaAA used in its cumulative damage analysis. Am I correctly characterizing your testimony?

A That's correct. Without going into the details of a particular model, I believe I understand by inference what was done. But I don't have a step-by-step detail on the thing. But the methodology is about what I would have

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anticipated on the thing.

Q Did you mean to testify that you agree with the FaAA's cumulative damage analysis as FaAA has presented it in this proceeding?

A Perhaps I wouldn't go that far. The only way one can equivocally agree with a cumulative damage analysis is to look at all of the steps thereof, how the cycles are included, whether the stresses that are applied to any batch -- or a collection of cycles seem to be realistic; things of that nature.

And I do not have detail to that extent so I am more-- The methodology agreed with the way I would think that the problem would be attacked, but that's about as far as I could go.

Q Did you attempt to evaluate whether FaAA properly applied the methodology to the facts at hand in this particular instance?

A Only indirectly in the sense that I have reviewed most of the Failure Analysis Associates' documents relevant to the diesel generators, and I have looked in some degree on there.

I had questions with regard to some aspects with regard to the numerics of the situation. I think I understood in general the conceptual approach, but I was looking more for you might say confirmation by looking at

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the numbers and how they would come out, and things of that nature. Those I have not had a chance to examine.

JUDGE BRENNER: Mr. Brigati, your time is up, as I told you several times now it would be at this point. And I have seen nothing in the last half hour as a basis for extending this. We've been over this ground many times now already with these witnesses.

Any redirect by the Staff?

MR. PERLIS: None, your Honor.

JUDGE BRENNER: All right.

LILCO, any burning questions based on the County's questions?

MR. ELLIS: Just one, Judge.

. FURTHER RECROSS-EXAMINATION

BY MR. ELLIS:

Q Mr. Henriksen, are you aware of the capacity of the water tank at Shoreham?

Would it refresh your recollection--

JUDGE BRENNER: Mr. Ellis, I'm going to object to that one myself.

WITNESS HENRIKSEN: I don't think I have ever--

JUDGE BRENNER: Mr. Henriksen, I have overruled the question.

WITNESS HENRIKSEN: Thank you.

JUDGE BRENNER: It's not new, it's not burning,

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and it doesn't meet any other test of significance at this point.

All right, we have completed the examination of this panel at this time, so you are going to be excused as a panel. As we stated, our procedure is going to be to return to the County's panel of witnesses on blocks, and continue the unfortunately interrupted cross-examination of that panel by LILCO.

After we have completed the examination of that panel, we are immediately going to go to the combined panel of witnesses for LILCO, the Staff, and the County, comprised of Drs. Anderson, Rau, WAchob and Bush, and they will be asked questions in their area of expertise including the rebuttal testimony to the extent we allow it, but not exclusively.

And obviously after having been through many, many days now of examination of those witnesses by all parties and the Board, the focus is just that, to focus on their differences as it affects their metallurgical analyses. Obviously those witnesses are going to have to be cognizant of all the testimony they have heard so far and all the testimony that is going to occur before they get on the panel. And we are going to immediately proceed in the sequence I just indicated.

All right, you gentlemen are all excused for now.

WRBeb

And Dr. Bush is going to be back as part of the combined panel.

You can leave at this time.

(Witness panel excused.)

JUDGE BRENNER: Mr. Ellis, you mentioned that you had some preliminary matters, and this would be a good time to take up any miscellaneous matters. And then we will break for lunch and come back with the County's panel in place.

MR. ELLIS: Yes, sir. three things.

First, I gave you this morning LILCO's motion with respect to the rebuttal testimony.

Second, I realize the Board has not yet had an opportunity to see anything that the parties are submitting with respect to the points on remand, so the answer may not be possible, but I obligated myself to ask, and I have asked it before, and I fully expect the same answer.

But Mr. Irwin--

JUDGE BRENNER: Why don't you save yourself the time then?

MR. ELLIS: Mr. Irwin wants me to ask whether you would like him to be here tomorrow. He would be delighted to be here but is looking for either an invitation or perhaps a demurrer.

JUDGE BRENNER: I said I don't know until I have

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seen the written answers.

MR. ELLIS: Yes, sir.

JUDGE BRENNER: And having said that, I will certainly be aware of the fact that it would be unreasonable, even for me, to expect somebody here right at that moment when I say for the first time that we will have to hear from Counsel.

MR. ELLIS: Yes, sir. He will certainly be prepared to be here on short notice.

Thirdly, I just wanted to advise the Board, to keep the Board apprised of the situation. The inspections are, as I understand it-- I have been advised they are largely completed, and the County had a representative there on Saturday to review the matters in contention. I just wanted to report that fact to the Board.

JUDGE BRENNER: We have not yet received the County's answer to LILCO's motion to reopen and supplement the record. Will we be receiving that today?

MR. DYNNER: Judge, I think we are going to have to furnish that to you tomorrow. We worked on it last night, and it is just a question of getting it retyped and checked over. So it is going to be Federal Expressed up this evening, and it will be here in the morning.

JUDGE BRENNER: Okay. We said we would give you that accommodation if you needed it, and we will.

WRBeb

All right. If there is nothing else--

MR. PERLIS: Judge Brenner, I indicated last week that Dr. Bush might have a scheduling problem. He doesn't, and he will be available for the panel testimony, but he does have ASME meetings in Washington this week.

I am wondering if you have any idea as to how long the cross-examination of Suffolk County's panel will take.

JUDGE BRENNER: No. But more to the point, he is going to have to be cognizant of the testimony of those witnesses in order to participate meaningfully as a member of the panel. Right?

MR. PERLIS: I understand that, but there are transcripts he can read, and so on.

JUDGE BRENNER: How is he going to read the transcript if he is going to take the stand immediately after the completion of their testimony, no matter when it is? There is no guarantee that there will be an overnight break between that time, and even if there is, the transcript is not available until the next morning usually, unless you know something about hearings that I don't know.

Are my observations correct?

MR. PERLIS: I was not challenging them.

JUDGE BRENNER: All right.

Let's break until 1:05.

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(Whereupon, at 11:35 a.m., the hearing in the above-entitled matter was recessed to reconvene at 1:05 p.m. the same day.)

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AFTERNOON SESSION

(1:05 p.m.)

JUDGE BRENNER: Good afternoon.

Whereupon,

ROBERT N. ANDERSON,

STANLEY CHRISTENSEN,

G. DENNIS ELEY,

RICHARD B. HUBBARD,

and

DALE G. BRIDENBAUGH

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

JUDGE BRENNER: This morning we received LILCO's motion to strike portions of Suffolk County's rebuttal testimony and LILCO's motion to submit surrebuttal testimony.

Insofar as the motion to strike portions of Suffolk County's rebuttal testimony, it is denied. We have considered the motion and the testimony which is the subject of the motion and in essence we find that the rebuttal testimony is arguably relevant to an issue of decisional importance in the proceeding, and that the rebuttal is relevant to an important point in the testimony. We disagree that the test is limited to the direct testimony of other parties.

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Some of the rebuttal testimony, although only isolated portions, may not pass the tests assuming, arguendo, they are applicable tests of being not cumulative with any other testimony in the record and having been incapable of being filed in a more timely fashion. But we find that such testimony is necessarily going to be the subject of the combined panel of witnesses for all parties that we have discussed, so there would be no point in striking it from the rebuttal and then having the same witnesses asked the same or similar questions as part of that panel.

For what it's worth, although we don't have to decide it, I personally think the "incapable of" test is a little harsh and a better way of phrasing it would be "not reasonably foreseeable" that the testimony which perhaps could have been available initially would have been the subject of interest it has become at the hearing, so as to be worthy of the treatment now sought to be given it in the rebuttal testimony. But in any event, we wouldn't strike it.

In terms of the motion to submit surrebuttal testimony, as we understand the motion, LILCO is talking only about testimony that would be related to metallurgical matters since LILCO states it can submit such surrebuttal testimony orally through Drs. Rau and Wachob -- am I

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correct? -- as part of that combined panel?

I'm repeating what the written motion says, I believe.

MR. ELLIS: That's correct, Judge Brenner.

JUDGE BRENNER: Given that limitation, the motion to submit oral surrebuttal testimony is granted. It would fall right in line with our procedure anyway.

We would have that combined panel. LILCO would be the first questioner. Each questioner questioning witnesses for different parties necessarily would be asking a combination of questions of its own witnesses as well as expressly giving the other witnesses an opportunity to comment. And I want the questioners to keep that in mind.

Don't pursue different subjects, that is, as to almost after each question, but in any event after a particular relatively narrow subject, the questioner should express or give the witnesses for the other parties an opportunity to comment, that being the idea of having all the witnesses up there in the first place.

All right. This brings us to where I think we are in the proceeding, subject to somebody telling me I am incorrect, and that would be the return of the Suffolk County witness panel on blocks, and I see all five of the witnesses are in fact back, and they have previously been sworn, as well as the necessity now of swearing in the

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rebuttal testimony at this point.

MR. BRIGATI: Shall we start that process, Judge?

JUDGE BRENNER: Yes.

FURTHER DIRECT EXAMINATION

BY MR. BRIGATI:

Q Do you have before you the rebuttal testimony that has been circulated to the parties, bearing your names, dated November 7, 1985 -- I'm sorry -- 1984, in this proceeding?

A (Witness Anderson) Yes.

A (Witness Christensen) I do.

A (Witness Eley) Yes.

Q Is that testimony true and accurate to the best of your knowledge and belief?

A (Witness Christensen) Yes, it is.

Q Do you adopt it as your own in this proceeding?

A Yes.

A (Witness Anderson) I do.

A (Witness Eley) I do.

MR. BRIGATI: Judge Brenner, I move the admission of the testimony as the County's rebuttal testimony in this proceeding.

JUDGE BRENNER: I'm sorry, I wasn't paying full attention. Did you have them make corrections?

MR. BRIGATI: No, I didn't, Judge, and that's a

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good point.

Let me explain that the copies we have for the Court Reporter have made certain corrections of a typographical nature. On the fourth page at about the middle of the page the word "shrinkage" was transcribed as "s-h-i-r-k-a-g-e" and the copy being filed with the Reporter corrects that.

On page 5, as pointed out by Judge Morris last Friday, in the last line and the third-to-last line, the word "cam shaft" was incorrectly printed "crank shaft."

On page 8, the questions were misnumbered, so that the question numbered 12 on that page should be 13, 13 should be 14, 14 should be 15, followed by a Q rather than an A, and on page 9, 15 should be 16.

Finally on page 8 again, Dr. McCarthy's name was misspelled, with a "u" following the "C" rather than an "a."

And those errors have been corrected in the version, the official version we intend to file with the Reporter. And I have other copies here if you or the parties care to have them.

JUDGE BRENNER: I don't think we need them. At least speaking for the Board, we don't need them, given your explanation.

All right. The testimony as identified then, the rebuttal testimony, will be admitted into evidence, and

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bound into the transcript at this point as if read.

(The document follows:)

November 7, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

In the Matter of LONG ISLAND LIGHTING COMPANY (Shoreham Nuclear Power Station, Unit 1)	Docket No. 50-322-OL

REBUTTAL TESTIMONY OF
DR. ROBERT N. ANDERSON,
PROFESSOR STANLEY G. CHRISTENSEN,
AND G. DENNIS ELEY

1.Q. Dr. Anderson, based on FaAA's description of the samples it took from the cylinder blocks of EDG's 101 and 102, do you believe that FaAA has an adequate basis for concluding that those blocks do not contain quantities of Widmanstaetton graphite similar to the quantity found in the old EDG 103 block?

A. (Anderson) No. As I understand FaAA's testimony, they took two small specimens and about ten replications from each block. Based on the FaAA witnesses' descriptions of the sampling performed, they evaluated less than 100 grams of material from each block, and each block weighs 24,000 pounds. Therefore, they have based their conclusions on analysis of approximately 10 parts per million, and that is hardly sufficient to warrant a high degree of scientific certainty about the composition of the EDG 101 and 102 blocks. The fact that FaAA did observe areas in the EDG 102 block samples that had characteristics similar to Widmanstaetton graphite (Tr. 24,754 (Wachob)) underscores my concern about the thoroughness of their sampling in this particular.

2.Q. Could residual stress create tensile forces in the block top and cam gallery areas of the cylinder blocks?

A. (Anderson) Yes, and those forces could be substantial because of the complex geometry of the casting in both of those areas.

3.Q. Do you believe it is possible to predict the existence and amount of residual stress in those areas using any analytical methods short of actual testing?

A. No, and no one can do that with any reasonable degree of scientific certainty. The preferred way to evaluate the amount of residual stress in a structure with any degree of scientific certainty is to undertake strain gage testing of the surface in its existing state and compare those results to strain gage readings of the same surface after a piece has been removed from the vicinity.

4.Q. Dr. Anderson, Dr. Rau testified that he did not observe the "multiple small disconnected cracks branching out into the cast iron material" below the tip of the 3/8-inch circumferential crack reported in your Supplemental Testimony (Answer to Question 18, pp. 11-12), and suggested that you may have confused artifact of Widmanstaetton graphite for the cracks you described. Is it possible that you confused artifact of Widmanstaetton graphite for cracks?

A. (Anderson) No. I viewed the particular specimen under a microscope with power varying from 20X to 60X. I did observe random artifact in the area, and I assumed that to be Widmanstaetton graphite. However, the branch-like cracks I described in the cited testimony were quite different. The cracks I observed and described in the cited testimony had an organized appearance consistent with the orientation of the larger crack above them and were not random as I would expect artifact from Widmanstaetton graphite to be.

5.Q. Dr. Wells testified that he considered the risk of structural failure from circumferential cracks to be highly unlikely because one-third of the circumference of the liner landing area consists of stud bosses. Tr. 25,100-01 (Wells). Do you agree?

A. (Eley, Christensen) No. We cannot be sure that a circumferential crack in the cylinder liner landing area is likely to extend deeply enough to cause a structural failure, but it is clearly possible and cannot fairly be characterized as unlikely. A more serious concern is, as described in our Supplemental Testimony (Answer to Question 20 at p. 13), that such a crack could cause the liner landing to flex under the force created by the 1600-1700 pounds of firing pressure, causing movement of the cylinder liner and leakage of combustion gases outside the cylinder into the cylinder liner landing area. In that event, and if the circumferential crack extends through the 1-inch depth of the liner landing area that does not consist of stud bosses (about two-thirds of the circumference), then gases would enter the cooling jacket water system. Such gases in the cooling jacket water could cause overheating and require engine shut-down. The alternative to engine shut-down would be to risk the same consequences of overheating due to loss of coolant described at pp. 152-53 of our Revised Joint Testimony, dated October 29, 1984.

6.A. Dr. Anderson, Dr. Rau testified that there is no way you can conclude that the weld material in the cam gallery crack

sectioned by FaAA from the old EDG 103 block pulled free from the crack surface due to operating stresses and not due to heat shrinkage as you testified in your Supplemental Testimony (Answer to Question 11 at p. 8). Do you stand by your testimony?

A. (Anderson) Yes. Based on my examination of the crack samples sectioned by FaAA, it appeared that the weld material had been simply "puddled" into the crack after it was widened by grinding or arcing. It did not appear that the crack site had been subjected to any pre- or post-heat treatment as part of the welding operation. If these premises are correct, then the weld material would adhere to the cast iron relatively uniformly and would break cleanly from that base metal if the moving force were tensile stress resulting from weld shrinkage. The fact that some cast iron was still adhering to the weld material that had separated from one side of the crack therefore makes it more likely that the separation was caused by operating stress and not weld shrinkage.

7.Q. Aside from that analysis, do you have any reason to question Dr. Rau's conclusion that the separation of the weld material from the cast iron in the crack which was sectioned by FaAA from the old EDG 103 block had been caused by tensile stress from shrinkage of the weld material itself?

A. (Anderson) Yes. I understand that the weld material is a nickel-iron alloy. The characteristics of nickel-iron weld material are such that they minimize shrinkage and therefore

minimize the likelihood of tensile stress caused by post-cooling shrinkage.

8.Q. Dr. Rau testified that, because of the general shape of the cracks in the old EDG 103 block, even if such a cam gallery crack did propagate, its deepest extension through the 1-1/4 inch cam gallery wall could cause only a pinhole leak at the inner wall. Tr. 25,249-50 (Rau). Do you agree, Dr. Anderson?

A. (Anderson) No, there is no scientific basis for assuming that a cam gallery crack which propagates through the wall in that area would be limited to a pinhole at the inner wall based on the shape of the crack indications that I observed. Although it is conceivable that the initial extension through the inner wall would begin as a pinhole leak, I would expect it to expand very rapidly once the initial penetration occurs so that the crack surface along the inner wall could extend up to a couple of inches in length.

9.Q. Professor Christensen and Mr. Eley, Dr. Wells testified that even if a cam gallery crack were to penetrate through the wall, there is a horizontal channel and perhaps other pieces of metal in the cam gallery area sufficient to provide support for the camshaft bearing. Tr. 25,254-55 (Wells). Do you agree?

A. (Christensen, Eley) Yes, provided that Dr. Wells intended his conclusion to be limited to the vertical support for the camshaft bearing. Our concern in this area as discussed in our Revised Joint Direct Testimony dated October 29, 1984, at p. 176 relates to flexing of the camshaft horizontally

along the plane of the cam gallery wall, not vertically as suggested by Dr. Wells' testimony. We continue to believe that such horizontal flexing is a concern that is not eliminated by the structural support discussed by Dr. Wells in his testimony.

10.Q. Dr. Rau and/or Dr. Wachob testified that they did not believe that the relatively low temperature environment of the engine when it is not operating would cause the volume of oxidation present on the samples of the cracks removed from the old EDG 103 block -- Dr. Anderson, do you agree?

A. (Anderson) No. As I understand it, the old EDG 103 block was manufactured in the mid-1970s and was maintained during a substantial part of the period after that time in a room temperature of 70°F. It is also my understanding that the jacket water temperature in the engine when it is not in operation is maintained at approximately 140°F and I would therefore expect the cast iron in the cam gallery wall to be approximately that temperature. Those temperatures are sufficient to cause oxidation in the quantities measured on the cam gallery crack samples (0.2-0.5 mm) over a period of a few years depending, of course, on other conditions.

11.Q. Mr. Schuster testified that the entire shaded region depicted on Suffolk County Diesel Exhibit 77 was "arced and perhaps subsequently ground out" before the weld metal was puddled in. Tr. 25,456 (Schuster). Do you agree with Mr.

Schuster based upon your examination of the samples and photographs, Dr. Anderson?

A. (Anderson) I have no basis for agreeing or disagreeing based upon my review of the samples or photographs -- the appearance of the repaired cracks is consistent with either arcing or grinding preparatory to welding. However, I visited TDI and observed that in making weld repairs to engine components, TDI followed the practice of grinding cracks, not arcing them. Of course, I cannot state that they followed the same procedures in 1975 but that is a reasonable assumption.

12.Q. Dr. Anderson, assuming that the oxide discovered on the cam gallery crack specimen removed from the old EDG 103 block was formed during the casting process and assuming that TDI attempted to repair those cracks subsequently, in your opinion is it reasonable to believe that there would be as much as 0.5 mm of oxide still adhering to the side of the crack to which the weld material had been applied but from which it is now separated?

A. (Anderson) No. The crack specimens which I examined definitely showed evidence of having been either arced or ground out in preparation for welding. Regardless of whether the cracks were widened by arcing or grinding, I would expect any oxide that had been adhering to the crack surface to be removed in the normal course of arcing or grinding. Neither process is so precise that the surface of both sides of the crack would be undisturbed in the course of it. Moreover, it

would make no sense to attempt to avoid disturbing one particular side of the crack because it is normal welding preparation to remove any oxide adhering to the surface to be welded in order to permit better weld adhesion.

13
~~12~~.Q. Dr. Wachob testified that FaAA did not perform any tests to determine whether the oxide on the cam gallery crack surface removed from the old EDG 103 block is a wustite, a hematite or a magnetite oxide. Tr. 25,414 (Wachob). Dr. Anderson, in your opinion would such a test be useful in determining the origin of the oxide?

A. (Anderson) Yes. If the oxide were a wustite it would tend to confirm FaAA's theory because wustite only forms at very high temperatures. On the other hand, if the oxide were hematite or magnetite, it would disprove FaAA's hypothesis concerning its formation because those oxides form only at much lower temperatures.

14
~~13~~.Q. Is there an accepted method for testing oxide to ~~determine~~ whether it is wustite, hematite or magnetite?

A. (Anderson) Yes. The method is by x-ray diffraction. It is not a very complicated procedure.

15.Q.
~~14.A.~~ Dr. McCarthy testified that the addition of 20 gallons of water to the engine lubricating oil would not compromise the lubricating systems of the Shoreham EDGs. Tr. 25,273 (McCarthy). Mr. Eley do you agree?

A. (Eley) Absolutely not. It is normal operating procedure to regularly test the lubrication oil in large diesel

engines for the existence of water. The reason for that practice is that relatively small amounts of water in the lubricating oil can have catastrophic effects on the engine, particularly piston seizure and bearing failure. The amount of water that would be a problem depends on the type of oil. The lube oil system capacity for each Shoreham EDG is 700 gallons so that 20 gallons would amount to almost three percent. Regardless of the type of oil used, that volume of water in the lube oil of a diesel engine would be dangerous. We have checked with Mobil Oil Company to determine how much water they believe is permissible in the Mobil Delvac 40 oil used in the Shoreham EDGs during engine operation. Mobil's chief engineer responded that when the water reaches 0.15 percent, the Delvac 40 oil should be discarded. He also advised that he would be "concerned" about operating the engine with as little as 0.2 percent water in Delvac.

16
~~15~~.Q. Professor Christensen, do you agree with Mr. Eley's testimony concerning operation of a diesel engine with water in the lube oil?

A. (Christensen) Yes, I do, but I had no communications with Mobil Oil Company on the subject.

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MR. BRIGATI: There is one other preliminary point, Judge, and that is I believe you directed that we file with the Reporter three copies of the FaAA Block Report, which was included in our exhibits in elided form as Exhibit Number 7, and also a revised index of exhibits reflecting that the complete Block Report is introduced as 7 for identification only, with the redacted copy that we proposed as the exhibit being admitted into evidence.

JUDGE BRENNER: That's right.

MR. BRIGATI: And those papers are here.

JUDGE BRENNER: All right.

For purposes of the record then, we would have the full Suffolk County Exhibit 7, Diesel Exhibit 7, but only for identification, being noted with today's date. And I mention it more for purposes of the exhibit list that we'll get with the proposed findings also, to have the indication, as well as the official records here.

And you have indicated what the situation is, Mr. Brigati. It's the same exhibit, except portions and only portions of it previously have been admitted into evidence as Suffolk County Exhibit 7 on a previous date. And right now we have the full document, which is a June 1984 document entitled "Design Review of TDI R-4 and RV-4 Series Emergency Diesel Generator Cylinder Blocks and Liners" prepared by Failure Analysis Associates, Palo Alto,

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California. And I don't know how many pages it consists of.

And as I have just indicated, that would be Suffolk County Exhibit 7 for identification.

(Whereupon, complete Block Report, excerpts of which were previously marked for identification and received in evidence, was marked as Suffolk County Exhibit 7 for identification.)

JUDGE BRENNER: Also at this point the County has shown me their revised index of exhibits and among other things, it nicely delineates which portions and at what point in the transcript parts of Suffolk County Exhibit 7 were admitted into evidence.

So let's bind that one-page index into the transcript at this point so we will all have it.

(The document referred to follows:)

VOLUME 4
CYLINDER BLOCK EXHIBITS

7.	Design Review of TDI R-4 and RV-4 Series Emergency Diesel Generator Cylinder Blocks and Liners, June 1984	For Identification Only
	Pages i, ii, iii 1-1, 1-2, 1-3 Figures 1-1, 1-2, 1-3,1-4,1-5,1-6,1-7,1-8 Pages 3-5, 3-6, 3-9 Figures 3-1, 3-6, 3-7, 3-13, 3-14 Pages 4-1, 4-5, 4-6, 4-8 Figure 4-2 Pages 5-1, 5-2 A-1, A-2, A-3	In evidence page 25566
24.	Deposition of Maurice H. Lowery, pgs. 1, 14-16	
32.	Deposition of Clinton Mathews, pgs. 106-107	
54.	Letter from Reis to the Administrative Judges Concerning a Morning Report of 4/16/84	
55.	3/20/84 Morning Report Concerning Con Rod Bearing Cracks and Eddy Current Examination of the Cylinder Blocks Cracks	
56.	TDI Owner's Group DRQR - Cylinder Block	
57.	Deposition of William J. Museler, pgs. 1, 7-8, 14-17, 43-46, 98-99	
58.	Deposition of Robert Taylor, pgs. 1, and Exhibit No. 1	
59.	Deposition of Robert Taylor, pgs. 1, 39-41, 67, 69-70	
66.	Deposition of Simon K. Chen, pgs. 1, 129	
67.	Handwritten Memo to Pratt from Lowery on Cylinder Block Casting - RV's	

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JUDGE BRENNER: Off the record.

(Discussion off the record.)

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JUDGE BRENNER: Back on the record.

MR. BRIGATI: I have one further preliminary matter, Judge.

To my chagrin, I discovered that when we put together the rebuttal testimony concerning the Mobil Delvac, we picked the wrong oil to concentrate on because there has been a change in the oil being used in the diesel generators and, therefore, what was used in the past is not terribly relevant to that particular point. And we are in the process of researching the situation with respect to the oil currently being used.

JUDGE BRENNER: Is this going to be in connection with your Question and Answer 15 -- the one about water in the oil?

MR. BRIGATI: Yes, Judge.

JUDGE BRENNER: All right.

I hope the numbering system didn't throw me off, but that question and answer was not a subject of LILCO's motion to strike the rebuttal testimony.

Is that correct?

MR. BRIGATI: That's correct, Judge.

JUDGE BRENNER: Let me ask LILCO also: the new 15 used to be 14, this one about how oil and water don't mix -- well, I'm going to assume it was not a subject of the motion to strike, since I didn't see it and you didn't see

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it, either, Mr. Brigati, which just goes to show you that when I try to make predictions in advance of what will be subjects of motions, I'm invariably wrong.

My message to you is: I have difficulty conceiving that the brand of the oil is going to be important in the context of the oil and water testimony. So I don't know what other research you're doing, but I have great doubts that we'll back up and allow you to admit further rebuttal testimony on this subject or anything of that nature.

For now, you've alerted us to the fact that the brand, the particular type, is incorrect in there, and we appreciate that notice.

MR. BRIGATI: My point, Judge, was that we didn't want to misrepresent the situation; and if the properties of the other oil are different, we would want to apprise the Board of that fact.

JUDGE BRENNER: As I said, in the context of oil and water, as opposed to other possible contexts, forget about it.

MR. BRIGATI: Fine, Judge.

JUDGE BRENNER: All right, we should be ready to go to LILCO's continued cross-examination of this panel, correct? I guess it's correct.

LILCO?

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MR. FARLEY: Thank you, Judge Brenner.

I am beginning with a supplemental cross-plan.

CROSS-EXAMINATION (Resumed)

BY MR. FARLEY:

Q Page 8, paragraph 5: Dr. Anderson, is it true that you have not performed any independent stress analyses of the cam gallery regions?

A (Witness Anderson) Yes, that's true.

Q It is also true, isn't it, that you and your assistant were present at the depositions of Drs. Rau and Wachob and Mr. Taylor on October 11, 1984, in Palo Alto?

A Yes. There was about a period of two hours which I believe I was not there, and my assistant was not there at the very first. But we had some overlapping time and some single time.

Q During the period that you were present, did it come to your attention in the course of the examination by Mr. Dynner that FaAA had performed strain gage testing of the cam gallery in the replacement 103?

MR. BRIGATI: Objection to any questions concerning those strain gage readings. The Board has ruled that they are to be excluded from evidence in this proceeding.

JUDGE BRENNER: Mr. Farley?

MR. FARLEY: Judge Brenner, I would respectfully

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suggest that I am entitled to show that he had this information available to him before the County filed their supplemental testimony, which is all I intend to do, in accordance with your prior rulings.

JUDGE BRENNER: Which portion of the supplemental testimony, or rebuttal testimony, or any of their testimony, is your question pertinent to? Can you key me in to where in the testimony you're questioning about?

MR. FARLEY: I believe it is pertinent, your Honor, to the supplemental testimony on page 2, paragraphs 1(a) and (b), and page 9, where they talk about propagation of these cracks.

JUDGE BRENNER: What was the date of the deposition, again?

MR. FARLEY: October 11, 1984, your Honor.

JUDGE BRENNER: All right.

The objection is overruled. We're going to allow the inquiry for the purposes indicated by Mr. Farley.

Do you recall the question?

WITNESS ANDERSON: Yes -- whether I had information with respect to the instrumentation of strain gages on new 103; and yes, I did. I was aware of it.

BY MR. FARLEY:

Q And weren't you also provided, and didn't you see, at that time, the preliminary strain gage test results

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from the cam gallery area of the replacement 103?

A (Witness Anderson) I don't recall if it was at that time or not.

MR. FARLEY: May I pass to the Board and the witnesses a copy of that data?

(Counsel distributing documents.)

JUDGE BRENNER: While that's being done, perhaps you can describe what's being passed out, Mr. Farley.

MR. FARLEY: It is a one-page graph, your Honor, entitled "Preliminary Cam Gallery Strain Gage Data".

MR. PERLIS: Excuse me. Could the Staff see a copy of that, please?

(Document handed to Counsel.)

BY MR. FARLEY:

Q Dr. Anderson, do you have now before you a copy of the document entitled "Preliminary Cam Gallery Strain Gage Data"?

A (Witness Anderson) Yes, I do.

Q Does this refresh your recollection that you did see this, or you were provided with a copy on October 11, before you filed your supplemental testimony?

A I have seen this. It doesn't refresh the date. It very well may be. I might. I'm not arguing. I just don't recall the exact date.

MR. FARLEY: Judge Brenner, LILCO would like to

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have this document marked for identification, Diesel Exhibit B-60.

MR. BRIGATI: We object, Judge, because, as I understand the Board's prior ruling on this subject, he's not going to be permitted to ask any questions about it.

We have conceded from day one, when this issue came up, that we were aware that FaAA had undertaken some strain gage testing of the 103 block. They didn't include any testimony concerning that in their supplemental testimony, and they were attempting to add it piecemeal to the record through various indirect means, the examination of witnesses subsequent to the filing of their supplemental testimony.

We didn't attempt to pursue this strain gage data in discovery for the simple reason that it wasn't part of their supplemental testimony, wasn't part of the record, so we saw no reason to follow up on it. We had more important things to do.

JUDGE BRENNER: Well, we made our previous ruling as to LILCO's supplemental testimony on the subject, and that ruling stands, subject to our reconsideration of this whole area in the context with the pending motion and answers thereto.

But the County can't have it both ways. You've got testimony here by these witnesses that bears on the

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subject, which testimony may post-date certain information that these witnesses have. And the legal arguments, where we found in the County's favor, is not the same as finding out what these witnesses knew or fairly should have known at the time they chose to offer testimony on the subject.

We're going to allow the cross-examination of them, using that information. So the objection is overruled.

We will mark it as LILCO Diesel Exhibit B-60 for identification.

(Whereupon, "Preliminary Cam Gallery Strain Gage Data" was marked for identification as LILCO Diesel Exhibit B-60.)

JUDGE BRENNER: Mr. Farley, there's a notation on mine, and I don't want the record to be silent on that fact. It states, "Exhibit 3, Raue, 10/11/84". Do you want to represent to the Board that this was an exhibit to Dr. Rau's deposition of that date?

MR. FARLEY: I do, your Honor.

BY MR. FARLEY:

Q Dr. Anderson, with Diesel Exhibit B-60 for identification before you, doesn't that in fact show stresses in the cam gallery saddle area were fully compressive during engine operating?

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A (Witness Anderson) Yes.

What is portrayed here is the analysis of the strain gage data, I presume. The strain gage data then has to be interpolated with respect to the type of material to get a stress.

What's not shown here, of course, is the residual stresses. So this, essentially, starts it wherever the equilibrium is; they started at zero. We have no idea from looking at this what the true stress of a given point is because we don't have incorporated in this the residual stress.

Moreover, it's interesting: after the quick start -- if I may go on, I have seen testimony that says that a quick start is no more of a load than any other. It's clear by their analysis that a one hundred percent quick start is the highest stress in the area. And then, if I add the residual stresses, which most likely would raise this line, then I would get into non-compressive, but tensile stresses.

Q Dr. Anderson, the testimony that you referred to on quick starts: didn't that refer to the block top and not the cam gallery regions?

A I believe you're correct there, because I have been reading the testimony of last week, trying to familiarize myself with that, and I'm still not sure I have

AGBbrb all the points down.

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Q Have you performed any independent stress analyses on any part of the engines regarding residual stresses?

A No, I haven't.

Q Is it true, Dr. Anderson, that Diesel Exhibit B-60 for identification does show that the stresses in the cam gallery regions are fully compressive perpendicular to the crack indications?

A I can't answer the perpendicular part because I don't have a characterization here of the orientation of the strain gage and of the crack, so I can't give you a direction; I'm sorry; and therefore I can't answer your question from this document.

Q Can you tell the Board or me whether or not Diesel Exhibit B-60 for identification shows that the stresses perpendicular to the crack indications in the cam gallery saddle area became increasingly compressive with the bolt tightening, or fully compressive during engine operation?

A No; there is an increase in compressive stress with bolt tightening. But we know that it doesn't start at zero. What starts at zero is the calibration of the strain gage. So the this is not with respect to the material unless we add in the residual stresses. But there is an increase. The trend is definitely compressive on bolt tightening.

Q The area that you're referring to on Diesel

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Exhibit B-60 for identification dealing with the bolt torque is the area to the left on that document; isn't that correct?

A Oh, yes, it's clearly marked "percent of bolt torque level," and I believe that Failure Analysis described the torque instrument that they used. There's no discrete data on here, and I assume this is smoothed data, but there's no information provided.

Q It is true, isn't it, Dr. Anderson, that cracks will not propagate in a fully compressive stress field1?

A Yes, that's true. If I can keep a compressive force on a crack totally compressive, then the propagation doesn't have a mechanism.

MR. FARLEY: Now, Judge Brenner, I'm referring to page 81 of our original cross plan.

BY MR. FARLEY:

Q Dr. Anderson, would you please look at Suffolk County Exhibit 55?

A (Witness Anderson) I have it.

(Pause.)

JUDGE BRENNER: I think they're waiting for you, Mr. Farley.

MR. FARLEY: I beg your pardon.

BY MR. FARLEY:

Q Dr. Anderson, you referred to this morning report

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in your original prefiled testimony at Page 175, didn't you?

A (Witness Anderson) Yes. I see that reference on page 147, Reference 168.

JUDGE BRENNER: You asked him about 175, didn't you?

MR. FARLEY: Yes, sir.

JUDGE BRENNER: Turn to page 175, Dr. Anderson.

WITNESS ANDERSON: Yes.

BY MR. FARLEY:

Q Dr. Anderson, is it true that you have not made any independent investigation or verification of any of the data that is purportedly reflected in Suffolk County Exhibit 55?

A (Witness Anderson) Could I have that question again? I'm not sure I understand it.

Q In your original prefiled testimony you referred to this morning report,--

A Correct.

Q --isn't that right?

A Yes.

Q Secondly, that morning report has been introduced in evidence as Suffolk County Exhibit 55, has it not?

A Yes, it is.

Q Now, my question was: Have you made any independent investigation or check on any of the information

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that is contained in Suffolk County Exhibit 55?

A No, I have not.

A (Witness Hubbard) Mr. Farley, I would like to supplemnt that answer.

MR. FARLEY: Judge, I object. Mr. Hubbard is not a sponsor of this--

WITNESS HUBBARD: Yes, I am.

JUDGE BRENNER: Wait, Mr. Hubbard. I told you I'm tired of administrative proceedings -- "you" meaning everyone in the courtroom, not just you, Mr. Hubbard -- administrative proceedings becoming somewhere where witnesses argue and everybody else testifies.

Do you want to follow up with Dr. Anderson immediately on this point, Mr. Farley?

MR. FARLEY: Yes, sir.

JUDGE BRENNER: All right. Go ahead, but don't carry it for too long a time, and then we'll let Mr. Hubbard supplement.

BY MR. FARLEY:

Q So it is true, is it not, Dr. Anderson, that you don't know whether the information contained in Suffolk County Exhibit 55 is accurate or reliable?

A (Witness Anderson) That's correct. I have no knowledge of the veracity of the people that were responsible for it; there are no crack maps that have been

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provided; the details are sketchy at best, and I do not know the importance of this document with respect to was it taken under oath. I just don't know those details.

Q Now, if you want, Mr. Hubbard.-

MR. FARLEY: Your Honor, I'm reading to move.

WITNESS HUBBARD: Judge Brenner, Dr. Anderson covered what I wanted to say, which had to do with the lack of camshaft gallery crack maps, but we tried to independently determine if the cracks had grown. And there's no information concerning camshaft gallery crack mapping in the FaAA reports or in any documents provided to us.

MR. FARLEY: Judge Brenner, I'm now on pages 82 and 83 of my original cross plan.

BY MR. FARLEY:

Q This question is directed to Mr. Eley.

Mr. Eley, in your testimony at page 176 you state that if the cam gallery cracks propagate the first effect will be increased flexing of the camshaft; isn't that correct?

A (Witness Eley) Yes, that's correct.

Q And the same subject is addressed, is it not, Mr. Eley, at pages 5 and 6 of the County's rebuttal testimony?

JUDGE BRENNER: Mr. Eley, I don't understand why

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your answer is taking that long.

WITNESS ELEY: Yes, that's true.

BY MR. FARLEY:

Q Isn't it true, Mr. Eley, that the main support for the camshaft comes from the continuous web below the cam saddle, and only a small amount away from the area where the cracks have been identified?

A (Witness Eley) The support for the camshaft is underneath the crack area, yes.

Q Professor Christensen, you're also a sponsor of the same testimony that I asked Mr. Eley about. Do you agree with his answer, his last answer?

A (Witness Christensen) Yes.

MR. FARLEY: These questions will be directed to either Mr. Eley or Professor Christensen, Judge Brenner.

BY MR. FARLEY:

Q Can either of you tell me whether you have performed any analysis, or have any calculations to establish how much the cracks in the cam gallery are must propagate before they will cause this increased flexing of the camshaft?

A (Witness Eley) No, I have not performed a calculation on that.

A (Witness Christensen) No, I have not performed any calculations on that.

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Q Have either of you performed any calculations to demonstrate how much increased flexing of the camshaft occurs as cracks propagate?

A (Witness Eley) No.

A (Witness Christensen) No, I have not done any calculations in that area.

Q Mr. Bakshi was formerly a sponsor of this area of your testimony. Do you know if he performed any analysis, or had any calculations in connection with this camshaft flexing?

A (Witness Eley) I don't recollect whether he has or not, but I don't think so.

Q Mr. Eley or Professor Christensen, do either of you have any calculations to support the conclusion that the load on the adjacent bearings to the camshaft increases as cracks propagate?

A I have not performed a calculation on that, no.

A (Witness Christensen) I have not performed any calculations on that. But it is obvious from engineering experience that if you have a shaft supported on three bearings and the support from the center bearing is reduced, the load must obviously increase on the other supports.

Q Professor Christensen, do you have any facts or data which shows any unloading of one bearing?

A No; this is based on life's experience dealing

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with line shafting and bearings in every area. If one bearing ceases to support its proper weight, the weight from the -- and when I say "weight" I mean not only the gravitational weight but the loadings coming on the other bearings must increase. This is a known fact, it doesn't need any calculations.

Q Mr. Eley or Professor Christensen, have either of you made any calculations to support your allegation that increasing the load on the adjacent bearings will increase the propagation rates of cracks in these locations?

A I have not done any calculations but again if you have a crack and you are increasing the loads that the material around that crack is supporting, there is every chance that that crack will grow. When I say "chance," one might forecast it and say that it will grow.

Q Mr. Eley, do you have any --

A (Witness Eley) I have not performed an independent calculation on that, no.

Q Mr. Eley and Professor Christensen, is it also true that you do not have any calculations to demonstrate your allegation that as flexing of the camshaft takes place the load on the cylinder where the camshaft flexing is occurring will be reduced?

A (Witness Christensen) I have not done any calculations in that area. But if a shaft, particularly the

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cam for the fuel pump which is adjacent to a bearing, if there is increasing flexing there the lift of the fuel pump will not be what it should be and there will be a reduction in load from that cylinder unit because the amount of fuel discharged into the cylinder will be reduced and that will cause the reduction in the load.

Q Do you have any calculations, Mr. Eley?

A (Witness Eley) I have not calculated that, no.

Q Mr. Eley and Professor Christensen, is it true that you have no basis to assume that any one bearing is unloaded by cam gallery cracks of the size indicated in any of the engines at Shoreham?

A (Witness Christensen) I couldn't quite understand the question, I'm sorry.

Q I will repeat it for you.

Do you or Mr. Eley have any basis to assume that any one bearing is unloaded by the cam gallery cracks of the size indicated at Shoreham?

A I'm afraid I get to the end of the question but I can't remember the first part. I can't quite see what you're getting at, sir.

JUDGE BRENNER: Mr. Eley, can you answer the question?

WITNESS ELEY: The size of the crack would obviously be a critical factor in how much support was given

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to the camshaft. If the crack was extensive it could cause that flexing of that camshaft.

BY MR. FARLEY:

Q Mr. Eley --

A. (Witness Eley) If that crankshaft -- sorry, if the camshaft then flexes then there would be some change in the loading on the engine because of the difference in loadings in the bearings.

Q In making your assumption that any one bearing is unloaded by cam gallery cracks, did you assume a particular size of crack?

You said the size of the crack was important.

A Yes, my recollections of various size -- I did see the cracking on the original EDG 103 block and I saw the holes that were drilled in the cam gallery regions on the EDG 103 and I looked down those holes and saw the extent of that cracking there and that did give me cause for concern of the integrity of the camshaft support.

I have not seen EDG 101 or 102 but I have seen some of the information on the crack depths. One of them was, if my memory serves me correctly, 0.325 inches deep, another figures that comes to mind was on the original EDG 103 block which was I believe about .863 if my memory serves me correctly. And that one gave me cause for concern because the total thickness of the block in that region

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being one and a quarter inches.

Q Mr. Eley and Professor Christensen, would you please tell me, if you can, the size of the crack that you assumed in the cam gallery area that would cause the flexing that you have testified about?

A No.

A (Witness Christensen) I can't say for the size of the crack but I think we can say this, that when we are balancing an engine for the amount of power developed in each cylinder, we only have to make very, very small changes to the fuel pump setting before we get quite a response in the power generated and it would only take small amounts of movement to throw the balance of power out between the cylinders.

Q Professor Christensen and Mr. Eley, it is true, is it not, that you do not have any calculations to demonstrate the amount of load increase that occurs on other cylinders when the load on the cylinder where the camshaft is flexing is released?

A (Witness Eley) I do not have a calculation on that, no.

A (Witness Christensen) No, I do not have a calculation on it except to repeat what I said just now, a small amount of movement can affect the power balance quite considerably.

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Q Do either one of you have any calculations to demonstrate the amount of load increase -- strike that.

Do either of you have any calculations predicting the amount of cylinder imbalance that can be tolerated before the EDGs will fail to perform their intended function?

A No, I have not made any calculations. The reason that I have not made any calculations is because, a, it would be impossible for me to get what I would call adequate input in order to make the calculations. So far as I'm concerned any crack anywhere in a block is dangerous whether it be in compression or whether it be in tension because usually speaking when we have something in compression, particularly in such a complicated area as we are speaking of at the moment in the support of the camshaft bearings, unless that whole area was adequately strain gaged you might not be aware of where there are some tensions showing which will be additive to any initial stresses which come about from the cooling of the castings.

We are working in such a complicated area it would be impossible to make the calculations and the only thing we can say, it is a very dangerous area, if there is cracks then we can usually say this which we have just spoken about.

A (Witness Eley) I believe that TDI does have

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a toleration limit for imbalance on their engine and if my memory serves me correctly it is an imbalance maximum pressure of 200 psi between two cylinders. I have not performed the calculation as to detail and how much the flexing of the crankshaft would cause an imbalance to each cylinder.

Q Do you or Professor Christensen have any calculations of the amount of the load, of the bearing load which is supported by the cam gallery fillet in the area where the cracks have been identified?

A Would you repeat that question, please?

Q Do you or Professor Christensen have any calculations of the amount of the bearing load which is supported by the cam gallery fillet in the area where the cracks have been identified?

A No, all we say in our testimony is that the loading would be reduced. And we also say -- sorry, that's on the cylinders.

And we also say that the flexing will increase the load on the adjacent bearings but we don't say how much.

Q Isn't it true, Mr. Eley and Professor Christensen, that in the service history of the original 103 it was demonstrated that there were no operational problems associated with the camshaft as a result of the cam gallery cracks that were measured to be as deep as .91 inches?

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A (Witness Christensen) There have been no problems reported to us but whether there have been any problems we wouldn't know.

A (Witness Eley) If I had a cylinder block with a 0.91 inch depth crack in the region of the cam gallery it would be cause for concern. I would be very, very apprehensive about whether it would propagate through into the jacket water system.

Q Mr. Eley, you are familiar with the service history of the original 103 block, are you not?

A Yes.

Q Based on that service history, did the 103 block ever demonstrate any of these problems that you are concerned about?

A Not that I'm aware of.

Q All right, sir.

MR. FARLEY: Judge Brenner, I am now moving back to page eight of my supplementary cross plan.

BY MR. FARLEY:

Q Dr. Anderson, it is true, isn't it, that when you examined the samples from the original EDG 103 the maximum depth of the circumferential crack did not exceed 3/8ths inch?

A (Witness Anderson) I can't answer that because when I examined it there was no ruler available for me to

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measure it.

Q Dr. Anderson, would you please look at pages 11 and 12 of your supplementary testimony and confirm for me that you did refer to the 3/8th-inch crack on the top of page 12 and the bottom of page 11?

A On the supplementary?

Q Yes, sir. It is your answer to question 18.

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(Pause.)

A Yes, I think on page 11 I attribute the 3/8ths inch diameter to Failure Analysis. I say "....which Failure Analysis says is 3/8ths." I had no independent measure of that crack in question.

Q When you examined the samples from the original 103 block, you did not ascertain that the maximum depth of the circumferential crack was 3/8ths inches?

A I did not measure it.

Q Dr. Anderson, at the time you examined the samples from the original EDG 103, were the surfaces polished metallographically where the circumferential cracks were visible in profile?

A No, the circumferential crack that I have in mind was not polished metallographically nor etched.

Q And isn't it true, Dr. Anderson, that when you examined the circumferential cracks in Palo Alto at the offices of FaAA, you did not use any non-destructive testing methods to measure the depth of the circumferential crack or any crack?

A That's correct, I did not use non-destructive crack analysis techniques.

Q You just looked at them visually under a microscope. Is that right?

A That's right.

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Q It is true, isn't it, Dr. Anderson, that the circumferential cracks in the original EDG 103 did not impair the operation of that engine during its service history?

A I don't know. I haven't done an engine study. I would have to defer to my colleagues.

Q This is directed to Dr. Anderson and Mr. Eley and Professor Christensen.

It is true, isn't it, that none of you have performed any calculations to determine the stress state in the cylinder liner landing area where the circumferential cracks were observed in the original EDG 103?

A (Witness Christensen) I have not made any calculations in this area, no.

A (Witness Eley) I would just say that Mr. Bakshi did do some calculations with regard to this which were not submitted because of the fact that we had to use some temperatures on the R-5 engine -- R-5 block rather than the EDG 103, so our Counsel advised us not to submit that data.

A (Witness Anderson) No, I haven't done an independent calculation.

Q Again this is directed to Dr. Anderson and Mr. Eley and Professor Christensen.

It is true, isn't it, that since you have not performed any calculations, you do not know that the

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stresses become fully compressive at some distance from the corner of the liner landing where the circumferential cracks initiated in the original 103?

A (Witness Christensen) No, I don't know of these things that you state, nor has anything, to my knowledge, been produced to show that it is there.

We, if I may carry on, are talking about a crack in an area where further propagation of the crack could cause great distress to the engine. Nobody can forecast where these cracks will run in the cylinder block in any place. The reason that you cannot forecast where they will run is tied up to the fact that we don't know that the material is homogenous in the first place.

In the next place, due to the complexity of the geometry of the parts there, we cannot make forecasts because we cannot get the correct input data to do any mathematical calculations which would be worth anything. They would be more or less surmises, based on assumptions which are put into the calculations, and I don't think they would be valid because we would not be able to make valid assumptions.

This is one of the reasons why I have not made any calculations in these areas which you are speaking about now and earlier.

Q Mr. Eley?

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A (Witness Eley) Again if my memory serves me correctly, I believe in one of the FaAA reports it did specify that the stress from the top of the block as it went down-- In one of their reports it says that it didn't change a great deal, and then in a later report, it said that the 3/8ths crack did grow decreasingly. So it was a bit confusing to us, I think. One said one thing, and one the other.

Q Are you aware now, Mr. Eley, that FaAA has performed two- and three-dimensional finite-element stress analysis which showed that the stresses become fully compressive?

A Yes, I am.

Q Are you familiar with those, Professor Christensen?

A (Witness Christensen) I am familiar with what has been shown in their reports, yes.

Q Do you have any reason to disagree with them?

A Yes. I have often stated about input data before and again, the finite-element analysis is only as good as the input data to it. In drawing up the grid which is used to forecast stresses and strains in these areas, there is a lot of experience needed.

I have been in diesel engines for a considerable number of years and I have looked at some of the grids

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produced by FaAA and I have looked at similar grids produced by diesel engine manufacturers in similar areas, and particularly in the crankshaft area.

And I find that there is great divergence between what FaAA has produced and what engine builders with masses of experience in these areas have produced. There is too much divergence here for me to say that the FaAA figures are valid.

Further, most of the material that I have seen from FaAA, I have not been able to make an evaluation on it because they have never given us enough data to make a valid evaluation on what they have produced.

MR. FARLEY: Judge Brenner, if the Board pleases, I would move to strike that answer as not being responsive.

JUDGE BRENNER: I don't think it is going to be necessary. We will only view it as it substantively may or may not answer the question.

BY MR. FARLEY:

Q Professor Christensen, is it true, isn't it,--

JUDGE BRENNER: Let me add, Mr. Farley,--

MR. FARLEY: Excuse me, Judge.

JUDGE BRENNER: It's my fault. This is an afterthought: or otherwise supplies some substantive information.

BY MR. FARLEY:

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Q Professor Christensen, it is true, isn't it, that you are not an expert by training, knowledge, education or experience in finite-element stress analysis?

A (Witness Christensen) I am not an expert in that area, no, but I am well-qualified to validate work that has been done in that area.

Q Mr. Eley, it is true, isn't it, that the circumferential crack on the original EDG 103 at Shoreham did not cause any operational problem based on its service history?

A (Witness Eley) I don't know.

Q Dr. Anderson, you haven't performed any calculations that demonstrate that the state of stress in a liner landing is not fully compressive below a depth of 3/8th inch, have you?

A (Witness Anderson) No, I haven't, nor have I seen definitive analysis or measurements in that area.

I have seen some documentation by Failure Analysis but it was a handwritten holographic notes.

Q Do you know, Dr. Anderson, how deep below the block top do the stud bosses extend?

A No, I don't.

Q It is true, is it not, Dr. Anderson, that in fact each of the bosses supports the cylinder liner land?

A I'm not familiar with the configuration beyond

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essentially the top and what I've looked at of that area.

Q You did not consider it relevant or material to become familiar with the geometry of the entire area other than the block top?

A No, I didn't say-- I meant the top of the cam galleries, the area that I inspected, which would inlcude the block top, but that's not the "top" I was referring to.

Q And you did not become familiar with whether or not the bosses support the cylinder liner land?

A Not really. I had an opportunity to look at the physical specimens and I got some familiarity with the geometry, but I still am not clear on completely how this is shaped below.

Q Well, Dr. Anderson, isn't it true that it is important in reaching a conclusion about the possible consequences of circumferential cracks to have evaluated the effects of the stud bosses and the gussets?

A I would think so, and that's why we have experts on this panel that are intimately familiar with all aspects of the design of the engine. And therefore, in that consideration in how it goes together and its operation, I rely very strongly on their information.

Q So this is directed to you, Dr. Anderson, and to you, Mr. Eley and Professor Christensen:

It is true, isn't it, that none of you have

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performed any analyses to determine the type of stresses that are present in the stud bosses or the gussets which support the liner landing ledge?

A (Witness Christensen) In my case, yes, I have done some analysis in that area.

Q What have you done?

A I looked at the amount of the stud boss which was supporting the ring of materials cast in which comes underneath the lip of the top of the liner. And so far as I can recall, the area which is supporting that is something of the order of about two inches wide by two inches deep with a semicircle radius of one inch beneath there.

And if we look at the amount of material there in that area and we start looking at stresses that are coming onto there, we're coming onto stresses which could evaluate to cracks propagating, in my opinion.

Q Is that just an assumption by you about the stresses?

A No. I roughed out some figures based on a shear stress -- an allowable shrear stress. I can't remember what the figure was. It was based on some percentage of the tensile stress for that iron.

And it came out to figures there which, if failure did come through from circumferential cracks, you could have problems there.

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Q Did Counsel for Suffolk County bring to your attention a request by LILCO that you produce any calculations or data?

A These were what I would call scratchpad calculations, just to look at something to get some idea of values. They were not full-run calculations where I had measured everything up like I did with the case of the side thrust on the piston which were produced. These were what I would call scratchpad calculations to give you some idea of figures and values.

Q Mr. Eley, do you remember my question?

A (Witness Eley) It was combinations that I referred to earlier which we submitted to Counsel. They advised us of the limitation of those calculations because of the fact that we were lacking some information with regard to the temperatures, et cetera, and we were using something an awful lot better and that told us what was wrong with that information.

Q Dr. Anderson, have you performed any analysis?

A (Witness Anderson) No, I haven't.

Q Do you remember the question?

A Yes, I do.

No, I haven't.

Q This is--

JUDGE BRENNER: I'm a bit confused.

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Professor Christensen, the calculations that you have just described, are those the same ones that Mr. Eley is referring to, part of the same package?

WITNESS CHRISTENSEN: No, I don't think so because we worked independently in that area, and this was something that I have done subsequently.

WITNESS ELEY: These calculations I am referring to, Judge Brenner, were done by my staff, Mr. Aneesh Bakshi.

BY MR. FARLEY:

Q Professor Christensen, how wide are the bosses?

A (Witness Christensen) The bosses' width is a variable from the outer circumference of the area in which we are speaking down to a place which is machined on, and from the drawing appears to be machined on and will come out the given nominal measurement of two inches wide, I think on the innermost radius. And that looks to be an area which is machined to allow coolant to come up between the liner and the block.

The geometry is difficult to describe, but I am going to say this: The amount of support to the cylinder liner is far from being the whole of the stud bossing area. It is only a very, very small part of the area of that stud bossing which supports the cylinder liner flange.

Q Do you know how wide the bosses are at the block top?

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A No, I cannot carry every measurement in my head. But as I mentioned, they do get progressively wider out, but we were looking at an area which is supporting the cylinder liner. And that's the area which I'm referring to which is two inches wide, or shown as a nominal two inches after machining in the block drawing.

Q This question is directed to Dr. Anderson and Mr. Eley and Professor Christensen:

It is true, isn't it, that none of you know at what positions there are compressive or tensile stresses in the stud bosses or the gussets?

A I would have some area, yes, by examination.

Q Can you tell me today?

A No, not unless I have the drawings in front of me, but in some respects we can look at it as a reversed cantilever and we know that we will have tensile/compressive stresses there. It is a complex stress that the area is subjected to.

Q Mr. Eley, do you remember the question?

A (Witness Eley) Would you repeat it, please?

Q It is true, isn't it, Mr. Eley, that you do not have or you do not know at what positions there are compressive or tensile stresses in the stud bosses or the gussets?

A That is true.

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JUDGE BRENNER: Professor Christensen, could you take a look at LILCO's Exhibit B-9, the drawing, the schematic?

WITNESS CHRISTENSEN: I'm afraid we don't have it -- we have that one, yes. We have one similar to that.

JUDGE BRENNER: You can look at something called Staff Diesel Exhibit 10 also, either one.

WITNESS CHRISTENSEN: That is Figure 113, Judge Brenner, that I have.

(Witness Christensen displaying document.)

JUDGE BRENNER: That's right. It comes out of the FaAA report also.

Your previous answer indicated I thought -- or at least one reading the record might infer that you could answer the question but you had difficulty doing so without describing the geometry or words to that effect.

Could you answer the question with reference to this schematic?

WITNESS CHRISTENSEN: Yes....

JUDGE BRENNER: The question, to rephrase it -- and Mr. Farley can correct me if I ruin it for him -- is the location of the stresses in the gusset or stud boss area and characterize them as tensile or compressive.

WITNESS CHRISTENSEN: Yes, as I mentioned earlier, Judge Brenner, the area is in a state of complex

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stress because you have a vertical pull on the stud coming up which is resisted by the gasket which is on the -- partially covering the liner and coming partly onto the block which does complicate very, very much any analysis of stress in that area. Then you have a load which, according to documentation which I have read on the inner gasket of the inner radius which takes the compressive load earlier, that puts a stress down there depending on the clearances at the bottom there. You have a shear stress coming directly underneath the support, you have a compressive stress coming away from it, you have tensile stresses coming up from the bottom of it and, as I mentioned earlier, due to the fact that you have bending moments and pulls, it is a difficult area to formulate what the stresses are.

In fact, I can go on and say that this area is one of the most problemmatical areas in an engine block design and the reason why they have departed in all modern engines away from this basic design, mainly because the calculation and the finding of stresses in this area is so difficult, it is in a complex state of stress there. But I think that I have enumerated what the various stresses would be in that area.

One of the things I would like to mention here when we are talking about block support and stresses, everybody is talking about the stud bossing and the support

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that that gives, I think one of the things that we must remember is that the part of the liner which is sitting on there is an area which is about two inches wide by two inches deep by a semicircle at the bottom of a one-inch radius if I remember correctly the dimensions, that is introducing a shear load there.

We know that shear loads bring in tensiles and compressions and we also know that failures, when they do occur in this area -- as they have occurred in older engines when they have been operated -- what will happen on one cylinder could be different on another cylinder and it is very difficult to forecast either by calculation or by examination which way the stresses will run. We have already seen that cracks are occurring in these areas and I think that is an indication of the complexity of the stresses because every stud is not getting a crack, others are, some are not, it is a difficult area to analyze.

BY MR. FARLEY:

Q Dr. Anderson and Mr. Eley and Professor Christensen, it is true, isn't it, that you do not know -- or that none of you have performed any calculations to determine how deep a circumferential crack would have to grow before the block stiffness would decrease sufficiently to permit significant up and down movement of the cylinder liner?

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A (Witness Christensen) The amount of cracking that would have to come there would be relatively small before you got up and down movement of the liner on one side.

One of the things that we must rule out here is that the whole of the liner must move up and down because it doesn't normally do so if you get a crack in that area. You may find that only one side of the liner starts to move from the strains and when that occurs then we can build up quite a lot of scenarios of devastating failure occurring soon afterwards and we would only have to have a very small amount of movement to occur here.

MR. FARLEY: Excuse me, Professor.

I asked him if he had any calculations.

JUDGE BRENNER: I think he is explaining his views nevertheless and I am going to allow him to do that.

MR. FARLEY: I apologize for interrupting.

WITNESS CHRISTENSEN: No, I have said before that in this area due to the complexity of the stress it is virtually impossible to make calculations which have any validity. We are dealing in an area which has very, very high stress. I have not made any calculations; I have given the reasons.

But what I would like to say is this: that any crack in this area must be regarded as being highly

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dangerous and lead to further dangers where we can run into the areas of failure whereby the engine would shut itself down or would have to be shut down to stop it breaking itself up.

BY MR. FARLEY:

Q Mr. Eley, do you have any calculations of data?

A (Witness Eley) I have not done a calculation on this area, but....

Q Have you, Dr. Anderson --

A Sorry, I haven't finished.

Q I'm sorry.

A There is a lot of pressure in this particular area due to the combustion gases. And when that pressure is at its highest and a crack is there, a circumferential crack is there, there is the possibility that that crack will move open and closed. And when that happens there will be movement, I feel. The depth of that -- before that would happen, the depth of that crack, I don't know what the depth would be, but it does bother me that the integrity of the block is lost when that liner landing face does have a crack in it. If the crack does extend to a depth where it does cause that fluctuation then there could be problems, that's what we're saying.

Q Dr. Anderson, have you made any calculations or do you have any data?

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A (Witness Anderson) No.

Q Isn't it true, Mr. Eley, that the circumferential crack in the old 103 block did not extend beyond 3/8ths inches deep, do you know that?

A (Witness Eley) I don't know that, no.

Q Do you know that, Professor Christensen?

A (Witness Christensen) Only from what has been put in the reports.

Q Okay.

So from what has been put in the record in addition to that depth of that circumferential crack do you know that that old 103 block had degenerate Widmanstaetten graphite that is of an inferior fracture property than 101 and 102?

A I was aware of that fact from the reports, yes.

Q And were you also aware that the old or the original 103 block had operated for approximately 1000 hours of operation?

A I was aware of that fact, the approximate number of hours, yes.

Q And were you aware that it had operated at loads at or above 3500 Kw?

A I was aware of that fact, yes.

Q Dr. Anderson or Mr. Eley or Professor Christensen, please confirm for me that it is also the fact

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that none of you have performed any calculations to determine the direction in which a circumferential crack would extend, have you?

A No, I have not performed any calculations in this area but I would like to go on and say further that any crack of this nature, together with the other cracks in the upper part of the cylinder block, I regard, based on many, many years of experience, as being dangerous.

I have said earlier that nobody can make calculations regarding growth rate of cracks or where cracks are likely to run because you cannot obtain or derive what I would call valid input data. And whenever we are running an engine with cracks of this nature in the block, we are running the engine at great risk, at far greater risks than we would consider in the marine field. In the marine field, if we had this type of crack we would want to know why, we would also start looking at changing designs, changing blocks and making a whole program to bring the thing about safely.

But here we are talking about running an engine with cracks in it in such an area of what I would call responsibility -- I believe I said once earlier that I don't know of any diesel engine which is called upon to do a more rigorous job than what these engines might be called upon to do. And to contemplate running an engine into the area of

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a loop LOCA situation with cracks in the block like this is running enormous risks, risks that we wouldn't take in the marine field.

MR. FARLEY: Your Honor --

JUDGE BRENNER: Professor Christensen --

MR. FARLEY: -- I move to strike.

JUDGE BRENNER: Granted.

You are going to have to keep your answers to the questions -- we were very liberal, I believe, in terms of giving you room to explain things but you didn't explain your answer there, you just used it as an occasion to state a lot of other things in a rather long-winded fashion -- I hope you will forgive me for pointing it out but I am worried about the future pace of the proceeding. And not only was it beyond the question but you repeated yourself several times within that answer.

So the motion is granted.

Mr. Farley, did you want to ask the other witnesses --

MR. FARLEY: Yes.

BY MR. FARLEY:

Q Dr. Anderson --

MR. BRIGATI: Excuse me, Judge. Is the entirety of his answer stricken?

JUDGE BRENNER: Yes.

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MR. BRIGATI: May I be heard on it?

JUDGE BRENNER: No. Come back on redirect if you find some nugget in there. It's not going to be my job to pull out the one partial phrase that might be pertinent when there is an answer that long, but you certainly have the right and freedom to do that on redirect.

BY MR. FARLEY:

Q Mr. Eley, is it true that you have not performed any calculations to determine the direction in which a circumferential crack would extend?

A (Witness Eley) That is correct, but....

One of the things that bothers me is the statement that was made by Mr. Anderson on pages 11 and 12 of the supplemental testimony where he said that that 3/8th inch cracks had at the base of them small, discrete cracks branching out into the cast iron material. And that is one of the areas that gave me cause for concern, the fact that the branching out is taking place and who is to know which way that crack is going to propagate.

Q But you don't know anything about those cracks other than what Dr. Anderson has told you, isn't that right?

A I did see the cracks, as I told you, on EDG 103. I did look at them on the old block.

Q You didn't see these cracks that Dr. Anderson is referring to in his supplemental testimony that allegedly

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branched out?

A No, I did not.

Q Dr. Anderson, have you done any calculations to determine the direction in which a circumferential crack would extend?

A (Witness Anderson) No, I have not examined the direction or its tendency to branch. I have not done the analytics behind that.

Q All right, sir.

MR. FARLEY: Judge Brenner, I am now turning to pages 9 and 10, paragraph B-3, of the supplemental cross plan.

BY MR. FARLEY:

Q Mr. Eley, is it also true that you have not performed any calculations to determine how deep a circumferential crack would have to propagate before the head-to-liner seal could leak sufficient combustion gases to require a shutdown?

A (Witness Eley) The calculation to do that, no.

Q Professor Christensen, have you?

A No, I have not done any calculations in that area, but I would like to go on and say that a considerable danger would arise from various causes if the inner seal leaked.

Q Dr. Anderson, do you have any calculations?

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A (Witness Anderson) No.

MR. FARLEY: I'm sorry, Judge, now I am going to pages 62 to 66 of the original cross plan.

JUDGE BRENNER: That's okay, as long as you keep telling us as you have been doing I'm having no difficulty.

BY MR. FARLEY:

Q Mr. Eley, is it also true that none of the EDGs at Shoreham ever leaked any coolant water, including the original EDG 103?

A (Witness Eley) I don't know.

Q Is it true -- strike that.

Mr. Eley, how deep would a ligament crack have to propagate on the cylinder liner counterbore side of the ligament before it could reach the coolant water system of the EDG?

A This is from the top of the block landing face?

Q Yes.

A -- into the jacket water system?

Q Yes.

A I don't recollect the dimension of the one, but I do believe that there was a crack measured in-between the studs which was 4-1/2 inches deep and that didn't leak.

Q Mr. Eley, could I have your attention, please?

A Sure.

Q Is it true that even if the coolant water were

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leaked by a ligament crack water would seep to the block top and out between the heads?

A Yes, it would.

Q And this would not affect engine operation, would it?

A That would depend on how large the leak was. If you've got a really large leak and the jacket water system was depleted of water, you would get overheating.

Q I asked you to assume that it was just seeping out of the ligament crack.

A A seepage out of the ligament crack onto the block and not into the combustion space?

Q Yes.

That would not affect engine operation, would it?

A As long as the makeup water was continuously supplied and the engine was continuously filled with water.

Q Do I correctly understand, Mr. Eley, that you have not performed any analysis of stresses in the area below the liner landing on the cylinder liner side of the ligament?

A Other than those calculations that I have previously referred to which we have not submitted here, no.

Q And Mr. Eley, as a result you do not know, do you, whether the stresses in the area below the liner

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landing on the cylinder liner side of the ligament would permit crack propagation below the liner landing to the depth necessary to permit a ligament crack to leak coolant water?

(Pause.)

A I wonder if you might repeat that question to me.

Q Yes, sir.

You do not know whether the stresses in the area below the liner landing on the cylinder liner side of the ligament would permit crack propagation below the liner landing to a depth necessary to permit a ligament crack to leak coolant water?

A I don't have information as to what that stress value would be but it does concern me that there are cracks in that region which may give that result.

Q All right, sir.

A (Witness Bridenbaugh) Mr. Farley, could I supplement that, please?

MR. FARLEY: I don't believe he is a sponsor of this testimony, your Honor.

JUDGE BRENNER: Let's see what he has to say because some of the testimony overlaps, even though you were asking about a particular answer here.

WITNESS BRIDENBAUGH: I was referring to the original testimony at page 152 where we do discuss leakage

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of coolant through ligament cracks.

I merely wanted to point out that some of the ligament cracks that are shown on, I believe it is LILCO Exhibit B-25, shows that a number of these cracks are 1-1/2 inches deep which I believe is the depth of the liner landing and at least one of the cracks is 1.6 inches deep. If the crack does get down to the liner landing area, it is my belief that there is no seal between the outer circumference of the liner below that landing area and therefore it would be possible for leakage to progress through that crack if it were down to the landing face.

BY MR. FARLEY:

Q Mr. Bridenbaugh, all I was asking was if you had any calculations or if you knew whether the stresses in the area below the liner landing would permit the crack propagation?

A (Witness Bridenbaugh) I'm sorry, I thought you were after whether the cracks could leak.

Q No, sir. I was after the stresses.

A I have no information on the stresses.

Q Mr. Eley, you have stated in your prefiled testimony that the coolant water could leak rapidly from ligament cracks because the coolant water is exposed to a pressure of 40 psi, isn't that correct?

A (Witness Eley) That's correct but it is

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incorrect, if I may say so.

Q All right, sir.

A We have investigated that and found that the pressure is running about the region of 30 psi but my views don't change any.

Q Excuse me, what was the rate?

A 30 psi. I believe somebody called it 25 psi in court earlier.

The point I was trying to make is that the system is under pressure.

Q Would you also agree that the leakage rate of coolant water is directly proportional to the coolant water pressure and crack opening?

A Yes.

MR. FARLEY: Excuse me a minute, Judge Brenner.

JUDGE BRENNER: I was going to take the afternoon break in the next 10 minutes, would you prefer it now?

MR. FARLEY: That would be convenient, Judge, and I might be able to eliminate some of these.

JUDGE BRENNER: Let's break until 3:00.

(Recess.)

WRBbrb

JUDGE BRENNER: You may continue whenever you are ready, Mr. Farley.

MR. FARLEY: Thank you, Judge.

BY MR. FARLEY:

Q Mr. Eley, isn't it true that there is a low-level coolant alarm, and the existence of make-up water capacity that can be added to the Shoreham EDGs while the engine is operating?

A (Witness Eley) That's correct -- as on most diesel engines.

Q And isn't it true that for leakage from ligament cracks to become critical the leakage rate through the crack must have to exceed the make-up rate?

A To get depletion in the water supply in the system, yes, it would.

MR. FARLEY: Judge Brenner, I'm now focussing on pages 74 to 78 of the original cross plan.

BY MR. FARLEY:

Q Dr. Anderson, can you tell me at what temperature the degenerate Widmanstaetten graphite forms during the casting process?

A (Witness Anderson) There is no single temperature that it forms at. It forms as a result of a cooling rate which is not at a temperature. It is passing through at a certain rate.

WRBbrb

Q Well, doesn't it form or doesn't it occur between the eutectic and the eutectoid temperatures?

A Well, that would put it between 727 degrees Centigrade and 1123, and that would be a likely area that I would expect it to form. But I can't give you a temperature because it's a temperature range.

I could go through that area at a different rate and not have anything form.

Q I see. So you cannot tell me today at what temperature degenerate Widmanstaetten graphite forms?

A It's not that I cannot tell you; it's that it cannot be told.

Q Assuming that it cools slowly over several days, can you tell me at what temperature it would occur?

A All sections of the block? We're talking about a block, still, so all sections of the block?

Q Assume the block top.

A And we're talking somewhere between two and four percent carbon?

Q Three.

A Three? By weight?

Q Yes.

A Okay. And we're talking about forming the structure of carbon which is the large form crystallographically-oriented structure? I still can't tell

WRBbrb

you because there's a question of the cooling parameters which aren't known in that block. I believe the Staff previously indicated that you'd have to put instrumentation in there to get the cooling rate.

JUDGE BRENNER: Dr. Anderson, you remind me of the customer who goes into an ice cream parlor with 27 flavors and has them run through all flavors and has them run through all flavors and then orders vanilla.

(Laughter.)

WITNESS ANDERSON: I do like vanilla, Judge.

(Laughter.)

JUDGE BRENNER: If it's not going to matter, you know, you can get right to the answer next time.

WITNESS ANDERSON: I'll keep that in mind.

JUDGE BRENNER: Good.

BY MR. FARLEY:

Q Dr. Anderson, let me ask you this: does it form completely at the eutectic temperature?

A (Witness Anderson) No.

Q All right.

Do you know what the eutectic temperature is?

A Yes.

Q What is it?

A I gave it to you.

Q All right.

WRBbrb

JUDGE BRENNER: Well, Dr. Anderson, I don't know what it is, and I'll tell you my problem. You gave us the range, and I don't know whether the eutectic temperature is the higher one or the eutectoid temperature is the higher one.

WITNESS ANDERSON: Oh. I thought I clearly said that the eutectoid was 727 degrees --

JUDGE BRENNER: Actually, you said 723; but go ahead.

WITNESS ANDERSON: Well, there's two: 727 and 1123, and 1123 is the higher in the eutectic.

BY MR. FARLEY:

Q That's degrees Centigrade?

A (Witness Anderson) Yes.

Q What would that convert to Farenheit?

A Multiply it by 1.8 and add 32.

Q All right.

Dr. Anderson, does the degenerate Widmanstaetten graphite form at any temperatures below the eutectic temperature?

A Below the eutectic temperature? Yes.

Q Does it form below the eutectoid temperature?

A I don't see how it could, no.

Q Does it form over a wide range of temperatures, if you know?

WRBbrb

A I think that was the point that I was trying to make, that there is not a particular temperature that I can say before that temperature arrived, we had no degenerate carbon structure and after that temperature we did. That was my point. Nobody can say precisely what the temperature is. It's a cooling rate, and therefore a range of temperatures.

Q Now, it is true, is it not, Dr. Anderson, that on November the second, when you were here, you testified that Widmanstaetten graphite forms under faster cooling rates?

A Yes. I believe that's well accepted.

Q All right, sir. What did you mean by "faster cooling rates"?

A Well, that's not a very definitive way of explaining it. If one held the temperature for some period of time, say, as in a soaking furnace, and did not allow the temperature to cool very rapidly, then you would not get that structure. You would get more of an equilibrium structure, a perlite or bainite. If you have a more rapid cooling, which would keeping the mold in air and letting it cool in natural, room-temperature air, then that would be a faster cooling.

See, originally the Widmanstaetten structure was found in meteorites that heated, then cooled, in entering our atmosphere. So we need a fast cooling rate, as opposed

WRBbrb

to a slow, soaking cooling rate.

Q Do I understand you, Dr. Anderson, that you are saying degenerate Widmanstaetten graphite in gray cast iron is more likely under more rapid cooling than under slower cooling?

MR. BRIGATI: Objection. Asked and answered.

WITNESS ANDERSON: Yes.

JUDGE BRENNER: Wait.

We went through this the first time you were on the stand. There was an objection, Dr. Anderson, and that's why you have to pause.

The objection is overruled.

I didn't want you to think it was being overruled by virtue of his answering the question, Mr. Brigati.

Go ahead, Dr. Anderson.

WITNESS ANDERSON: If you cool extremely slow, using a soaking furnace, you would not be able to get that structure. If you cooled extremely rapidly, such as quenching it, you would have a different structure also.

BY MR. FARLEY:

Q Also, didn't you testify on November 2nd that the casting cracks were hot tears, which form at 400 to 600 degrees Centigrade?

A (Witness Anderson) I believe that the cracks that were repaired, the casking cracks -- is your reference

WRBbrb

to the gallery area that we were talking about, that was repaired? If so, I believe they are hot tears as opposed to shrinkage cracks; and the exact temperature -- I gave a very wide range, but I don't know for sure for that material, but somewhere in that range.

Q Well, wouldn't that mean, Dr. Anderson, that the degenerate Widmanstaetten graphite had already formed and was present when the hot tears formed?

A Yes. I have no argument with that.

Q And wouldn't you also expect deeper hot tears in the original 103 cam gallery region, due to the extensive degenerate Widmanstaetten graphite, than in 101 and 102?

A Certainly, if the stresses were equal in each case. Assuming everything was equal -- blocks and everything -- then I would expect, because the material is substantially weaker, that we would have an exacerbated crack.

Q Fine. Have you -- well, you have examined the microstructure of each of the blocks at the four locations that were sampled by FaAA, haven't you?

A Each of the blocks? No. I have only examined structurally the old 103.

Q You did not look at the samples from 101 and 102?

A No. They were not provided. I have not seen them.

WRBbrb

Q Isn't it true, Dr. Anderson, that when you were at FaAA's offices in Palo Alto on October the 12th, 1984, following the deposition we referred to earlier, all the specimens and replicas that FaAA had made on 101, 102 and the original 103 and the replacement 103 were made available to you for examination?

A I'm not clear on that. I did not inventory everything I saw. I don't recall, at this time, replicas. They may have been there; I just have no recollection of them. I believe there were a couple of specimens there that -- I don't recall, but they may have been from one of the other blocks.

Q Were you denied access to any of the samples or replicas?

A Do you mean physically withheld from me in some way?

Q Told you couldn't look at them.

A No. They were very charitable.

Q Dr. Anderson, isn't it true that the LILCO inspection records show that no circumferential cracks exist in the 101?

JUDGE MORRIS: Mr. Farley, do you have a particular testimony cite? It might help the witness and move this along.

MR. FARLEY: May I ask him if he knows what was

WRBbrb

provided to him?

WITNESS HUBBARD: Can I respond to that?

JUDGE BRENNER: Mr. Farley, do you have a reason to restrict this to Dr. Anderson?

MR. FARLEY: Yes, sir. I thought he was the metallurgist who was being proposed by the County.

WITNESS ANDERSON: I don't have any reference in mind. I will continue to look.

BY MR. FARLEY:

Q Did you personally review any of the --

WITNESS HUBBARD: Judge Brenner --

JUDGE BRENNER: Let him stay with Dr. Anderson.

WITNESS HUBBARD: All right.

JUDGE BRENNER: But your offer to provide information or answer is on the record.

WITNESS HUBBARD: Thank you.

BY MR. FARLEY:

Q Did you personally inspect any of the LILCO inspection records on the circumferential cracks in the 101, or the lack of them?

A (Witness Anderson) Personally inspect? Yes, I've seen some inspection records. There were a lot. I don't recall what I looked at at the moment.

Q Didn't they show that there were no circumferential cracks on EDG-101?

WRBbrb

A Quite honestly, I don't recall at this moment.

Q Isn't it important to know, in connection with your testimony, whether or not there are any circumferential cracks on EDG-101?

A I think that was shared testimony, and I'm sure that I would have been closer to the references at the time that we prepared it. And I just haven't looked at these. There have been so many, I just haven't looked at them today.

Q Are you aware that the same ultrasonic inspection method which has been shown to detect circumferential cracks in the original 103 was used, and showed no cracks in EDG-101?

MR. BRIGATI: Objection. There is no evidence in the record to that effect.

JUDGE BRENNER: Well, he's asking the witness whether he knows. I will overrule the objection.

WITNESS ANDERSON: I have no recollection of that.

BY MR. FARLEY:

Q Is it true, Dr. Anderson, that FaAA inspection records show that the circumferential cracks you examined in the pieces cut from between Cylinders 4 and 5 of the old EDG-103 are less than three-eights inches deep?

A (Witness Anderson) Again, I have no off-hand

WRBbrb

recollection. I will just have to go through it and see.

Q Dr. Anderson, on page 2 of your supplemental testimony you testified that the cam gallery cracks in EDG-101 and 102 and the original 103 were formed during casting and have since propagated. How deep was the casting-induced crack?

A I'm sorry. Which supplement are you referring to? I have two. November or October?

Q The supplemental testimony.

A Oh, okay.

May I have the question, please, now that I have the right document?

Q Yes, sir.

At the time of that page 2 in answer to 1(a), you testified that cam gallery cracks in EDG-101, 102 and the original 103 were formed during casting and have since propagated. Now, I'm asking you to tell me how deep was the casting-induced crack.

A I don't think that anybody can tell. The procedures -- we know that there were casting-induced cracks since there are repair welds; they wouldn't have repaired the cracks unless they were there.

The procedures as TDI, and the standard accepted procedures, are to grind all indications of the crack out before repairing it with the weld; and, therefore, the

WRBbrb

original casting-induced crack may have some dimensions similar to the weldment, but not necessarily can be deduced by measuring the weldment.

Q How do you distinguish, Dr. Anderson, where the casting crack stops and the subsequent propagation begins?

WRBeb

A Well, if you were listening to the previous answer, I said that the procedures were to totally grind out the casting crack to solid material. That is also the specific directions that are given in the Welders' Handbook, and therefore, there should be no initial residue or residue of the casting crack there.

Q Dr. Anderson, on page 2 of your supplemental testimony, at the top of the page, as I understand it, you are saying that there were cam gallery cracks in the 101, 102 and the original 103 that were formed during casting and have since propagated.

And then I asked you how deep was the casting-induced crack. Isn't that right?

A Yes. And I said it would be some portion of the repair weld.

Q All right.

Now how do you distinguish between where the casting crack stops and the subsequent propagation begins?

MR. BRIGATI: Objection. Asked and answered.

JUDGE BRENNER: I'm going to sustain that. And I want you to know, Mr. Brigati, on the basis of my reading of the witness it is that it was asked, and the witness' answer was he doesn't know, he can't distinguish.

And that's the way the record stands in my mind if I sustain that objection, which I've just done.

WRBeb

WITNESS ANDERSON: I'm sorry, is it a sustaned objection?

JUDGE BRENNER: Yes.

WITNESS ANDERSON: Then I will wait for the next question.

MR. BRIGATI: Judge Brenner, before we go on to additional cross-examination on a different subject, I think Mr. Hubbard had something to add about prior questioning that we refrained from putting in.

JUDGE BRENNER: Yes, except in this instance, Mr. Farley gave his reason, and given his reason, there is no need for Mr. Hubbard to add. And I made a point of stating that the record will reflect that Mr. Hubbard felt he had information on the subject that Mr. Farley didn't want to turn to him for.

None of those questions were going to adduce new substantive information, other than what was on the record. He was asking Dr. Anderson whether he knew A, B and C about what groups or agents for LILCO purportedly found or reported. And so it was only pertinent in terms of the cross-examination of Dr. Anderson.

None of the questions are evidence, as you know and I know. Mr. Hubbard might not realize that, but it doesn't matter. I realize that.

MR. FARLEY: May I have just a minute, Judge?

WRBeb

(Pause.)

MR. FARLEY: I have no further questions.

JUDGE BRENNER: The Staff?

MR. PERLIS: Thank you, your Honor.

CROSS-EXAMINATION

BY MR. PERLIS:

Q Mr. Eley and Professor Christensen, could you refer to the figure on page 2 of the Staff's supplemental testimony? Do you have that reference?

A (Witness Christensen) I have that here, yes.

Q Thank you.

With respect to the bottom drawing, the lower drawing of the two, is this representation of the support structure consistent with your understanding of the support structure in the camshaft area?

A No.

Q Mr. Eley, is that your answer as well?

A (Witness Eley) It looks slightly different to this when you actually view it.

Q Could you explain those differences to us?

A The block that is shown in both the crack region wasn't quite orientated like that as far as my memory serves me. It was slightly to the right of that. And the crack, especially on the EDG 103, was -- it looked to me to be slightly higher and wider along the base of the thicker

WRBeb

block than, say, the block above the crack.

A (Witness Christensen) Could I comment?

Q Yes.

A My reasons for stating "No" are that the section, the vertical section of the side of the block is not as shown. There is quite a lot of curvature behind the bearing support, and then underneath the bearing support which is not shown is the hole which forms the crankcase door.

Looking at this sketch here, one would presume that the whole of that bearing area was supported when in point of fact it is not so. The edge of the crankcase door comes a little bit to the left of the bracket area, so that part there is virtually unsupported and would have a considerable bearing on the stresses which are coming in that area.

Q Dr. Anderson, this is on page 4 of your supplemental testimony with regard to Question 5.

Could you explain why you call FaAA's interpretation of the composition of the coating erroneous when, in your next response on this page, you state it is possible that all or part of the coating is an oxide, as was interpreted by FaAA?

A (Witness Anderson) Yes, I can.

The response I have there was an examination of Failure Analysis' basis for saying that the cracks are

WRBeb

conclusively-- This is a quote taken from page 7 of their -- is it called the supplementary? -- the supplementary testimony.

"....demonstrate conclusively that cracks are fabrication-induced."

I have examined the basis for that. One was the appearance of calcium. I have clearly demonstrated to my satisfaction that calcium is not something that you can reliably say will be present on any type of fabrication-induced crack. There are other explanations for it.

The contamination or the thick dark oxide was the basis for their assumption. And yes, I do believe it is an oxide. There are several causes for it to be an oxide. But the color I believe is the graphite residue of the cast iron and therefore, I believe that just the presence of a thick dark oxide is not evidence that it was fabrication-induced. And therefore, the underlying argument that was used I feel has no substance.

Q But so the record is clear, you do believe it is an oxide?

A I believe, because I have seen the results of their microprobe, that they have oxygen and therefore, I know it is not free, and therefore, it is an oxide.

I believe there is also carbon present.

WRBeb

But yes, the record should show that I believe that in part there is an oxide present.

Q In the same general area, what is the basis for your conclusion that the coating on the crack section from cam gallery Number 7 is attributable to graphitization or graphite corrosion on the surface of the crack?

A I am not wedded to any particular explanation. I think it is difficult, without further work, to have an explanation that is completely reliable.

I postulated in another statement that I read at this hearing that it could be fretting. Now fretting is unusual but it would have that coating. It would have to be extremely low-motion, low-movement compared to what you normally see in fretting, but that's another possibility.

I am not an advocate of graphitization. I am not an advocate of fretting. I am saying that at the present level of understanding we can't really say.

Q Have you ever observed hot tears in any gray iron castings where graphite corrosion occurred on the crack surfaces?

A Well, of course there are a number of atlases--I guess the answer would be No. But there are a number of atlases which provide pictures of all sorts of fractures and failures. The problem is to match those up with this particular material.

WRBeb

As I say, or as I have said in the past, the Widmanstaetten degenerate form is not that common that you see it, and therefore I was not able, in my group of horrors, my collection of fractures, to come up with such an item, nor did I find it in the various atlases or fractographs.

Q Have you ever observed oxide layers on crack surfaces of hot tears in gray iron castings?

A Well, I'm not sure. I can probably identify that it was a hot tear. But I have seen some fabrication-induced fractures that I estimated were hot tears, and I found colorations on those which appeared to be oxides.

Again, though, we have a problem here because we are talking about an oxide formation on something that has a good deal of carbon, and you've got to understand that what we're looking for is-- The carbon is more sensitive to oxygen than anything else, and we ought to see decarbonization or some loss of the carbon if it happened at elevated temperature. And I haven't seen that in this case.

Q In those examples you've mentioned, did your observations confirm the conclusion in your testimony that the oxide layer would be unevenly distributed over the crack surface?

A No. I can't think of any support to anything I

WRBeb

have seen in the past. Because the conditions of the crack itself produce its own microenvironment, the environment is different in that crack than it is in most of the rest of the block.

Q Thank you.

Would you expect to find calcium deposition on the surface of hot tears?

A Always, as a general given, given a hot tear, there will be calcium?

Q Yes.

A No.

Q When would you expect to find calcium deposition?

A I subscribe that one cause could be a welding repair. I subscribe to the possibility that the dye penetrants could produce it, and that various lubrication oils carry it with them.

Q On page 8, in your response to Question 10, you indicate that:

"Cast iron does not form beachmarks during the process of crack propagation."

A Yes.

Q Are you aware through your personal experience of any exceptions to that statement? Have you ever seen beachmarks formed by cast iron?

A There are always exceptions. I am relying on--

WRBeb

I can give you the references but I'm relying on some specimens of this particular cast iron that have been tested in fatigue. It's an ITTRE publication and it describes the surface and the conditions which it occur . I mean this generic type of cast iron, Schedule 40.

And their condition was no fatigue marks and essentially smooth surface, not a -- even though it was a fatigue condition.

Also in the Handbook, the Handbook clearly says there may not be fatigue marks, and so I can imagine conditions where there might be, if the loads were perfectly arranged. But from what I have seen from my studies, I would not expect it.

Q What is the basis for your conclusion that the presence of some cast iron on the weld material shows that the weld material pulled free from the crack surface due to operating stresses as opposed to heat shrinkage?

A Let's see. That's not a Yes or No, so I'm going to have to explain in some detail.

Q Please.

A There are two ways I can have a crack there. One could be that the puddled weldment could shrink and that could cause the stresses which would cause the crack in that particular area. And that's very likely with a cast iron material, except the weld material has been particularly

WRBeb

selected. It's a high nickel, about 50 percent nickel-, I understand, iron material. And that is particularly good for cast irons in that it avoids shrinkage. Now it does it in several ways.

The coefficient of expansion or thermal change isn't perfect, but it's pretty good.

Second, it has very low solubility in carbon so it tends to give up whatever carbon has gone into solution, and that causes an expansion, a local expansion.

So generally when you see that kind of weldment, you believe that it has taken care of thermal contraction and you look for some other cause. So that is one basis for that.

I think the second basis is the fact that it is so nicely attached to the substrate in that location that had this been a thermal problem, I would expect that there would be a much greater dividing line on the heat-affected zone. And there really isn't much of a heat-affected zone, and it appears to be through the matrix of the cast iron.

Q Do you have any evidence to support your statement that the cam gallery cracks in blocks 101 and 102 are propagating?

A In 101 and 102?

Q Yes.

WRBbrb

A I think the type of evidence that I would require would be to cut in and examine the surface of those cracks, which I understand has not been done at this time. I think that it's likely that they have the same etiology and the same existence and the same behavior as the old 103. But I am really kind of concerned that nobody really knows until we inspect them in detail.

Q Well, my question was: do you have any evidence to indicate that they are propagating, as you stated in your testimony? And my question to you is: what evidence do you have that they are, in fact, propagating?

A I think hidden in my answer was the response that I think it's impossible to tell with certainty. I draw analogies from what I saw in old 103. But certainty requires a destructive analysis.

Q Is it fair to say, then, that other than drawing whatever analogy you would draw with engine 103, you have no evidence to support the fact that the cracks in 101 and 102 are propagating?

A Well, that's not fair because it is not balanced. I have no evidence that they are not propagating nor are propagating. It requires analysis that just hasn't been done.

Q Thank you.

JUDGE BRENNER: Just to make sure I'm clear, Dr.

WRBbrb

Anderson: I think you explained this, but you say it requires an analysis that has not been done. Are there any further nondestructive examinations that you believe should have been done that were not done?

WITNESS ANDERSON: No, sir.

BY MR. PERLIS:

Q I take it, then, Dr. Anderson, that you are asserting that the cracks in block 103 did propagate during operation?

A (Witness Anderson) Old 103.

Q Old 103?

A Yes.

Q Okay. What evidence do you have to support that statement?

A I think I've gone through that.

JUDGE BRENNER: Yes. Let me sustain your objection, Dr. Anderson.

(Laughter.)

JUDGE BRENNER: It's better than having to make my own objection.

Unless you have a particular point to probe, Mr. Perlis, and I certainly don't mean to inhibit you from doing that, the general question has been asked and answered, and then asked again and objected to previously.

MR. PERLIS: That's fine.

WRBbrb

BY MR. PERLIS:

Q Dr. Anderson, if the cracks in the cam gallery were tight and existed prior to operation, would you expect them to be visible during a visual inspection of the cam gallery areas?

A (Witness Anderson) If they were tight?

Q Yes.

A And unprocessed? In other words, we've done no surface treatment of any type, no polishing, no --

Q That's correct.

A Possibly.

If you had the right light and you knew where you were looking, and you had all the experience in the world, it is possible that you might pick something up. But as you go the limit in tightness, then my answer would change to less possible to improbable.

Q Have you seen the cracks in the new 103 camshaft area?

A Yes. I have inspected the new 103.

JUDGE BRENNER: I don't think you've answered the question. You said, yes, you have inspected the new 103.

WITNESS ANDERSON: I'm not sure I was done, because I was going to say that I also looked at photographs that -- and other documentation on the new 103.

JUDGE BRENNER: Did you see the cracks, I think,

WRBbrb

was the question.

WITNESS ANDERSON: Yes. The photographs show it quite nicely.

JUDGE BRENNER: Did you see them visually?

WITNESS ANDERSON: I had a problem. The light was a fixed light in a location that did not enhance it. My recollection was I did see the area. I am uncomfortable swearing to that, though, because the light just wasn't one I could move around and try to get it enhanced.

JUDGE BRENNER: And this was with somebody pointing you to the area of where they claimed the cracks had been observed by the non-destructive tests?

WITNESS ANDERSON: I believe there was somebody there indicating, yes.

BY MR. PERLIS:

Q If there had been no surface preparation there, would you expect to have been able to see those cracks visually, assuming good lighting?

A Without any enhancement?

Q Yes.

JUDGE BRENNER: Do you want to let him have a magnifying glass?

MR. PERLIS: Sure.

WITNESS ANDERSON: I always carry one, so it would be natural for me to look at -- if I knew the area, if

WRBbrb

I really knew the area, and I wasn't going to go over the whole thing, and I had the light that I would want, I would say it's possible.

BY MR. PERLIS:

Q Is that with or without a magnifying glass?

A (Witness Anderson) I would normally use a magnifying glass.

Q If you would turn to page 12 of your supplemental testimony, you refer to "multiple small disconnected cracks" that you observed below the tip of the three-eighths inch circumferential crack.

In your opinion, are those cracks fabrication-induced or operationally-induced?

A Well, the opinion would be incomplete, because they weren't opened up or anything that I could look at in greater detail. It was my impression that they would have been operational, because of their characteristics. But I have nothing to support it other than just their general behavior.

Q Could you explain those characteristics, please?

A The branching of the -- apparently following the line of the original, as it's been characterized, three-eighths inch crack.

Q And, if you could explain to a layman, why is it that branching would tend to indicate that it's fabrication-

WRBbrb

induced -- I'm sorry, that it's operationally-induced as opposed to fabrication-induced?

A Well, when we talk about fabrication-induced, we're normally talking about a crack that's going to occur at more elevated temperature, when the material has a little less strength; and, therefore, the idea of it having to branch to relieve itself is less likely whereas, when it has developed all possible strength, then the branching is more likely.

JUDGE BRENNER: I'm sorry, Mr. Perlis. I wonder if I might interject on that point.

Dr. Anderson, is it correct that the area of the circumferential cracks, that is, that liner landing area, is an area of different types of stresses competing, if you will, in different directions?

WITNESS ANDERSON: That's my understanding. I mentioned previously I don't have a clear understanding of the whole area, so I could not give you directions. But it is my understanding there is a competition. There are certainly fabrication-induced stresses, by the fact you have an angle generated at the time of manufacture.

JUDGE BRENNER: I was wondering: would it be reasonable to suppose that some of those stresses -- in competition, if you will -- existed during the fabrication stage, including the cooling stage, and therefore that you

WRBbrb

would not be as unlikely as you previously suggested to get some branching effect?

WITNESS ANDERSON: I believe the thrust of my answer was the tendency or relative prejudice; but I'm not ruling it out, and it wasn't my testimony to say that it could not happen.

Normally, as the material is at lower temperature, you tend to get more branching. There's more opportunities for it. But I'm not ruling it out. I do not mean to sound like I'm ruling it out. I just don't know.

JUDGE BRENNER: I understood you're not ruling it out. But my impression was you thought it less likely to have occurred during the fabrication cooling stage for the reasons you indicated, and you say the branching you say you observed was one of the reasons.

Am I right so far?

WITNESS ANDERSON: That's correct.

JUDGE BRENNER: So that's why I asked my question as to whether the effect of these competing forces might affect your qualitative judgment, if you will.

WITNESS ANDERSON: I also relied, in part, on a book on defects of casting, an old ASM manual, which has hundreds of pictures of different defects. And it was clear that branching wasn't one of the common forms of a hot tear or of a defect. But again, I can't rule it out because the

WRBbrb

geometry that they showed was a rather simple one and this, as you know, is complex.

JUDGE BRENNER: Is my suggested basis even correct, that these competing forces would have -- competing stresses, I should say, would exist during the preoperational stage in the fabrication cooling process?

WITNESS ANDERSON: Yes. I believe they would.

JUDGE BRENNER: I'm sorry for the interruption, Mr. Perlis.

BY MR. PERLIS:

Q Staying with your response to Question 19 on page 13, what is the basis for your statement that the circumferential crack you examined appeared to be propagating? Is it just the branching, or is there some other evidence that you had in mind there?

A (Witness Anderson) I can't give it more force without it having been opened up and examined. Branching is principally the basis for that, and the orientation -- the fact that they are running away, as it were, branching out from the so-called three-eighths inch crack. So it is the branching.

Q Other than branching and orientation, do you have any other basis for this statement?

A Not that I can think of.

Q Thank you.

WRBbrb

MR. PERLIS: The Staff has no further cross-examination.

EXAMINATION BY THE BOARD

BY JUDGE MORRIS:

Q Dr. Anderson, following up on a couple of the Staff's questions: with respect to the beach mark situation, does it make any difference whether it's low cycle fatigue or high cycle fatigue whether beach marks occur in cast iron?

A (Witness Anderson) Well, I would feel more comfortable that I would get beach marks on a low cycle, a few hundred cycles. I would think that we're doing more damage on each cycle, and therefore I would believe that that would be the trend.

And, more difficult to see, as the cycles somehow approach, more or less, the crystal size of the graphite that's present, then that would probably be where the beach marks would drop out.

And then, as the cycles got extremely high, then they might be resolved in a scanning electron microscope, if you prepared the surface.

So I think there's a range there, and I think you're very perceptive in seeing that it can change with the cycles.

Q With respect to the nickle alloy weld material, I

WRBbrb

think Dr. Bush testified fairly strongly that he thought that weld would shrink, regardless of what its thermal expansion properties might be.

Do you agree with that?

A Well, it's a nirod weld material, which is either 50 or 55 percent nickle, and it is possibly the most optimum welding material that you can use for cast iron. I believe it still has a shrinking tendency, especially under these conditions. There may be more.

What it's saying is, it prevents shrinkage by dissolving some carbon and then precipitating it out. But I think this one was put on so cold, with so little thermal effect, I don't think it dissolved much carbon, and therefore precipitated it out. But I think that because it was put on so cold, it wasn't sufficient to shrink away and cause a tear.

BY JUDGE BRENNER:

Q I'm sorry: was or wasn't?

A (Witness Anderson) Was not.

Q Why don't you give me the thought again, in your own words?

A It was put on so cold that there wasn't that much shrinkage that occurred. So I believe it was not a weld shrinkage crack that occurred there.

A Forgive my confusion; I hope you will anyway.

WRBbrb

I was wondering as to your emphasis on the quality of the material before, given some of the testimony, including your own, as to the adequacy of the application procedure. And I thought that the lack of proper procedure, including the lack of pre-treatment of various types, would tend to have greater shrinkage of the weld material than would otherwise be desired.

A Normally, the nirod requires pre-heating and post-heating. I see no signs that that was done.

What I was drawing the conclusions from, if it had been put on very hot and dissolved the carbon which was there in great extent, it would tend to not shrink because it would precipitate out carbon. If it had been put on very cold -- and it appears to be the case, because there's really no discernible heat-affected zone -- then there just wasn't that much shrinkage on cooling.

So, somewhere in the middle, I think, it would be more likely to crack and I think there are two ends where it would be less likely.

And yes, I wish there had been pre- and post-thermal treatment. Then there wouldn't be any question.

Q I see.

Well, if they didn't grind the crack out all the way -- and I put that to you as a hypothetical -- wouldn't that, combined with the lack of pre-treatment,

WRBbrb

have a greater tendency to cause shrinkage than if all the proper procedures had been followed?

A The crack itself wouldn't cause shrinkage, but it would cause some stresses in there; and we already know that the old 103 is weaker than the average block, and therefore it would have had a greater tendency to crack.

But the procedures are to grind until there's no indication.

Q All right.

If you answered my question in there, I'm sorry, but I lost it.

A I'll try again.

Q Would the situation I posited to you have a tendency to cause shrinkage of the weld material greater than what you would anticipate, given the quality of the weld material and proper procedures, including grinding as well as heat treatment procedures, pre- and post-weld?

A Wait. I lost it. I thought you were talking about a residual crack left below --

Q I am. I'm positing a residual crack left below, and I'm also positing crummy procedures, if you will.

A Okay.

Well, the crack itself will not change the amount of shrinkage. But the crack itself will act to cause a thermal cracking on shrinkage, so it's just going to weaken

WRBbrb

that area, so that it would be more easily cracked than it would before.

Q And wouldn't that end up with the effect that you observed -- that is, of a cracking, if you will, but not a clean, well-defined cracking?

A That would tend to smooth out the results, and there could be small areas of cast iron attached to the weld so that if it wasn't ground out if there was an appreciable crack, then that could, on cooling, could cause something similar to what we see now.

Q Did I hear you correctly earlier that you did not examine the cam gallery cracks on the 101 and the 102 block? Let me just ask directly.

A No, I have never seen those blocks.

Q Thank you.

BY JUDGE MORRIS:

Q Dr. Anderson, with respect to the circumferential cracks and the branch cracks that you observed in the vicinity of the tips, are you aware if anyone else saw those branch cracks?

A (Witness Anderson) Yes, my assistant, who has good metallurgical background, has done metallography, was there at the time that I was doing my examination and I asked if she would come over and look and then I asked her what she had seen and independently she came to the same

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conclusion.

Q Were any LILCO or FaAA persons present?

A Yes, I didn't ask them to come over and tell me what they saw.

Q Did you discuss it with them?

A No, I didn't. I didn't know if that was proper or not.

JUDGE BRENNER: Off the record.

(Discussion off the record.)

JUDGE BRENNER: On the record.

BY JUDGE MORRIS:

Q Dr. Anderson, with respect to the ligament cracks, do you have an opinion where those cracks are most likely to originate?

A (Witness Anderson) No, I really don't.

Q How about the stud-to-stud cracks?

A You mean whereabouts on the engine?

No, I really haven't looked at that question.

Q Thank you, that's all I have.

BY JUDGE BRENNER:

Q Dr. Anderson, following up on the last questions and answers, do you have an opinion with a supporting basis as to what direction the first, the ligament and, secondly, stud-to-stud cracks, if you postulate their initiation, what direction they would propagate in; whether they would

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propagate up toward the block top or in some other direction?

A (Witness Anderson) I believe I have seen some testimony on that.

Q I want your opinion if you have one.

A I really haven't formed a conclusion on that. We are talking about a heterogeneous material, a brittle heterogeneous material, and depending on what is present in the area that certainly could affect the direction. I think if I postulate subsurface I think I will see it reach the surface fairly rapidly. Beyond that I really haven't looked at the direction.

Q When you say a brittle heterogeneous material, did you mean to describe the 101, 102 and replacement 103 block by that description?

A Yes, I believe that cast iron is considered brittle and it is certainly heterogeneous.

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Q I'm probably pushing you too far, but is there any way you can quantify your opinion that if you postulated subsurface initiation that it would propagate rapidly up toward the block top?

A If I gave you a number would you ask what it's based on?

Q I don't know.

A I would rather not give you a number. I think it would be-- I don't think I have a sound basis for a number at this time.

Q In your rebuttal testimony -- and I'm looking at Question 3 and actually the answer which starts on page 2.

I'm assuming that is your testimony, Dr. Anderson, following up on the previous question. Is that right?

A I'm sorry, which page is that?

Q I'm on page 2 of the rebuttal testimony. I am looking at the first answer which appears there, and it is actually Answer 3.

My initial question is whether my inference that you are the sponsor of that answer is correct.

A It is not marked but it sounds like something I said, so yes, I will accept that.

Q All right.

In the answer you talk about the preferred way to

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evaluate residual stress, and you are talking about the cam gallery. Does that answer apply to the cam gallery area?

A Yes-- Well, it is I believe a preferred way for measuring residual stress anywhere, but that was in response to the cam gallery, yes.

Q I don't understand, and I am sure it is my lack, why you have to actually destructively take a piece out from the vicinity of what you're measuring in order to be able to strain gage the area to evaluate the amount of residual stress. I thought-- I will give you a little more of why I'm confused.

I thought if you put the proper gages on there and the proper configuration that you could in fact measure the residual stress, at least to the degree of determining whether they are compressive all the time or not.

A No, that's not correct. Let me explain.

There are stresses in the metal. When you put the gage on you do not preload it because you wouldn't know what to preload it. You essentially determine changes. But there are stresses in the metal that are balanced. If they weren't balanced you would have something like the linear cat. You would have motion.

The linear cat is a cat where you hold it upside down and it turns over and there are no forces on it. We can't have that in a material, so there are a number of

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forces that are in equilibrium.

Now since the strain gage only takes the change from that, what you would do is cut out a section and see what effect the removal of that section, which was balancing forces, causes on your strain gage. And you would do that once, twice, how many times it was required in order to get the actual residual stresses.

And I should say that the strain gage of course measures a displacement change, and then you have to essentially calculate what that displacement means for the particular material in question, and then you will get the stress from it.

Q Maybe I'm using terms wrong, but in order to solve the problem that I think I have before me -- that is, to determine whether cam gallery cracks will propagate -- is it important to isolate the residual stress, or is it sufficient to discover what the total stress situation would be on the cam gallery under operational conditions?

A I think it is important to know the residual stresses. We know that there had to be some tensile stresses or there wouldn't have been any cracks there, so that's a given.

Now it's possible that all the tensile -- residual tensile stresses are gone because of those cracks, but nobody knows until you make the appropriate analysis, so

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measuring and not taking into account the residual stresses does not give you an adequate answer. You would not be able to determine whether you're going into the tensile mode or not.

And as you'll notice on the exhibit that was put into testimony earlier, you will see that we're coming very, very close upon quick start on the two -- what they say is -- well, close to zero, compressive. And if I had something like -- and it would just be a guess, but say I had a five Ksi residual stress operating, well, then that would put that plateau over the line.

So that is why is going to shift this diagram and that's why it's important to understand.

Q That's where I'm confused. Wouldn't the residual stress, to the extent that it exists, already be reflected in a diagram like this that purported to collect data?

A How? It's impossible, because the measurement does not touch on residual stress.

Q Because you are only measuring--

A It starts at zero. So there is our part cast with all its stresses and all its glories, and they set that as zero. And then they start torquing it down. So the zero is what it is sitting there, but it does not take into account what other stresses are operating, or what stresses the crack would see.

WRBeb

Q All right.

Staying with that same answer, the words you used are that it is the "preferred way" to evaluate the amount of residual stress.

A That's subjective. I think that is my preferred way.

Q Is there another way that would be valid?

A Yes. There's some plastic films. Well, Failure Analysis did do, I believe, on -- was it pistons? There are some films that can be placed on-- Viseo-elastic changes can be measured in those films, and you can try and get an idea of the stress field that way.

But in something this thick and as heavy as this section, I don't believe that would be appropriate although I would certainly be willing to keep an open mind on the procedure.

Q Well, I take it it is not usual for experts in the area to take pieces out of things that they want to measure with the result that they have now destroyed a potentially valuable piece of equipment. Am I right so far?

A Well, --

Q How do you solve the dilemma of getting the answer that you think would be adequate without destroying the equipment.

A I understand 100 percent destructive testing

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turns out zero products. And so what you would do is get a representative item and test that to find out what the average residual values were. If that was truly representative, then you would extrapolate that to a greater sample.

A (Witness Hubbard) Judge Brenner,-- Excuse me.

A (Witness Anderson) I was just going to say certainly when we're talking about a cam gallery one wouldn't have to do that to every single cam gallery. And there are repairs available after you have done that destructive analysis that are called welding. And we have already seen small examples. This would just be a larger.

Q Well, I take it -- maybe I'm wrong -- that the piece you would take out would be larger than the cracks you're concerned with.

A That's true. But since I'm not happy with the crack there, we would replace it with a properly welded and heat-treated material and so there would be a repair at the end.

A (Witness Hubbard) Judge Brenner,--

Q Let me stay with this. I will let you add, Mr. Hubbard.

But what if they did that to all of the cracks that they found?

A (Witness Anderson) Well, it is certainly

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Likewise, if the testing that was just completed, the 700-hour test, if that had been done on 101 or 102 and pre- and post-measurements were made of the cam gallery cracks, one would have evidence of a non-destructive means whether those cracks were propagating.

So what I'm basically saying is that through operation and taking measurements, one can have non-destructive evidence of what is actually going on with these cracks.

Q Why can't we do that now, from this point forward?

A You could. And in fact, you know, that is one of the questions that will be answered on 103, but it will not be answered on 101 and 102.

And it won't explain really how the cracks got to where they are today, but it will surely provide additional evidence.

JUDGE BRENNER: That's all we have at this point. We have some questions-- We might have some further questions of Dr. Anderson, but we think that they would be most efficiently gotten at, if not previously asked by the parties, in terms of that combined panel.

So we have completed our questions for now, and we will go to the County for redirect.

Mr. Brigati.

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MR. BRIGATI: Can we have a 10 or 15 minute break for organizing our thoughts?

JUDGE BRENNER: Only if you are going to finish today.

MR. BRIGATI: So far as I'm concerned we will.

JUDGE BRENNER: How much do you have you think?

MR. BRIGATI: I don't think a whole lot but I must say that I am surprised we are finishing this early. I am not disappointed at that.

JUDGE BRENNER: I was going to give you the break anyway. I am giving you an unnecessarily hard time, I want to confess to that right now, I should have said yes you can have the break but do you think we'll finish today.

MR. BRIGATI: I'll finish by 5:00, Judge.

JUDGE BRENNER: The reason I backed up is that's the sequence I meant to give you my comments in in the first instance.

We'll take a break in a minute. Let me point out that as soon as we finish this panel we are going to the combined panel. I don't see Dr. Bush in the room and I made my points already so unless the Staff finds some way of getting him a transcript before he takes the stand at 9:00 tomorrow morning you're going to have some answering to do given the point we made earlier. I'm going to leave it at that right now.

WRBagb

After we finish with blocks nobody has told me that pistons have been settled, I therefore assume they are not settled and I don't know how much time I will have to absorb the County's answer but I'll try to do it in the time frame I have.

Assuming we have to litigate pistons, as I recall the preferred sequence of all of the parties was to get LILCO's further testimony on polishing or non-polishing of the boss region testified to first, is that right?

MR. ELLIS: Judge Brenner, that was the procedure that LILCO had agreed to. Logistically we may have to ask the Board and the parties to accomodate us and take the County first as we took the Staff first for the County because getting all the people here on this short a notice -- I felt we wouldn't get there before Thursday morning.

JUDGE BRENNER: All right. We'll let the parties work it out. We don't have a preference since it is written testimony and we have an idea of what it is going to say and all I did was reflect the parties' preference, the Board had no preference. I hope you haven't abandoned the possibility that some or all of that testimony could come in by way of affidavit, but maybe you have pursued that and found that it couldn't be done. But I will make the comment and you will have the evening to consider that also.

All right. Is 10 minutes enough, Mr. Brigati?

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MR. BRIGATI: 15, if you will, Judge.

JUDGE BRENNER: All right. 15 minutes until 4:35.

(Recess.)

JUDGE BRENNER: Mr. Brigati.

MR. BRIGATI: Very brief redirect.

REDIRECT EXAMINATION

BY MR. BRIGATI:

Q Mr. Bridenbaugh and Mr. Hubbard, do you have to have performed a finite element analysis in order to review and comment on the results of one?

A (Witness Bridenbaugh) No.

A (Witness Hubbard) No.

Q Do you have sufficient background, training and knowledge or experience to review and comment on the results of finite element analyses to the extent you have done so in your testimony?

A (Witness Bridenbaugh) Yes, I do.

A (Witness Hubbard) Yes, I do.

Q I would ask the same questions of you, Dr. Anderson, in connection with fracture mechanics analysis.

A (Witness Anderson) Yes, to both questions.

Q I'm sorry. Do you have to have performed a fracture mechanics analysis --

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JUDGE BRENNER: I think he saved you the time.

Go ahead. If you are going to change the questions slightly go ahead but if you just want us to substitute fracture mechanics for finite element, we can do that.

BY MR. BRIGATI:

Q Dr. Anderson, you gave certain testimony at pages 166 through 168 concerning cumulative damage analysis and, Mr. Bridenbaugh, you sponsored one part of that testimony at page 167.

MR. FARLEY: Objection, Judge Brenner, I did not ask a single question on cumulative damage analysis.

JUDGE BRENNER: I have a recollection that a long time ago when this panel was on the stand -- that is, before the interruption -- you asked some questions going to their qualifications.

MR. FARLEY: Qualifications, yes, sir.

JUDGE BRENNER: -- including qualifications in the context of finite element analyses?

MR. FARLEY: Yes, sir, but not about the testimony, that's what I was referring to.

JUDGE BRENNER: Well I assumed you asked the questions in order to write a finding that they didn't know what they were doing when they supplied the testimony at page 166, et cetera. So in that broad context I will allow

WRBagb

what I think the subject of this question or questions is going to be.

WITNESS ANDERSON: Yes.

BY MR. BRIGATI:

Q Do you have to have performed a fracture -- I'm sorry, a cumulative damage analysis in order to review and comment on the results of FaAA's cumulative damage analysis as you did in that testimony?

A (Witness Anderson) No.

A (Witness Bridenbaugh) No.

Q Do you both feel that you have sufficient background, training, knowledge and experience to review and comment on the results of FaAA's cumulative damage analysis to the extent you have done so in your testimony?

A (Witness Anderson) Yes.

A (Witness Bridenbaugh) Yes, I do.

Q And Dr. Anderson, at page 170 you gave certain testimony concerning FaAA's fracture mechanics analysis, do you recall that testimony?

A (Witness Anderson) Yes.

Q Do you have to have performed a fracture mechanics analysis in order to review and comment on the results of such an analysis?

A No.

Q Do you have sufficient background, training and

WRBagb

knowledge and experience to review and comment on the results of a fracture mechanics analysis to the extent you have done so in your testimony?

A Yes.

Q Dr. Anderson, I believe early in your testimony you stated that you believed graphitic corrosion must be porous.

Am I correctly characterizing your testimony?

A Yes, because the metal leaches out from the interstices, so it leaves you with essentially a graphitic material, yes.

Q I believe you also testified that the oxide you observed on the cam gallery crack sections from the old 103 block were not porous.

Do you recall that?

A Yes, I was referring to something slightly different. If there had been an oxide coating, the oxide would have a porous consideration. And when I was thinking of the oxide, that's a fairly -- much more porous than this graphitic one.

Q Well did you mean by your testimony to suggest that the substance you observed on that crack specimen was not or did not have the porosity that you would expect with graphitic corrosion?

MR. FARLEY: Objection to the form of the

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question.

JUDGE BRENNER: Overruled.

WITNESS ANDERSON: No, that's not what I was saying. I believe when I was talking about it I said that their cutting solvent had been absorbed into it, that there was an odor, and that it was porous, I knew that because the solvent could not be removed apparently.

Also there was a bit of transfer. When handled apparently carbon would transfer to the surface of your hands, and all of this is consistent with what I would expect in the graphite matrix.

BY MR. BRIGATI:

Q You also testified early in the examination of this panel that you would ordinarily look for a reddish oxide for an oxide formed at low temperature.

Do you recall that testimony?

A Yes, a hydrous oxide is quite common for low temperature aqueous corrosion.

Q Do you consider the fact that reddish oxide would normally be formed at low temperature to be inconsistent with the notion that the oxide that you observed on the same bolts from the old 103 block cracks from the cam gallery area to be inconsistent with the notion that that oxide was formed at low temperature?

MR. FARLEY: Objection. Argumentative,

WRBagb

cumulative, repetitive, compound and leading.

WITNESS ANDERSON: Also I didn't understand the question.

JUDGE BRENNER: All right.

MR. BRIGATI: I think I garbled that question, Judge.

JUDGE BRENNER: Yes. It was confusing because you garbled it, that's true. It was more leading than I would like to see. I inferred, perhaps incorrectly, that that was Mr. Farley's previous objection, too, and on that one I let you slide so to speak in the name of efficiently and I didn't think it was dangerously leading. But see if you can get where you're going by letting the witness supply the words.

BY MR. BRIGATI:

Q Is the fact that the oxide layer you observed on the crack samples from the old 103 block were reddish inconsistent -- were not reddish inconsistent with the idea that they were oxides formed at a low temperature?

MR. FARLEY: Objection, leading.

JUDGE BRENNER: It's leading. I'm going to let him ask it just because we are at this point in the testimony where we have been through it a lot so the danger of his educating the witness to supply information that the witness doesn't believe is very low at this point,

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particularly given the fact that it is expert testimony.

WITNESS ANDERSON: First of all, you must understand that there is reddish corrosion there on the surface and that, I believe, is an artifact from the liquids that were used to cut it and has occurred since the crack was opened up so that it is present.

Second, I have seen the oxygen analysis by the microprobe and I have asked for locations which would assure me that they weren't looking at the hydrous oxides that have been formed since the sample was opened up and I have not seen that. Apparently they don't know what locations they took it so there are oxides of a hydrous red oxide nature, I don't know if they have been analyzed or not and the presence of them does not deter me from the graphitic corrosion.

BY MR. BRIGATI:

Q Dr. Anderson, why did you fail to mention the preliminary cam gallery strain gage data sheet reflected in LILCO B-60 in your supplemental testimony concerning the cam gallery cracks?

A (Witness Anderson) Is that also marked Exhibit 3, Rau, of 10/11/84?

Q Yes, it is.

A When this was given to us during the deposition it had a caveat attached to it that it was preliminary and

WRBagb

subject to change. That was described in the testimony that was given to us.

With that caveat it was difficult to know exactly how to use it.

MR. BRIGATI: No further questions, Judge.

JUDGE BRENNER: Any follow-up based on questions asked since you last inquired? LILCO?

MR. FARLEY: Yes, sir.

JUDGE BRENNER: Hopefully not very much at this point.

RECROSS-EXAMINATION

BY MR. FARLEY:

Q Dr. Anderson, I understood you to testify on cross-examination by the Staff and on questions from the Board that an ITTRE publication showed no beach marks in cast iron, is that correct?

A (Witness Anderson) Yes, this was a Schedule 40 section that was fatigue tested and in fact its --

Q What were the temperature and stress range conditions under which those tests were done?

A Oh, let me look.

The section I took out does not give those specifications other than the characteristics of the surface finish. I just copied a couple of pages. The standard procedures which are reported elsewhere I don't have with

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me at this time. But it was done in dry air at room temperature in a standard testing machine and 3-inch length specimens were used.

Q Were any of the tests that you describe in that publication done under a combination of low cycle fatigue and high frequency fatigue at variable temperature?

A Variable temperature? No, I'm sure they were not. Though I don't have the specifications I'm sure they were not done in that manner.

Q Were they done under a combination of low cycle and high frequency fatigue?

A Low cycle and high frequency fatigue?

Q Yes.

A No.

Q Isn't it true, Dr. Anderson, that under those circumstances those tests mentioned in that publication would not be relevant or applicable to the Shoreham EDGs because they are operated under low cycle and high frequency fatigue?

A Well I think I have trouble with the applicability. The material is the same, it is a fatigue test and it is addressing the fracture surface. I'm not sure that the fracture surface would be characterized differently under different cyclic loads. I have seen no information to indicate that it would be different.

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JUDGE BRENNER: You say you have seen no information that indicated that it would be different, is that right?

WITNESS ANDERSON: That's right.

BY MR. FARLEY:

Q Dr. Anderson, what is the coefficient of thermal expansion of 50 percent iron nickel?

A (Witness Anderson) Oh I don't recall. It's in the welding handbook and I don't have a copy of it with me.

Q Is it zero?

A No, of course not.

Q If it is not zero what's the range?

A I don't know.

Q Is it the same as steel?

A I just don't know.

Q Was it necessary to know that information in connection with any of the opinions or conclusions that you have expressed?

A Yes, it was necessary to know that it was similar to cast iron.

Q That's all you need to know?

A That's the way it's described, yes.

Q Dr. Anderson, you testified, didn't you, in response to a question by Judge Brenner that tensile residual stress must have been present to produce the

WRBagb

casting cracks in the cam gallery?

A Yes, there had to be some stress of a tensile nature in order to open those cracks at the time of fabrication.

Q All right, sir.

Isn't it also true that the crack tip -- that at the crack tip the residual stress must have been compressive or at least very low, otherwise the hot tear would have continued to extend?

A Yes, that was the terminator of the crack.

Q You also testified, I believe, that the TDI weld procedure is to grind out the crack before repair.

What basis do you have that the TDI weld repair procedure were in 1974 with respect to the 101, the 102 and the old 103 blocks?

A I previously stated that I had visited the facility which is much more recent and I could make no comments on how it was done in 1974.

Q What fractographic or metallographic features would you expect to see if the oxide were the result of fretting corrosion?

A Well if it had been large amplitude fretting corrosion I would expect to see a rather smooth surface, macrosmooth with micro gouges; The oxide having been a more refractory phase would tend to gouge microscopically into

WRBagb

the surface. But the surface would be principally characterized by a smoothness which would allow large movement.

If it had been a very small movement, very small relative movement from one side of the crack to the other then the surface could be considerably rougher and could have a very characteristically fractured surface to it, a torn apart fractured surface.

Q Is it true that none of those features would be present due to oxidation during casting?

A None of those features?

Q That you just talked about, the metallographic and fractographic.

A I told you the two types of fretting corrosion, the large movement and the small movement, and I don't see the nexus to your question.

JUDGE BRENNER: Well can you answer the question?

WITNESS ANDERSON: No, I can't, I don't understand it.

JUDGE BRENNER: You gave him some features that you said would be present under the two types of fretting corrosion. So his question is whether those symptoms, if you will, would not -- whether it's true that those symptoms would not be present in the event of, I guess, non-fretting oxidation.

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WITNESS ANDERSON: The symptoms would be present.... It must be getting late because I still don't understand the question.

JUDGE BRENNER: Well let me rephrase it probably in a way Mr. Farley would not like, but you testified as to some things that you would expect to see in the event of fretting corrosion. The question is why does that prove fretting corrosion? Would those same things be present in the case of non-fretting oxidation?

WITNESS ANDERSON: Non-fretting oxidation by itself -- first of all, for the large motion where I get micropolishing and microgouging, I would have no analogy for that. You couldn't see it from just ordinary oxidation from a hot tear.

The fretting on the very small relative motion could be very, very similar. It could be very hard to decide because it would have the rough morphology and it would have the coating on it, and it would be very difficult to determine from a hot tear oxidation.

JUDGE BRENNER: I suspect we are going to be able to get into this more to the extent any party or the Board desires when they are up there together as a panel. That's one reason I, at least, am going to refrain from following up on that answer for now.

BY MR. FARLEY:

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Q Dr. Anderson, did you observe any of these features that you described as characteristic of fretting corrosion on any of the samples you looked at at FaAA?

A (Witness Anderson) Well the samples in question would be the [illegible]m galleries where the weld has existed and then had been split open so they could look at the surface. Certainly there is no signs of large motion, absolutely not. Of small motion, I can't rule that out.

JUDGE BRENNER: Mr. Farley, if you have any non-metallographic questions of this panel I suggest you ask them now or you are not going to get the opportunity again.

MR. FARLEY: I have no further questions.

JUDGE BRENNER: Mr. Perlis?

MR. PERLIS: I have no further questions of this panel.

JUDGE BRENNER: The County based on Mr. Farley's questions?

MR. BRIGATI: No further redirect.

JUDGE BRENNER: All right. We can dismiss this panel on blocks. It's hard to keep up with all of the characters -- and I use that in the best sense of the word in this proceeding in the sense of cast of characters -- but I think all of you are going to be back for pistons, am I correct?

I guess I don't remember the sponsors of the

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piston testimony.

MR. BRIGATI: They will all be back -- oh wait, they won't be, that's right, Judge.

JUDGE BRENNER: I will have to go through the modified piston testimony again because I don't have it in front of me.

Who am I saying goodbye to?

MR. BRIGATI: You'll have to ask Mr. Dynner.

JUDGE BRENNER: Well if you don't know offhand I'm not going to belabor it.

MR. DYNNER: Why don't you say goodbye to all of them and then we can rewelcome them?

JUDGE BRENNER: All right.

To those of you who won't be back, take care.

You don't know either is what you're telling me?

MR. DYNNER: At this point, no.

JUDGE BRENNER: All right. You are all dismissed at this point.

(The witness panel excused.)

JUDGE BRENNER: We are ready to release us for the day. When we are off the record Mr. Ellis thought that he would absolutely have to discuss a scheduling matter now. I would certainly prefer that full efforts be made to work out any scheduling matters and we pick it up in the morning. But if you still insist, I will let you. The

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bottom line is that we are going to schedule everything this week in my opinion.

MR. ELLIS: Yes, sir. We'll discuss it.

JUDGE BRENNER: Okay. We'll be back at 9:00 tomorrow.

MR. ELLIS: Yes, sir.

Does the Board have its own estimate of how long it thinks the joint panel might last?

JUDGE BRENNER: No, and let me state something on the record because somebody did ask me something in passing off the record.

The way we envision it is that by now, given the divergence in the testimony, that the parties are going to take the lead in focusing their testimony and if that occurs we will have very few questions.

MR. ELLIS: Judge Brenner, I understood that what you wanted -- what the Board wanted the panels to focus on is the issues that are raised in the supplemental and the rebuttal testimony and the disagreements that appear.

JUDGE BRENNER: Only in the metallographic information, that's why the composition of the panel is as I have indicated, so that's one limitation narrower than your description just now. And I said that several times so I certainly hope that is not a surprise at this point.

We did not limit it to the rebuttal and

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supplemental testimony because some of the foundation, as well as other statements are in the original testimony of the various parties also.

But there is a clear dichotomy of opinion on the origin of some of these cracks and the prediction of what will happen to some of these cracks in the blocks, and that's what we want to focus on. And everybody has spent a fair amount of time, including the Board, asking Witness A what they thought of Witness B and so on, and then there have been times when I at least would have liked to have been able to turn back to Witness A immediately and said How about that, Witness A, with perhaps a little more specifics, and I envision that the parties by now should have question like that. And we'll have LILCO starting and then the County and then the Staff.

I don't envision the need for follow-up rounds unless somebody make the point that they have one or two particular questions because the nature of the beast is going to be that follow-up will occur right then and there in the body of the witnesses at least. I don't know how it will work out. It may be a not-so-noble experiment. I have seen it work well in another case.

MR. ELLIS: Yes, sir. We certainly think it is useful to do --

JUDGE BRENNER: I guess I saw it work semi-well

WRBagb

in this case before.

MR. ELLIS: I thought it did.

JUDGE BRENNER: It works better when there is a sharper divergence of opinion.

MR. ELLIS: When we did it previously, though, we didn't have all of the background.

JUDGE BRENNER: That's right.

All right. So we'll be back at 9:00 tomorrow morning.

(Whereupon, at 5:05 p.m., the hearing in the above-entitled matter was recessed, to reconvene at 9:00 a.m., the following day.)

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.: 50-322-1 (OL)

PLACE: Hauppauge, New York

DATE: November 13, 1984

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(Sigt) William R. Bloom Anne G. Bloom
(TYPED) William R. Bloom & Anne G. Bloom

Official Reporter

Reporter's Affiliation
Ace-Federal Reporters, Inc.