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UNITED STATES
NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF: **DOCKET NO:** 50-322-OL

LONG ISLAND LIGHTING COMPANY
(Shoreham Nuclear Power Station)

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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In the matter of: :

LONG ISLAND LIGHTING COMPANY : Docket No. 50-322-01 (OL)

(Shoreham Nuclear Power Station:

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State Office Building,

Veterans Memorial Highway,

Hauppauge, New York

Wednesday, 24 October 1984

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

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APPEARANCES:

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PROCEEDINGS

JUDGE BRENNER: Good morning.

Are there any preliminary matters?

(No response.)

JUDGE BRENNER: Hearing none, you may continue your cross-examination, Mr. Dynner.

MR. DYNNER: Thank you, your Honor.

Whereupon,

ROGER LEE MC CARTHY,

HARRY FRANK WACHOB,

CHARLES A. RAU,

CLIFFORD H. WELLS,

EDWARD J. YOUNGLING,

CRAIG K. SEAMAN,

DUANE P. JOHNSON,

and

MILFORD H. SCHUSTER

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

CROSS-EXAMINATION (Continued)

BY MR. DYNNER:

Q Dr. Rau, I asked you yesterday to get me some information concernng Exhibits B-49 and B-50, and I think you agreed to do so for at least two of my requests, and the third I think was taken under consideration.

Do you have the information that I asked you to calculate today?

A (Witness Rau) I have made several calculations. As I recall, the first thing which you asked about was what the magnitude of the mean stress and the magnitude of the cyclic stress or the alternating stress was at the Gage 13 location at 3830 Kw. I think you asked 3900 but the test was run at 3830, as we previously stated.

Q Yes. The way I think I phrased it was if you looked at B-49 and B-50 at the overload condition, which the only information you have is 3830, where would those asterisks or stars appear for the stud-to-stud crack initiating in a block that already had a ligament crack.

That's your understanding of my question, wasn't it?

A No, it is not quite, Mr. Dynner, but I think you will get the same information.

My understanding of what you wanted were two things:

First, you wanted-- You said 3900 but in doing the test you wanted to know how high the steady or the mean and the alternating stress got, and I will give you those numbers.

At Gage 13 the mean stress is 14,900 pounds per square inch, and the alternating stress is 3,410 pounds per

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square inch.

The second thing that you asked me to do was to estimate for you or determine for you from the analyses presented how much the alternating stress and the mean stress increased at the stud-to-stud crack location due to the presence of a ligament crack. In other words, what increase in stress resulted at the stud-to-stud location between the time there was no ligament crack and the time there was.

As I indicated, that information could be obtained from scaling the points shown on B-49 and B-50. I have gone to the actual numbers and they are as follows:

For Exhibit B-49, the low-cycle fatigue, the ratio of the increase in the mean stress is 1.26 or, if you like, a 26 percent increase in the mean stress associated with low-cycle fatigue due to the presence of the ligament crack.

The corresponding increase in the alternating stress due to the presence of the ligament crack is 1.23, or a 23 percent increase.

The corresponding increases in mean and alternating stress relevant to high-frequency fatigue, that is, those that would be associated with B-50, are for the mean stress, 1.27 or a 27 percent increase due to the presence of the ligament crack, and the corresponding

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increase in the alternating stress is 1.12 or a 12 percent increase in the alternating stress due to the presence of a ligament crack.

Q Dr. Rau, I want to direct your attention to the fact that my question to you was not to ask you the mean and alternating stresses at gage 13 at 3830 but as the transcript reflects on page 24,651, in fact I asked you to tell me, on B-49 and B-50, where these asterisks or stars would be located in the event that the engine was at 3900 Kw.

Have you done that calculation and can you give me that information?

A Mr. Dynner, I did not do that calculation in precisely that way. Obviously, I misunderstood slightly what you were asking.

That number can be obtained from those I have just given you.

Q Well, again to clarify for you what I asked was where would the asterisk which indicates the point at which the crack would initiate in various conditions, where would that asterisk be at the overload condition? I said 3900 Kw. I gather from what you have told me that you could only give me that information for 3830 Kw, and I accept if that's all you can give me, that's all you can give me.

But I would like to know plotted points.

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If you need additional time to give me that information, perhaps you can give it to me after the break or after lunch. I don't want to put you on the spot right now to do some more calculations.

A That would be no problem. I would be pleased to do that. It will just take me 15 or 20 minutes of quiet time and I can do it.

Q All right. Thank you, Dr. Rau.

And Dr. Rau, with respect to the increased factors that you gave me for B-49 and B-50, where you have a ligament crack already present as opposed to when there isn't any ligament crack present in the top, you gave me the factors in terms of mean and alternating stress increases.

Would one add those together in order to get the total increased factor?

What I'm trying to do, you see, as I made clear in my question yesterday, is to compare the results of these diagrams with the statement in the Block Report that I quoted to you yesterday to the effect that the increase was by a factor of two, and the Block Report did not break it down into mean and alternating stresses. So I would like to get a number that I could compare with the statement in the Block Report that the increase was by a factor of two.

A I think there were several things in that question. Let me stress the last one. I think I have

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forgotten what the first half was.

But in order to make the comparison which you said — which you're asking about, the ratios I gave you for the alternating stress are the appropriate ratios to compare with the approximately factor of two which we presented in the preliminary — the draft report in June.

In other words, the draft report in June talked only about the increase in the stresses associated with firing pressure as being approximately a factor of two higher by the presence of a ligament crack. So the corresponding comparison is that factor of two for the effective firing pressure increase due to ligament crack with the ratio or the percentage increase in alternating stress which I have given you to be 12 percent or 23 percent, depending upon whether you're talking about high frequency or low cycle fatigue.

Now there's good reasons for those differences, and I think we talked about some of those yesterday.

Q I haven't asked you to explain that. I just wanted to know—

JUDGE PRENNER: Mr. Dynner, excuse me. It was not a very clear question. Just ask another question. It was not clear in the sense that it did have several subclauses, so instead of going over what you think you asked in the previous question, it has become a

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conversation instead of question and answer.

MR. DYNNER: I certainly don't want that.

BY MR. DYNNER:

Q In the Block Report on page 3-1 there is a statement that says:

"Once a ligament crack is present, the transverse stress between the stud holes increases by a factor of two."

Do I gather from the information you have just given me this morning that you are now saying that once a ligament crack is present, the transverse stress between the stud holes increases by a factor of anywhere from 1.12 to 1.27?

A (Witness Rau) Yes, Mr. Dynner, that's exactly what I'm saying. And as I indicated yesterday, there has been substantial improvements and refinements in the analyses used to compute the effect of the crack and to compute the scale factors from gage 13 to the higher stress locations adjacent to the stud and to the ligament area.

The biggest change is the one that I mentioned yesterday, that we used a two-dimensional model back in the preliminary analysis in the report in June, and that preliminary two-dimensional analysis, by its very nature of being two-dimensional, had a ligament crack which effectively, because it's two dimensional, runs to infinity.

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It starts at the block top and runs as if it went on forever.

And clearly that produces a much larger increase in the region adjacent to the -- on the stud side than the realistic case where a ligament crack is only 1.5 inches deep compared to the entire thickness of the boss. And that's why the factor has decreased in the more refined lysis compared to what it was in the preliminary two-dimensional approximation.

Q The third request I made was whether you were able to tell us what the lowest load level on the block would be -- on the engine would be before your Goodman-Smith diagrams would show that a crack might initiate.

Have you completed that-- Can you give me that information?

A No, Mr. Dynner, I cannot.

Q Are you going to give me that information?

A No, Mr. Dynner, I don't think it is appropriate to do that calculation for the reasons we talked about yesterday.

I thought about it last night again, and for the same reasons I stated yesterday I don't think the Goodman-Smith analysis is appropriate because of the conservatism implicit in it for making that kind of a prediction. And if I were to attempt to answer your

question directly, that is, to produce a prediction of the load levels at which fatigue crack initiation would occur. I would have to take out and do a much more -- even still more refined three-dimensional analysis of the combined block and head to eliminate the conservatism in order to make a meaningful calculation of those load level above which you might expect fatigue crack initiation.

MR. DYNNER: Page 37 of the cross plan, Judge Brenner.

JUDGE BRENNER: Maybe you're not interested in this, Mr. Dynner, and maybe I missed it if we got it, but I have a recollection that you also asked for what the particular plotted points were for the asterisks in B-49 and B-50. Did we get that?

MR. DYNNER: Yes, sir, that was the first questions I raised, and Dr. Rau had said he did not do that. What he did give me was mean and alternating stresses, and he said that he would give me the plotted differences in the asterisks this afternoon.

JUDGE BRENNER: It was not clear. He said he did not move them for you, but I thought you wanted to get on the record what the particular points were at which they presently appeared on B-49 and B-50. You remember, he was going to measure them-- You asked him to measure them from the diagram, and I said we could all do that.

I just raise it for your consideration, and you can move on to whatever you want to, Mr. Dynner.

MR. DYNNER: What I really want to know, Judge Brenner, is what I have asked Dr. Rau, which is to show me where the asterisks or stars are, and he said he will do that by either after the break or after lunch.

JUDGE BRENNER: Okay.

BY MR. DYNNER:

Q Dr. Wachob, is the as-cast thickness of the block top 3-1/2 inches?

A (Witness Wachob) The block top is nominally shown in the drawings as 2-1/2 inches, and the information provided to us by TDI was that approximately an extra inch of material is involved in the original casting and is subsequently machined off, so that would make the original block top that 3-1/2 inches thick in the as-cast condition.

Q Is that true of the original 103 block and the blocks for 101 and 102, and also for the replacement 103 block?

A That is true for the original 103, and the original 101 and 102.

The new 103 block, however, is slightly thicker and therefore the original casting thickness is correspondingly that much thicker.

Q Can you tell me what that is, what the thickness is as cast on the replacement block?

I would like to refer you to your own testimony on page 68 where you say that the increase in the thickness at the top of the block was approximately one half-inch. And what I am trying to get at is is that half-inch also the increase of the as-cast or was that the increase in the machined block thickness and therefore would the increase in the as-cast thickness be more than a half-inch greater than the original blocks?

A The cast thickness of the new 103 block as shown in the drawings in the machined condition is three inches. I am not aware of any changes in the additional material but I do not know exactly what the as cast thickness of the block top would be.

Q Now you testified I believe yesterday that the original 103 block was not 2-1/2 inches but was 2-3/4 inches thick, is that right, Dr. Wachob?

A That's true, sir.

Q Have you measured the thickness of the block tops of 101 and 102 as they currently are in the engines?

A I have not made a measurement of the block top thickness in the 101 and 102. Mr. Seaman or Mr. Schuster may be able to provide information to clarify that.

Q Well if anyone on the panel could tell me what is the actual measured thickness of the block tops of EDG's 101 and 102...?

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A (Witness Schuster) We have not made specific measurements for thickness in the block top. The block top geometry and the varying thicknesses because of studs, et cetera, do not lend themselves to the thicknesses as defined by yourself, sir.

Q But you could do it for the original 103 block? And you did in fact do it, didn't you, Mr. Schuster?

A I did not do that. That was done metallographically. It was done with the sectioning, that would be confirmed with sectioning. We did not use standard non-destructive examination techniques to verify thickness of the block top.

Q Dr. Wachob, on page 29 of your testimony in answer 38 you refer to extensive testing.

Is all of that testing described in your written testimony?

Dr. Rau, you know the rules — or at least the request and the Board has already said this: when I ask the question of a witness by name would you please refrain from talking to him before he answers the question. After he answers the question if you are the co-sponsor you can then add what you have to say.

JUDGE BRENNER: The other side of the coin, as you know, Mr. Dynner, but I will state it expressly is that you should only limit questions to a particular witness when

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you feel the need to do so, because it is more efficient to direct it to the panel and you have witnesses who have been involved in several different aspects of the work here.

MR. DYNNER: Yes, sir. I am also aware for other reasons that it was Dr. Wachob who actually performed the testing, the metallurgical test.

JUDGE BRENNER: I repeat. I am not commenting on this particular question and answer because of course I don't have the detailed knowledge. But I made my general statement. And some of what occurred when the County witnesses were up there had some differences in degree, because you had some County witnesses up there who had nothing whatsoever to do with an identifiable aspect of the work. And it was clear to everyone and the witnesses so informed us.

MR. DYNNER: Just so the record shows, while you were talking to me, Dr. McCarthy and Dr. Rau were continuing a discussion with Dr. Wachob, and that is the kind of thing where I would like the Board to enforce the rule that it has enforced I think even-handedly with previous panels.

JUDGE BRENNER: I didn't see that.

MR. DYNNER: Yes, sir, that's why I am bringing it to your attention, sir.

JUDGE BRENNER: Well if it took place it shouldn't have, but try, as I said, just to — I am

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repeating myself now -- only limit the question when you need to because otherwise we are going to get the follow-up and the follow-up and you have a time frame also.

WITNESS SCHUSTER: Judge Brenner, may I add to --

JUDGE BRENNER: No.

BY MR. DYNNER:

Q Dr. Wachob, can you answer the question for me now?

A (Witness McCarthy) Just as a preliminary matter --

JUDGE BRENNER: Wait a minute. Let Dr. Wacob answer the question.

WITNESS WACHOB: Both Dr. Rau and myself have performed extensive testing on the block top on Engine No. 103 materials. This has included metallographic as well as mechanical testing and other evaluations.

BY MR. DYNNER:

Q My question is is the extensive testing that you refer to --

A (Witness Rau) Before you go on, Mr. Dynner, can I add to that, please?

MR. DYNNER: No.

WITNESS RAU: You made a statement that I did not participate --

MR. DYNNER: No.

WITNESS RAU: -- did not do any of the mechanical testing...

JUDGE BRENNER: Wait a minute. Mr. Dynner's statement doesn't matter, it's that simple, and he is not going to take offense when I say that.

BY MR. DYNNER:

Q Now can you answer the question:

Is the extensive testing that you referred to in answer 38 described in your testimony?

A (Witness Wachob) The results and conclusions that are stated in our testimony are based on the extensive testing that we have done on this material.

Q Now once again, and I would like you to answer yes or no and then you can explain it:

Is all of the extensive testing that you referred to in answer 38 described in this written testimony?

A (Witness Rau) Is that directed only to Dr. Wachob or to anybody?

Q Well I will let you answer too now, Dr. Rau.

A The answer to that is it can't be answered yes or no. I mean clearly not all of the details and each and every bit of testing both metallographically and mechanically is described in the written testimony. But as Dr. Wachob has indicated, the significant results and conclusions are.

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Q Thank you.

Did the original EDG 103 block and the blocks of EDG's 101 and 102 all meet the specification requirements for Class 40 gray cast iron? Anyone.

A (Witness Wachob) The specifications require that the mechanical test strength be greater than 40 Ksi. All three blocks did exceed this minimum. And in fact, 101 and 102 exceeded the minimum requirements for even a Class 45 gray cast iron.

Q And were all of the chemical and physical reports for those blocks satisfactory?

A The chemical and mechanical results that were reported on the certificates fall within the bounds anticipated. There is no chemical specification on the Class A-48 ASTM materials.

Q Were they satisfactory?

A There is no specification, so that they cannot be compared and say that they were -- met a specific specification. They were within the bounds of the nominal material chemistries.

Q Were the chemical and physical reports satisfactory?

It is very easy, you can say yes or no and then explain your answer.

A (Witness Rau) Mr. Dynner, excuse me. We

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understand that you would like a yes or no answer. We understand that. You have told us at least 20 times. And when we don't give you a yes or no answer it is because, unless it slips by mistake occasionally, we can't give you one. Now you can continue to do this but we will give it to you if we can.

You have asked a question about the chemical and physical parts of it -- whether it was satisfactory. Dr. Wachob has said the specification has not called out -- it requires nothing with regard to chemical or physical specifications, it has only a mechanical test requirement, period. Therefore you cannot answer yes or no to that question.

Q Now Dr. Rau, you have to listen to my questions. I don't think you are.

I asked you... I didn't ask... The second question was not about specification. Now you listen closely this time:

I said were the chemical and physical reports satisfactory? I did not ask whether they met any specifications, I said were the chemical and physical reports satisfactory for these blocks.

MR. FARLEY: Objection, asked and answered.

JUDGE BRENNER: It was never answered. Overruled.

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WITNESS RAU: Mr. Dynner, the answer is almost the same. I can't answer yes or no whether it is satisfactory because the specification has no criteria with which to evaluate those reports other than the mechanical test. There is a specified mechanical strength in the B bar and the results of the mechanical test were satisfactory in that they met the required minimum in the specification. There are no specifications for physical or chemical, which is what your question went to, and therefore I can't answer yes or no about whether they are satisfactory.

BY MR. DYNNER:

Q Did anyone else on the panel, including LILCO, evaluate the chemical reports for these blocks in order to determine whether or not they were satisfactory?

A (Witness McCarthy) Just for clarification, what do you mean by "satisfactory," if you did not mean conformance with the specification?

Q Well just for clarification, "satisfactory" means that the chemical reports show that the chemical composition was something which would not cause the person reviewing the report to say that we don't want this block because of its chemical composition.

A Well unless one had some aesthetic preference for some certain composition, without a specification there really isn't a basis for that unless they forgot something

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like carbon or iron. We still --

Q Well you are arguing --

A No, we still don't --

Q -- the propriety of the question and I am looking for the answer as pending.

MR. DYNNER: And Judge Brenner, I would ask you -- I have done my best to try to control this panel and move along with expedited questions and answers and I am not succeeding.

JUDGE BRENNER: Well you have gotten answers as to why those answering so far didn't believe they could answer the question --

MR. DYNNER: There is a pending question --

JUDGE BRENNER: Wait, let me finish.

MR. DYNNER: I'm sorry, I thought you were.

JUDGE BRENNER: -- in the terms you asked it.

I understand what you are trying to get and I understand what they are saying also and I have allowed you to put the question several times to see if you can get refinement on the answers. But I don't agree with any implication in your remarks that they are trying to avoid answering the question to date. I can see why it would be confusing to them and they have given certain answers already which we have heard.

And I have allowed you to put the question again

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and we are waiting — you have changed the question slightly and that question is pending.

WITNESS RAU: I will need the question back now. I didn't understand the difference.

MR. DYNNER: The question was not posed to you. You have already said that you didn't --

JUDGE BRENNER: Mr. Dynner, let me interrupt you, even though I don't let you interrupt me. You posed it to anyone on the panel, if you remember your phraseology.

MR. DYNNER: Yes.

JUDGE BRENNER: All right. He is on the panel.

BY MR. DYNNER:

Q Does anyone, including LILCO, know whether there was an evaluation done of the chemical reports on the three blocks to determine whether or not the reports were satisfactory?

A (Witness Youngling) Mr. Dynner, LILCO was not aware of any chemical reports that came with the original shipment of the blocks, so we did not review those reports.

Q Dr. Wachob, would you please identify-- I refer you to your answer 40 on page 30. Would you please identify the areas associated with the heavy section portions that you were referring to in that answer?

A (Witness Wachob) The heavy sections that we were referring to in that answer are associated with the block

tops themselves; therefore, a very thick section among -- and incorporated into the block, the cylinder block.

Q Please identify the particular section from which this testing took part on.

A This is referred to as the replication that we did of the cylinder blocks at Shoreham.

Q Which part of the block top are we talking about?

A The block top itself, at the No 1 cylinder position.

Q Is that on 101, 102 and 103 that we're talking about?

A Yes, sir.

Q Dr. Rau, can you help out?

A (Witness Rau) I would like to add to that.

I think what you're asking, Mr. Dynner, is where do the specimens come from that we cut from the block top regions as well as the replicate locations.

There have been four different sites on each of those three blocks; that is, original 103, 101 and 102. On the original 103, of course, there had been many more than that associated with the cut-ups and examinations at different sections of the block.

But for each of those three blocks there is a section cut off from the corner adjacent to Cylinders 4 and 5 on the exhaust side, as well as a section -- not a

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section but a piece of metal removed from the block top near the end of the engine. And there's also a replica. Let me defer to Dr. Wachob for the precise location of the replica and the small piece. My recollection is not that clear.

A (Witness Wachob) The four pieces that were taken, the first two were as described by Dr. Rau. Another piece was a small chip taken out of between one of the crotches in the cylinder on the exhaust side, and the fourth one was the replica that I was referring to of the block top, and that was taken off of the No. 1 cylinder position.

Q Dr. Rau, I would like to specifically now ask about the metallurgical examination of the blocks of 101 and 102 EDGs as opposed to the original EDG-103 for a moment.

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When you refer to the corner adjacent to cylinders 4 and 5 on the exhaust side from which samples were taken from 101 and 102, were you referring to the corner of the block top up near the exhaust manifold support which is a flange?

A (Witness Rau) Yes, it was taken from a corner of the block in the vicinity of the exhaust manifold support.

Q And what is the thickness of that particular portion which sticks out from the block from which the sample was taken?

A (Witness Wachob) At that position it is the same thickness as that of the block top.

Q Two and three-quarters inches or two-and-a-half?

A In the finished condition it would be the two and three-quarter inches.

Q Do you know whether that particular area which sticks out from the block top cools at exactly the same rate or, in fact, did cool at exactly the same rate as the area of the block top between adjacent stud holes of adjacent cylinders?

A There are two things. One, the thickness of that section would suggest that the block top in that area are approximately the same cooling rate. In addition, you have a very large casting that you have put into the ground to make the cylinder block and as a result the whole casting

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itself is moderating the cooling rate. So therefore, it's a very strong indication that the cooling rates are very similar at those two positions.

A (Witness Rau) If I could just add to that, too, Mr. Dynner, I think the comparison of the microstructure in the original 103 block, which I know we're not talking about now, but we have compared the microstructure at this location at the edge above the exhaust manifold -- I mean, the edge of the block top above the exhaust manifold support -- with the microstructure at the locations of the ligament cracks and stud-to-stud cracks, and confirmed the microstructure to be -- in the original 103 -- comparable amounts of the degenerate Widmanstatten in all other ways comparable microstructures.

So that's additional substantiative evidence that the coolant rates were comparable in that location as well as the location anywhere in the block top.

JUDGE BRENNER: Mr. Dynner, excuse me. I may have missed something on one of the dimensions discussed about three or four questions ago.

What's the thickness of the block top between adjacent stud holes or stud bosses?

WITNESS WELLS: The thickness is nominally two-and-half inches, your Honor. The particular location that Dr. Wachob has described is actually thicker than the

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nominal block top. We have a sketch here that will indicate that. There is a reinforcement that runs along the rim, if you will, of the block top. The actual section is considerably thicker than either the sidewall or the block top.

While there was an implication that this was a flange it is, of course, an integral part of the block top.

JUDGE BRENNER: All right. But the stud bosses which, of course, are thicker than the nominal thickness of the block top are, in fact, separated. That is what you're telling me about the geometry?

WITNESS WACHOB: The boss areas are not separated from the block top at that position, it's one continuous piece which is several inches thicker than the block top itself.

JUDGE BRENNER: I'm sorry. I wasn't precise in my question. What you're telling me is that there is a separation between stud bosses — between adjacent stud bosses?

WITNESS WACHOB: There is a web which separates the cylinder cavities that runs between the stud bosses.

JUDGE BRENNER: Thank you. And that's the area that Dr. Wells just described?

WITNESS RAU: Yes.

The stud bosses, those run together.

JUDGE BRENNER: It's clear to me now. That's why I asked the question. It was not clear to me before.

WITNESS RAU: Yes, sir, that's correct.

JUDGE BRENNER: I'm sorry, Mr. Dynner, go ahead.

BY MR. DYNNER:

Q Dr. Wachob or Dr. Rau, do different parts of the block, when it is cast, cool at different rates?

A (Witness Wachob) In very thin sections versus very thick sections there may be differences in the cooling rate. However, again, we're talking about a casting that is extremely large. And as a result of that, it's controlling the cooling rate of the whole casting. It isn't going to be just the local geometry that is cooling -- that is controlling the cooling rate.

Q When you say very thin sections --

A (Witness Rau) Let me just add to that.

Q No. I'm going to followup on what his answer was, Dr. Rau, and I'm going to control this questioning, not you.

Now, can you tell me, Dr. Wachob, what you meant by "very thin?"

A (Witness Rau) Excuse me, did you direct that to Dr. Wachob? I misunderstood if you did.

Q I'm following up on Dr. Wachob's answer and I would appreciate it if you wouldn't give your comments until

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I'm finished following up.

A (Witness Rau) If it is not appropriate, your Honor, I won't. Whichever you like.

JUDGE BRENNER: I don't want to interject, because Dr. Wachob will forget the question but as soon as he answers I'll have something to say.

WITNESS WACHOB: Very thin, in my estimation, is like a quarter-inch or a half-inch type of thickness. When we get to thicker regions than that, the cooling rate becomes closer to that of the block top and the thicker you get the slower you would like. But it is only imperceptibly slower from the point of view that again you have the block cast in the ground and it's containing a lot of the heat and you're dealing with a lot of metal. And therefore, the cooling rates will be very similiar. So I'm talking about extremely thin sections versus when we're talking about inch, two-inch, three-inch sections.

Q Thank you.

JUDGE BRENNER: All right.

When a questioner wants to followup immediately, he's entitled to do that provided he doesn't proceed too long in time and the number of questions. And then if another witness had an explanation to a previous answer we'll back up and allow it. And if you still have an explanation or an amplification of the answer to the

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previous question, you can give it now if you want to.

WITNESS RAU: I think Dr. Wachob finally said it in the last clause. I wanted to make sure that people understood that it's not just that the casting is big. It's an integral connected casting. It's in a big mold, it's buried in the ground and it's like a big heat sink and it's very difficult to get substantial differences in the cooling rate unless, as Dr. Wachob has indicated, you have a very thin section and then locally you might get a little bit more rapid cooling. But in general, they're going to be very similar.

BY MR. DYNNER:

Q Either of you, does Widmanstatten graphite relate to the cooling rate of the casting? That is, the presence of Widmanstatten graphite.

A (Witness Wachob) Heavy section castings which have slow cooling rates are more susceptible to Widmanstatten formation, yes.

Q So is it your testimony that the entire block casting, given it's cooling rate, which you say, as I understand your testimony, is relatively uniform, would in its entirety be susceptible to Widmanstatten graphite presence?

A Yes. The block would be susceptible in its entirety and our examinations of various areas around the

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block do support and substantiate that quite well.

Q It's true, isn't it, that when you sectioned the portions of the original EDG 103 block, that you found varying amounts of Widmanstatten graphite in varying samples, although you have stated that in each case it was excessive?

A (Witness Rau) Are you referring to a particular part of our testimony, Mr. Dynner?

Q No.

A I think the answer is yes. In the various places we looked in the block we saw from point to point variations in the concentration of the degenerate Widmanstatten graphite, but in all places in which we looked we found excessive amounts of degenerate Widmanstatten graphite in the original 103 casting.

Q If a crack initiated in an area where there was a higher concentration of Widmanstatten graphite than in another area, would that crack tend to propagate on a faster rate?

A (Witness Wachob) The degenerate graphite microstructure that is there, if it is worse, will tend to allow the propagation of cracks at a much higher rate.

A (Witness Rau) Mr. Dynner, I would like to add that is definitely true. You have to just be careful again that that could initiate in a region of higher amounts of

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degenerate Widmanstatten graphite for the propagation. To answer your question, that Widmanstatten graphite would have to be continuously as bad as it propagated. So clearly where the crack goes is also important as well as what the structure was where it started.

Q So for example, Dr. Rau, if the crack initiated in an area -- well, for my sake, simplicity's sake, let's put a number on it. Let's say where the Widmanstatten graphite presence was 5 and if it initiated in that area and then propagated in that area where the Widmanstatten graphite was 5 and then it hit an area where the Widmanstatten graphite presence was 10, the area where it hit the 10 it would propagate at a faster rate than it had previously, is that what you meant?

A I can't answer that the way you've asked it. But let me indicate that if everything -- if nothing else changed, if the stresses were the same and the crack sizes were the same, if everything else were the same then surely if there were increasing amounts of degenerate Widmanstatten graphite, qualitatively you'd expect it to grow faster.

Of course, it would depend... Generally speaking, that's true.

Q Is there an accepted way for quantifying the amount of Widmanstatten graphite in any particular area?

A (Witness Wachob) There are no set procedures to

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quantify the amount of Widmanstatten graphite. It is just a metallographic procedure whereby you polish the specimen and examine it.

Q So am I correct that the determination when you used the word before "an excessive amount", that that would depend upon the visual judgment of the observer as to whether it was more excessive or less excessive?

A (Witness Rau) The answer is generally, yes. I mean, it certainly is dependent upon the visual observer without a specific procedure to define an accept/reject. But the differences we're talking about here are very, very obvious to a skilled metallographer.

Q Would you take a look for a minute at Exhibit B 36, which is entitled, "Microstructure of DG 101," and also Exhibit B 37 entitled "Microstructure of DG 102?"

Now, first of all, with respect to Exhibit B 36 am I correct that these are photomicrographs of samples taken from EDG 101?

A (Witness Wachob) That's true, sir.

Q Would you identify the specific sample, that is to say, the original of the sample from which these photomicrographs were taken?

A I cannot tell you specifically which corner piece off of cylinder 4 or cylinder 5 this comes from. These are fair representations of the general microstructure observed

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in both of those specimens.

Q Were there additional photographs, photomicrographs taken, besides the three which are shown on this page of samples from EDG 101?

A Yes, there were photographs taken for other areas and other specimens.

Q Do you know how many of those photographs were taken?

A I would say 20. I can't give you the specific number of photographs that were taken.

Q Do all of them have the same appearance as the — for the various magnification levels as the three photographs shown on B 36?

A Except for various light variations they are all identical.

Q So it's your testimony that there are none which would show a greater amount of Widmanstatten graphite; is that true?

A None of these photographs in 101 show Widmanstatten graphite. They show a normal gray cast iron microstructure.

Q Well would you, Dr. Wachob, look at Exhibit B 33 and in comparison with Exhibit B 36 Exhibit B 33 is labeled, "Widmanstatten microstructure in DG 103." And it contains, to my eye at least, a number of dark blotches, I

would call them, and I also see a few dark blotches on Exhibit B 36.

Could you identify for us which of those dark blotches are Widmanstatten graphite or thick lines, if you will, and which are not?

I don't want to make you do that for each and every one because I know that we're going to end before the year is out. But just one or two samples so we can get an idea of the distinctions?

A Taking the highest magnification, one which is the one to the far right, as an example, the large clusters or balls or thistles which occur at the tips or the ends of the long lenticular gray graphite flakes are the regions of extensive Widmanstatten graphite formation. You will see that only in the 103 original material. You do not see those balls and clusters associated at all with any of the normal eutectic graphite flakes in the 101 material.

Pardon me. That's exhibit -- comparing numbers 33 and 36 in the exhibits.

Q Yes.

Could you take a look for a minute at the middle photograph which is labeled 0.1, and I guess that is millimeters.

A That's correct.

Q Now about one-third of the way up on the right-hand side in the photograph for DG-101 there is what looks like a circular black blotch, and I don't know whether this is a photograph of— Well, when I look at that and then I compare that with the middle photograph of Exhibit B-33, I see similar types of black blotches.

How do you know that the black blotch on the photomicrograph of DG-101 is not Widmanstatten graphite in that picture?

A I have examined areas similar to that, and what you are really trying to compare here on DG-101 in Exhibit 36 is a eutectic graphite flake which is almost in the plane of the polish and therefore, you're looking at it basically as a planar cornflake type thing. You are looking at it in the plane.

The rest of these graphite flakes that you see here, you are really looking at the edge-on projection of that graphite flake. So that in the 101 material where you

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see this black blotch, that is just the normal eutectic graphite flake.

If you also make the comparison of looking at the black blotches then in the center photograph of DG-103 in Exhibit 33, you will also see the spikes, the needle-like features that surround those dark regions which, in close examination of that region in 101, does not exist.

A (Witness Rau) Can I add something to that?

It is also a well-known fact, Mr. Dynner, that in polishing gray cast iron it is difficult to maintain the graphite in the plane of the polish, even if you are very careful with the graphite because this is so weak it tends to pull out as part of the polishing process.

And sometimes when you prepare one of these pictures you actually get a flake, as Dr. Wachob has indicated, which is almost in the plane at the top, and it just gets pulled out by the polishing process. It falls out and leaves a very shallow hole on the top of your plane of polish which then doesn't reflect light the same way and it comes out dark in the picture.

But when you go to the higher magnifications, that is, the right-most picture in both of those Exhibits 33 and 36, it is quite clear that there is a distinction between a hole or a parallel flake and a Widmanstatten graphite region.

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A (Witness Wachob) If I could add one more thing to that, if you go to Exhibit 34, where we are really comparing that optical photograph with the scanning electron micrograph, you get much more depth of field and you don't lose this reflectivity in the areas where the thistles are.

You can see that there is detailed microstructure associated with the corresponding area in the left-hand photo and the right-hand photo because these are identical areas. And you can see the needle-like projections around what appear to be the black regions on the left. And you look at the right and you can see the fine detailed needle-like projections that are on the outside and then propagate to the inside.

So it is very conclusive evidence that this is really a microstructure we're looking at that is consistent with this Widmanstatten.

Q Take a look for a minute, would you, at Exhibit B-37, which is the microstructure of DG-102?

Were there other photomicrograms taken of the samples from DG-102?

A Yes. Again there were numerous photographs taken of DG-102.

Q And are the three shown in the various magnification levels also similar to the other photographs in appearance?

A They are representative of the other areas, yes.

Q And is it also your testimony that none of the samples taken from EDG-102 showed any presence of any Widmanstatten graphite at all?

A We found no evidence of any extensive Widmanstatten graphite, no.

Q Did you find any evidence of Widmanstatten graphite at all?

A There are very local regions that have minor characteristics similar to it, but I can't -- from all the looking I've done, been able to say quantitatively yes, that was a little area.

You see the photographs here and they are as representative as you can get, and you don't see those features on that photograph.

Q Where were the areas located that contained some Widmanstatten graphite, Dr. Wachob? Where were those areas taken from on the 102 block?

A Again they were taken out of the corner pieces off of the 4/5 cylinder exhaust manifold positions off the block top.

Q Let me go back to--

A (Witness Rau) Can I add something? Are you done with....

Q Of course. Go ahead.

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A I think it is important to point out that I looked extensively at all these areas, too, and we couldn't-- You cannot confirm that it is in fact degenerate Widmanstatten graphite in 102 at all. But what Dr. Wachob said was there were certain regions which have some of the characteristics of it.

But the most important thing is that these are very isolated locations which even have those characteristics. They represent such a small fraction of the cell wall of the eutectic graphite in that location, and a negligible fraction of the cell walls in the structure that, even if they were, they would have no significant impact on the mechanical properties.

Q Do you mean to say that in that particular spot on the block, or do you mean to say even if you had-- Well, is that what you're saying, at that particular spot on the block?

A Yes, even at that particular spot, the fraction of the particular eutectic cell in the graphite which is the strength part of the graphite represents a little cellular network, like a honeycomb in the eutectic system. And even in those areas where you see any indication of things that might be construed as Widmanstatten microstructure, they might represent less than 5 percent of even a single cell, and it can have no significant impact on the mechanical

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properties of even that cell, let alone the entire macroscopic piece of gray iron.

Q Why didn't you disclose the facts about 102 that we have just been discussing in your testimony?

A What facts do you mean?

Q The facts of the presence of a microstructure that in some ways has the appearance of Widmanstatten graphite in EDG-102?

MR. FARLEY: Objection, your Honor. I don't think he said that.

JUDGE BRENNER: I will allow the witness to answer.

WITNESS RAU: As I've indicated to you, Mr. Dynner, in my opinion and that of Dr. Wachob, too, I believe, it is insignificant, irrelevant.

BY MR. DYNNER:

Q Going back for a moment now to the samples from EDG-103, you have examined, I think you testified, a number of portions of the block of the original 103 EDG block, and you said you found varying amounts in various places of the Widmanstatten graphite.

How many photomicrographs did you take of the samples of EDG-103?

A (Witness Wachob) Again that is very difficult to quantify. We took over a hundred photographs of different

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areas. I can't give you the specific exact number of photogaphs, though.

Q If you were trying to quantify the amount of Widmanstatten graphite in various parts of the 103 block for comparative purposes, how would you express the different quantities?

A Again in all the areas that we examined, I can't put a number on it. They look exactly the same or within.... I don't know, I can't even put a percentage on it, so I can't quantify them.

The only place that we have seen, if you would like, enough of a reduction in Widmanstatten graphite to see a perceptible change is in the web section which runs -- which separates the cylinders, but again that is only a small change. In every instance there that we looked at it, you see the extensive thistles at the end of the flakes and the needle-like formation all over, so I can't give you a quantifiable....

Q You testify on page 38 in Answer 53 that no literature results of the effects of Widmanstatten graphite on either the fatigue endurance limit or the fatigue crack growth rate were found.

Doesn't this mean that one cannnot quantify the effects of Widmanstatten graphite on the fatigue endurance limit or the fatigue crack growth rate?

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A The literature references to Widmanstatten graphite have been associated with loss of ultimate strength which can be as high as 75 percent, and in those structures fatigue was not an important factor. When we have taken the 103 original block material and done the fatigue testing we have been able to correlate substantially the effect of Widmanstatten graphite on the reduction in the fatigue endurance limit, on the fatigue properties as well as the tensile strength and the fatigue crack growth rate.

So just because it is not in the literature doesn't mean that it has been unquantifiable.

Q Well, in fact there is a reference that you gave on page 4-5 of the Block Report to support the statement that the presence of a degenerate graphite microstructure has been shown to reduce the strength of cast iron significantly. And that reference, if we look at it, is to C. E. Bates and J. F. Wallace, entitled "Trace Elements in Gray Iron," and also to C. E. Bates' Ph. D. thesis. Those references are on page 4-8.

J. F. Wallace is Professor Wallace who is the consultant to Delaval. Isn't that right?

A Those are the references that we did use in the draft report, and we have looked at a substantial number since that time.

In addition, Professor Wallace is also a

consultant to TDI.

Q And Mr. Bates in fact was working under Professor Wallace when he did his Ph. D. thesis for the second of those references. Isn't that right?

A I do not know that, no.

Q And in fact in his testimony, which since has been withdrawn because Professor Wallace was withdrawn from this witness panel, Professor Wallace did not conclude that the Widmanstatten graphite which occurred in the EDG-103 block in any way caused the extensive cracking in that block, did he?

MR. FARLEY: Objection.

JUDGE BRENNER: Do you want to give me a hint?

MR. FARLEY: The same as yesterday, your Honor. I object to any reference to testimony that has been withdrawn.

JUDGE BRENNER: Well, I am going to sustain the objection to that question, but not for the reason. He can use anything he wants to cross-examine from to test the expert opinion and the bases therefor of these witnesses, including documents prepared by somebody whom they also have chosen to reference for another purpose. But that question was just too general to be helpful.

Zero in on something particular if you want to put something to the witnesses, Mr. Dynner.

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BY MR. DYNNER:

Q Did you discuss with Professor Wallace your theories about the effects of the Widmanstatten graphite in the EDG-103 block?

Anyone?

A (Witness Rau) We did discuss both our theories and also our mechanical test results on the actual specimens cut from the original 103 block which he the degenerate Widmanstatten graphite, yes.

Q And Professor Wallace did not agree with your conclusions that the Widmanstatten graphite you found in the EDG-103 block was the cause of extensive cracking in that block, did he?

A I don't think that's true at all, Mr. Dynner. We discussed this extensively with Professor Wallace. He concurred that it was in fact degenerate Widmanstatten graphite. He concurred with us that degenerate Widmanstatten graphite would in fact clobber the ultimate tensile strength. He concurred that it would in fact clobber the fatigue resistance. He concurred that it would in fact clobber the fatigue crack growth resistance.

And in all respects he agreed that the presence of degenerate Widmanstatten graphite would result in markedly inferior fatigue and fracture properties of the gray cast iron.

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Q Did you say "clobber"?

A Clobber, reduce dramatically, make less resistant, destroy; whatever you would like to call it.

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JUDGE BRENNER: Mr. Dynner, I would like to make a comment. I don't know where you're planning to go in the rest of your cross examination but the County has prefiled testimony that presumably as far as we know today it still plans to present. And in quite a bit of that testimony the County witnesses disagree not just with conclusions but with bases for conclusions presented by LILCO's witnesses. And there is a clash between the experts as to how they interpret certain underlying facts and bases as I read the prepared testimony.

I'm going to put some of those to these witnesses at some point.

MR. DYNNER: Well, I'm not sure I know what you're referring to. You have my cross plan.

JUDGE BRENNER: Your cross plan was prepared before some of the County's testimony was prepared.

Well, I made my comment. You can evaluate it.

BY MR. DYNNER:

Q Dr. Wachob, did you observe the Widmanstatten graphite in only the samples removed from the EDG 103 block or did you -- were you also able to observe by polishing and examination of the block itself in its entirety? That is, could you polish portions of the block without removing those as samples and, by examination, determine whether or not those portions which are on the block as it exists

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contain excessive amounts of Widmanstatten graphite?

A (Witness Wachob) The region of the block which we etched, I mean polished, etched and replicated again, shows extensive Widmanstatten graphite.

Q Well, that was a region that was not removed from the block?

A That is a region that was not removed from the block.

Q And where was it located?

A Again, it was at the block top at the number 1 cylinder position.

Q And was that the area where the large crack initiated from cylinder number 1 and then ran down the front of the engine?

A That was in the general area where the crack ran down edge, yes.

Q Did you polish or otherwise examine the particular crack running from cylinder number 1?

A Could you repeat the question again, I'm sorry.

Q Did you examine the crack itself in order to determine whether or not it contained excessive amounts of Widmanstatten graphite?

A Which crack are you referring to?

Q The crack on EDG 103 which ran from cylinder number 1 about four-and-half inches down the face of the

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cylinder block?

A And beyond the metallographic preparation that was done for the original replication no other metallographic polishing was done in that area.

Q Is your answer no?

A (Witness Rau) Well there are two parts, Mr. Dynner. We did look at that crack in the original 103 block after it was removed from service visually. But there was no metallographic, no polishing or cutting in that particular location.

Q So you didn't examine it for the presence of Widmanstatten graphite; is that your answer?

A I don't mean examine it. We examined the microstructure -- you don't examine a crack, but the vicinity of -- we didn't get where the crack is. We were in the vicinity of it on the block top. We have no replicas which are right on top of the crack.

Q How far from the crack was the area that you did examine for the presence of Widmanstatten graphite?

A (Witness Wachob) I don't remember.

Q On page 38 in answer 54, you refer to measurements of fatigue properties from the replacement EDG 103 block. Was the smooth bar that you're referring to there from the replacement block the test bar that was cast along with the block itself?

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A The test specimens were removed from a three-inch diameter bar which had been cast somewhere in the original 103 casting -- I mean the replacement 103 casting.

Q It's true, isn't it, that the replacement block material is not class 40 gray cast iron but class 45 gray cast iron; isn't that right?

A The specification originally was for a class 45 material. However, the B bar testing of that material would classify it as a 50 B material, a grade 50 -- class 50 -- pardon me.

Q Does a class 50 gray cast iron have a higher -- have higher or better fatigue properties than a class 40 gray cast iron?

A Normally, yes.

Q Then would it have a higher UTS?

A The designation 50 and 45 refers to the tensile strength in Ksi. So, a 50 Ksi ultimate strength would be anticiated.

A (Witness Rau) Let me just add to that, Mr. Dynner. Generally, nominally that's a true statement. You could have a nominal class 40 gray iron which happens to have 5500 pounds per square inch tensile strength. And you could have nominal class 50 which happens to have 5100 pounds per square inch tensile strength so that there could be exceptions. But on average the minimum properties are

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higher, the properties are likely to be higher and, therefore the fatigue strength will be higher.

Q And in fact in the case of the cast iron in the EDG's 101 and 102 blocks, there UTS was about 42 or 4300; isn't that right?

A (Witness Wachob) That's not correct, Mr. Dynner. The UTS strengths for the 101 and the 102 blocks were in the range of 45 and 47 Ksi.

Q What was the actual UTS of the material in the replacement block?

A (Witness Rau) The B bar reported ultimate tensile strength for the replacement 103 block was 54 Ksi, 5400 pounds per square inch.

JUDGE BRENNER: As long as there's a pause here, is that the appropriate -- is it the appropriate practice to form a professional opinion as the UTS of the block based on the UTS of the B bar?

I'm following up on the way you gave your previous answer.

WITNESS RAU: Yes, your Honor. To the extent that the microstructure is normal there is a correlation as we discussed yesterday which is shown in one of our exhibits. I'll get the number for you in B 12.

JUDGE BRENNER: You're talking about the different thickness correlation?

WITNESS RAU: Yes, there's an engineering correlation which rates the ultimate tensile strength in various thicknesses if you know what the measured tensile strength is in the B bar which is a 1.2 inch diameter cast bar. So it is appropriate to form professional opinions based on the B bar presuming you also know the thickness which is relevant to the areas of concern.

JUDGE BRENNER: Now, how do you know the microstructure is the same for the replacement 103 block and 103 B bar?

WITNESS RAU: We've examined them, your Honor. As you recall, we've examined the three-inch diameter bar -- I'm sorry, we didn't examine the B bar but we have in fact examined the three-inch bar which was cast at the same time and compared that microstructure with the microstructure in the corner cut off from between cylinders 4 and 5 and the replacement 103 block and have shown them to be typical.

JUDGE BRENNER: I don't want to interrupt you any longer, Mr. Dynner, but I think I may have some remaining questions about this B bar process. So, go ahead.

BY MR. DYNNER:

Q And, in fact, the UTS of the actual block material varies even in adjacent regions and certainly varies, sometimes significantly, depending upon the part of the block that you're taking the UTS reading from: isn't

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that true?

A (Witness Rau) Generally speaking, Mr. Dynner, it is true that you will get variations in the tensile strength you measure in any material if you measure it over -- or select samples from different locations. That's true in regular steels. It's certainly true in cast irons which, in general, have slightly more variability than a steel would have.

Q Those kinds of variations, in fact, are shown for -- as an example, on Exhibit B 40, aren't they?

A Yes, sir, that's correct.

Again, there is no result summarized on B 44 -- typical class 40 block material. I just wanted to indicate -- I think I said it -- but, it's clear you would expect some scatter in the tensile strength, some variability, even in conventional typical gray iron as well as in the original 103 block with the degenerate microstructure.

Q Well, I'm a little curious. If you'll look at Exhibit B 40 for a moment. You testified that the UTS of the replacement 103 block was 54 Ksi. The numbers shown on Exhibit 40 for the new EDG 103 block material are 39.9 and 46 Ksi.

Could you explain why there are those differences?

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A (Witness Wachob) The differences, Mr. Dynner, are due to the fact you are comparing different test results. The 54 Ksi that was quoted earlier is from the B bar test that was performed by TDI at the time of certification of the casting. The tests that are referred to on the bottom of Exhibit 40, where the 39.9 and the 46 are reported, are for tensile tests that Failure Analysis performed out of specimens cut from a three-inch diameter plug, or slug or casting diameter block, that was subsequently tested.

A (Witness Rau) Let me just add again if it's not obvious that the B bar is a 1.2 inch diameter bar and the samples which -- that's the one with the 54 Ksi tensile strength -- whereas the 39.9 and the 46 which we measured were from a three-inch diameter casting.

Q You have on Exhibit B 40, shown the tensile strength of different specimens from the block top of the original EDG 103 block. Do you have similar UTS figures from tests made on specimens from the block tops of EDG's 101 or 102?

A (Witness Wachob) We did not perform a mechanical tensile strength on material from 101 and 102. The main reason being is that you could not obtain sufficient material from the block top without compromising the integrity of the engine and trashing the entire block as the

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result of taking those test bars. However, we have used the following engineering analysis and that is: One, we have evaluated the microstructure in 103 and shown that it was bad. And that corresponded to, in addition, the bad tensile strength properties that were measured. So we have a correlation between bad microstructure and bad mechanical behavior.

Secondly, we have microstructure from 101 and 102 which show nominal gray cast iron class 40 microstructures.

Third, we have the B bar results that were with the certification of the 101 and 102 blocks. Those are of class 45 at least and, therefore, we could draw the conclusion from Exhibit B 12 that we are going to have at least as minimum a 24 Ksi ultimate tensile strength and that's a conservative estimate. The tensile strength, since it was at a higher classification material, would be higher than the 25 that we are quoting.

A (Witness Rau) Let me add to that that we have also done some exemplar testing on typical class 40 gray iron and confirmed the microstructure relationship to the ultimate tensile strength measurements once the material cut from a different TDI casting which had conventional class 40 gray iron.

Q But don't you agree that specific materials testing is required to quantify any degradation in fatigue

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or fracture properties of the thick section block castings in 101 and 102?

A No.

Q That's the statement that you made on page 4-5 of the block report. What happened to change your mind?

A What's your reference, Mr. Dynner?

Q Take a look at page 4-5 of the block report, the first complete paragraph. It says, "Specific materials testing is required to quanitify any degradation in fatigue or fracture properties of the thick section block casting."

A Mr. Dynner, we were referring to the original 103 block which our replicas and our metallography had indicated had degenerate microstructure and that data refers to quantifying how badly that original block's properties were compromised and degrated by the presence of the degenerate Widmanstatten graphite microstructure.

Q Put if you don't take the actual test properties of the blocks for EDG 101 and 102, what you're basically doing is assuming that they are comprised of normal usual class 40 gray cast iron, aren't you?

A Definitely not, Mr. Dynner. We are relying upon our explicit observations that the microstructure is typical of class 40 gray iron. We're relying upon the measurements of the B bar strength which confirm that it is in fact or was in fact -- is in fact class 40 gray cast iron. There

are no assumptions at all.

Q Just to clarify so that I can understand, the B bars you're talking about for EDG's 101 and 102 in fact were cast entirely separately from the blocks themselves, weren't they?

A They're not cut from the block. I think I indicated that yesterday. They are, in fact, cast at the same time. Typically they are gated off the same pour. They adhere to the mold, and as you pour the liquid metal it runs off into the separate bar which is, perhaps, separate from the big block that the metal runs into.

Q So your answer is, yes, they are cast separately?

A I can't answer that precisely because I don't know whether you consider that separately or not. It's the same metal pour but it goes into different places in the same mold.

Q You don't remember your prior testimony that it was cast separately and therefore would not necessarily be representative of the entire block material because it would be cooled at a different rate, et cetera?

A I think you're misunderstanding what I said. It's one and the same thing. What I said was that because it is not attached, it is not an integral part of the block top, it is not going to necessarily experience the same cooling rate as the block top and, in fact, it apparently

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did not. It has got significantly higher ultimate tensile strength but cast in the B bar diameter.

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JUDGE BRENNER: We're going to take a break at this time. We'll return at 10:50.

(Recess)

JUDGE BRENNER: We are back on the record.

You may continue, Mr. Dynner.

BY MR. DYNNER:

Q It's true, isn't it, Dr. Rau, that the UTS of particular portions of the top, the block top, can vary by as much as 30 or 33 percent; isn't that right?

A (Witness Rau) Which block top are you talking about? The original 103?

Q Any block top.

A I would be surprised if a normal gray cast iron ultimate tensile strength varied by that much. I think the degenerate Widmanstatten microstructure by its very nature would introduce additional variability. I think that is probably representative of what you might expect in the old 103 block.

Q How much would you expect the UTS in various portions of the block tops of EDGs 101 and 102 to vary? --by a percentage, if you can?

A Mr. Dynner, it's not possible to give you a precise number. I wouldn't be surprised by-- Certainly I wouldn't be surprised by plus or minus 5 percent. I think plus or minus 10 percent is probably expected. I don't

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think you'd see much more than that in the block top region.

JUDGE BRENNER: Mr. Dy er, would you excuse me a moment. I left your cross plan next door. I'll be right back.

MR. DYNNER: I'll wait for you.

(Brief recess.)

JUDGE BRENNER: I'm sorry for the interruption. Go ahead.

BY MR. DYNNER:

Q In fact, there are a number of other factors that would determine the particular UTS of particular portions of the block top aside from the presence or absence of Widmanstatten graphite; isn't that right?

A (Witness Rau) Yes.

Q And those additional factors that would determine variations in the UTS of the material would be present in the blocks for 101 and 102 EDGs, wouldn't they?

A Certainly some of them would be, yes.

Q Do you know what some of those factors which would cause such variations would be?

A Yes.

Q What?

A Without attempting to be exhaustive, certainly the specific cell size of the — the eutectic cell size of the graphite microstructure is an important factor, and to the

extent that varies slightly from one position to another that would affect the ultimate tensile strength.

Certainly, the precise test procedures and specimen fabrication and surface finish when you make the samples can't be reproduced 100 percent, and the slight variations in that will, you know, have minor effects on the measured tensile strength.

To some extent the graphite morphology, that is, the precise shape and form of the graphite flakes within the eutectic microstructure will have an effect on the tensile strength, although not nearly so large as the eutectic cell size.

And, again, these are in typical material.

Again, to the extent we have degenerate Widmanstatten structure which is degrading markedly the strength of the cell walls, we have that additional factor which will cause variability.

Q Is there anything in the literature that quantifies the effect of Widmanstatten graphite on cast iron Grade 40?

A I don't think the question is completely clear, but let me just give you a short description. I think I know what you are getting at.

There is much evidence in the literature for the impact of degenerate Widmanstatten graphite on the ultimate

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tensile strengtn of gray cast iron. I don't remember the exact number, but I've certainly looked at a half-dozen or a dozen paper references in the technical literature which describe the presence and the causes of degenerate Widmanstatten graphite microstructure and measure the consequences of that on the strength of that material.

As we said earlier, however, most people have measured only the effects on strength and have not made explicit measurements on the fatigue resistance or the fatigue crack propagation resistance. But the inference in the literature, confirmed by our testing, is that there is a relationship between, and if the ultimate tensile strength is decreased by the degenerate Widmanstatten microstructure then the fatigue resistance is decreased and the crack propagation rates are accelerated, compared to a typical microstructure.

Q My question was, Is there anything in the literature that quantifies that relationship, that tells you, for example, given 'x' amount of Widmanstatten graphite in a particular sample, one would expectl 'y' amount of a reduction in UTS, for example?

MR. FARLEY: Objection. Asked and answered.

JUDGE BRENNER: I'm not convinced that it has been answered. I'll allow the question again.

WITNESS RAU: Perhaps Dr. Wachob will want to add

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to this, but my recollection of those references I reviewed indicated-- Again, they made specific measurements of the tensile strength, and they have shown pictures of the degenerate Widmanstatten graphite.

They made no formula that I can recall which says some characteristic of the measurement of the Widmanstatten graphite is related to a number to the reduction in the tensile strength. But there are extensive correlations showing decreases up to 75 percent of the original or down to 25 percent of the original ultimate tensile strength, maybe a little bit lower.

MR. DYNNER: Judge Brenner, I'm moving on to page 30 of the cross plan.

JUDGE BRENNER: Page 30.

MR. DYNNER: Yes, sir.

JUDGE BRENNER: You're moving back to page 30, not on to page 30.

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Counsel knows, maybe we should tell the witnesses that those pages, of course, refer to an entire cross plan on subjects other than blocks so as we discuss pages with different numbers they shouldn't have the fear that those numbers refer only to questions on blocks.

Go ahead, Mr. Dynner.

BY MR. DYNNER:

Q Gentlemen, I have some questions I'm going to ask you about your cumulative damage analysis.

Dr. Rau, I want a better understanding in layman's terms exactly what your cumulative damage analysis involved.

Now as I understand it FaAA used as sort of a baseline, the known cracking and loading experience on EDG 103 between March 11, 1984 and April 14, 1984, is that correct?

A (Witness Rau) Yes, sir.

Q Now, in order to determine the information you needed for that -- if I may call it a baseline, I know you call it something else in the scientific jargon -- isn't it true that what you did was to take the loads times the time that the engine had run during that period as one element?

Do you understand the question, Dr. Rau?

A That's not true, Mr. Dynner.

Q All right. Did you, in developing that baseline

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for EDG 103 during the period March 11 to April 14, 1984 have to calculate -- have to know the amount of time that the engine had run during that period at various load levels?

A Yes. I had to utilize the load levels and times run during that period of testing.

Q And then did you take that information and calculate on the basis of other information what the stress that the block would have seen with those loads and during that time?

A Would you repeat that, please?

Q Taking that information on the amount of time that the engine ran at various loads during that period, did you then use that information in order to determine the stress that the engine block saw during that period?

A Well, not exclusively, Mr. Dynner. Certainly --

Q I'm going to go on to other things but is that one of the things that you did?

A Yes, certainly the loads were one of the inputs.

Q Now when you refer to cumulative damage during that particular period of time, isn't it true that the damage -- actual damage that you were referring to -- was the amount of propagation that occurred between March 11th and April 14th of the stud-to-stud crack between cylinders number 4 and 5 on the exhaust side of the engine block?

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A I can't answer that as simply yes or no. Certainly the amount of damage demonstrated by that test period -- the cumulative damage demonstrated by the test period is computed from the stresses and the amount of crack extension which occurred at the location between 4 and 5 on the exhaust side is a measure of the amount of crack extension which occurred at that time during that amount of demonstrated cumulative damage. Other regions of the block are also considered and the things that happened or didn't happen there during the same test period are also computed in the same way.

Q Isn't it true that the numbers quoted in the direct testimony were based on the average depth of the crack between cylinders 4 and 5 on the exhaust side?

A Yes, sir. They were based on the average depth at that location, the ones quoted.

Q And it was that single crack which was taken into consideration; isn't that true?

A No, sir; that's not true. That was, as I indicated, one of the cracks which was considered. Other locations in the performance that is the extent of cracking or non-cracking were also considered.

Q Are you testifying now that as the baseline, the standard that you are using for comparison of the loop LOCA service that the 101 and 102 blocks might see, are you

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suggesting that that baseline standard which is the service of EDG 103 used in its calculation cracks in addition to the single crack -- that is, crack behavior in addition to the behavior of the single crack -- between cylinders 4 and 5 on the exhaust side?

A I'm sorry, Mr. Dynner. I don't understand what you're asking.

Q All right. Do you agree that various locations in the EDG 103 block all experience the same operating history during this period?

A Again, that question doesn't make any sense, Mr. Dynner. The engine received a certain operating history in various locations in the block top and elsewhere received -- responded in the ways in which they respond to that particular operating history.

Q Well, I'm quoting you, Dr. Rau, on page 131 of the deposition of October 11, 1984, where you said, quote --

A One minute, please, Mr. Dynner: let me get that reference.

131?

Q Yes.

You said, "Various locations in the block all experience the same operating history." And then you went on to say, "That particular location between 4 and 5 started out with a 1.6 inch deep stud-to-stud crack during the

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beginning of that test period which extended again some depth we now know to be about 3 inches, but at the time of the initial calculation to about 5.5. That was the maximum amount of crack extension which occurred from the deepest initial crack in the original 103 block material."

You agree with that testimony, don't you, Dr. Rau?

A Yes, sir; that's what I said.

Q And in fact it was that fact which formed the basis for the baseline of the cumulative damage analysis; didn't it?

A Again, that is one of the locations, Mr. Dynner. I have also examined other locations.

Q I'm not talking about what you examined and I know from your deposition that you testified that you could have applied the same cumulative damage index to other cracks, but that the one that you are relying upon as the standard or the baseline or, if you will, the worst case is the crack running running from stud-to-stud between cylinders 4 adn 5 on the exhaust side; isn't that right?

A Very definitely, Mr. Dynner. What I said was that that crack is, in fact, the worst location. Other locations though were, in fact, considered and the reason they were not presented as the worst case is because they were not. They were less severe than that particular

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location.

Q All right.

And just so I understand again, and so we're consistent with your deposition testimony, the basic approach of the cumulative damage analysis is to take the extension of the stud-to-stud crack between cylinders 4 and 5 as a worst case occurring at the time that EDG 103 experienced certain loads during certain times between March 11 and April 14, 1984, and using that as the baseline; is that right?

A Again, the baseline, I don't think, is representative. Let me explain the concept one more time. The amount of damage done during the test period between March an April '84 due to the various times, the various power levels, which the engine was exposed to over that period of time, produced a certain amount of cumulative damage and that amount of damage, if you like, the contribution of load, stress ranges, steady stresses, and the times at each of those different levels can be used to analyze different regions.

Now, the performance of the original 103 block during that test period is the response which that material has demonstrated might result from exposure to that amount of cumulative damage.

In other words, everything that transpired

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between before that test period and after, and as demonstrated by the inspections before and after, is the response of the material, albeit, the degenerate Widmanstatten graphite material in a block to that amount of damage.

So, in that respect, it represents a baseline which I call the amount of damage demonstrated. The damage resistance demonstrated by the original block when exposed to this amount of cumulative damage.

Clearly you can look at different locations in the block -- they all experience the same load levels and times -- and you can consider any of the locations. What I've testified to is that the worst location -- but what I mean by worst is that location which, when you complete the analysis not only of the original 103 test period but also of the requirements should there be an accident, a loop LOCA accident, the requirements for 101, 102, or the new 103 block, when you complete that comparative analysis with the cumulative damage analysis, the region between the studs -- as represented by 4 to 5 exhaust side — turns out to be that region which is worst case in the sense that the margin between that amount of damage which has been demonstrated by the testing and that amount of cumulative damage which would be required to be resisted by the 101, 102 or 103 block, is the smallest. The margin is the smallest for that

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particular location.

Other locations, if you make the analogous calculation show a larger margin between that which would be required for an accident -- a loop LOCA event for 101, 102, and the new 103 -- and that which has been demonstrated by the performance of the original 103 block.

Q Dr. Rau, let me get you back to answering my question and I'll try to make this a little more clear by referencing you to answer 71, which begins on page 52 where you more succinctly, I think, state your conclusions and basis regarding the cumulative damage analysis.

A Starting where, Mr. Dynner?

Q On the bottom of page 52 and continuing to the top of page 53?

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Now the reason that you had to change or revise that testimony where you had to change the less than one-half to about two-thirds, then you later on go on and say that:

"During that period of time the block of EDG 103 which has been shown to contain inferior material experienced a maximum crack extension of four inches" -- and you have now revised that to 1-1/2 inches -- "with the deepest stud-to-stud crack extending to a maximum, instead of total depth of" -- you now say three inches rather than "5-1/2 inches."

The reason you had to make those revisions in this testimony is in fact because as your testimony shows you were regarding that experience of the extension of that particular crack during the period from March 11th to April 14th as the basis for comparing the damage which would -- which was accumulated under that set of operating experiences with the stresses to which 101 and 102 might be subjected to during a loop LOCA during their load profiles. That's right, isn't it?

MR. FARLEY: Objection, compound and complex.

JUDGE BRENNER: I don't think it is all that complex, frankly. It is compound, but let's see what happens with the answer. The objection is sustainable,

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let me give you that much, Mr. Farley, but I think it might be more efficient to see if we can get an answer to it.

Try a short answer, Dr. Rau, because we have already got your long explanation and we haven't forgotten it.

WITNESS RAU: Since I don't remember all of the compound aspects let me state what I am going to answer and then I will give you an answer and see if it gives Mr. Dynner what he needs.

There is no question, as I just stated, that the most -- the region with the smallest margin, the worst case, was in fact this location and the numbers which were quoted in the original testimony and are now part of the final submitted testimony are based upon the average amount of crack depth experienced during the test period, the original 103 block with degenerate microstructure and, in fact, when we broke open -- cut up that particular crack and we determined that its extent was really three inches rather than the indicated depth of 5-1/2 inches. That required revision of the specific numbers in the calculation.

The conclusion certainly didn't change but it certainly did result in slight modifications to the numbers. It didn't change the fact that this location was still the worst case, the one with the least margin, and it in no way affected the conclusions about the enormous amount

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of margin which is between that which was demonstrated by the testing of the original 103 during this period and the amount that would be required of 101 and 102 or the replacement 103 should there be a loop LOCA event.

BY MR. LYNNER:

Q Now it's true, isn't it, Dr. Rau, that the amount of damage that you refer to in your testimony for this period was calculated by comparing the depth of the crack from stud-to-stud between Cylinders 4 and 5 on the exhaust side before the testing and after the testing was completed on April 14th?

A (Witness Rau) Could you restate that question? I don't think it is correct the way you stated it but I think if you ask it again I think I could answer it.

Q All right. I will state it slightly differently.

It is true, isn't it, that your conclusions in your testimony about the cumulative damage index that we have just been referring to were based upon and calculated by comparing the depth of the crack before testing began on March 11th, 1984 -- that is, the crack between Cylinders 4 and 5, stud-to-stud, and the average extension of that crack during the period through April 14 which you then assured yourself was correct by sectioning and finding out that the maximum depth was three inches, is that right?

A Again I can't say it was right, let me explain

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why -- I'm sorry, Mr. Dynner, you are just not an engineer and it is not stated in a way which is technically correct.

It is true that the crack has been measured to extend from the order of an inch and a half to three inches at this location during the test period.

It is true that I calculated the cumulative damage index corresponding to the loads, durations at those loads, during that test period.

It is true that I compared the damage accumulated during that test period with the damage that would have been required had the original 103 block been left in service and had there been a load profile identically equal to that expected during a loop LOCA event on that original 103 block if it had been left in service and seen that kind of an accident condition.

And these numbers are based upon the test results and the computations of what the loop LOCA requirements would be if, in fact, the 103 with the degenerate Widmanstatten graphite had been left in service. In other words, even it with the bad properties would have survived a loop LOCA if it had experienced one with some margin...

That's it, I'm sorry.

Q All right.

Now Dr. Rau, how did you determine that the depth of that crack running between Cylinders 4 and 5 on the

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exhaust side stud-to-stud was in fact 1.6 inches at the time that the test began on March 11th, 1984?

A That is the maximum depth reported by the non-destructive inspections performed at or about that time.

Q Well the non-destructive inspection you are referring to in fact is the eddy current inspection, isn't it?

A It would be the crack depth reported at that time on the crack maps. I really don't recall — Dr. Johnson perhaps would want to say — which of the inspections gave the deepest indication, that would have been the one which was utilized.

Q Well you testified yesterday, didn't you, Dr. Johnson, that the stud-to-stud cracks were measured by eddy current and they couldn't be measured accurately by dye penetrant, isn't that right?

A (Witness Johnson) Yes, the number 1.6 inches is from an eddy current test in the August time frame --

Q August --

A Excuse me, April, right after the event.

Q No, I'm talking about the depth of the crack before the block failed, I'm talking about the depth of the crack before March 11th, 1984 — which you have testified, I think, Dr. Rau, was 1.6 inches.

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A I do understand which crack you are talking about. I got the date wrong, it is in March actually and, yes, that was measured by eddy current.

Q And that was one of those unreliable eddy current measurements that you said yesterday you wouldn't rely upon, isn't it?

A That eddy current test would indicate that the crack at that time was no deeper than 1.6 inches.

Q And in fact, based upon your testimony yesterday, that crack could have been much shallower than 1.6 inches, couldn't it?

A Based on the test results, yes, it could be shallower.

JUDGE BRENNER: Incidentally, Mr. Dynner, just for the record, did you ever get that March 8th eddy current inspection report that you wanted?

MR. DYNNER: I did not, sir.

JUDGE BRENNER: Mr. Farley, didn't you state on the record you were going to give it to him yesterday?

MR. FARLEY: I did, your Honor.

JUDGE BRENNER: All right. You two work it out over lunch and then come back and tell me what the situation is.

BY MR. DYNNER:

Q Now Dr. Wells, aside from this cumulative damage

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analysis that we have been talking about, it's true, isn't it, that FaAA carried out what is normally referred to as a normal fracture mechanics analysis of the cracks in the block top in order to determine the crack growth rate, isn't that right?

(Pause.)

Dr. Wells, do you know that?

A (Witness Wells) A normal fracture mechanic analysis, Mr. Dynner, in the sense that we calculated the detailed stress distribution through the block top and assumed the presence of a crack and calculated its rate, was not performed in this case.

Q Let's take a look at Suffolk County Exhibit 48 for a moment.

A (Witness Rau) Can I follow up or are you following up on that question in particular?

Q You can add something, Dr. Rau.

A In the sense of a conventional analytical calculation, as Dr. Wells indicated, it is true we didn't perform that directly but I would just like to remind you the cumulative damage calculation is in fact a fracture mechanics analysis of crack growth. But it is calibrated or based upon the observed performance of the block top: in other words, the crack progression through the block top is calibrated based upon the experience and observations of

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the original 103 and it is that experimental calibration that incorporates the effects of any variations or changes in the stresses as you move from the block top down along the path which the crack is progression and, if you like, precludes the need to do analytically what has been demonstrated experimentally by the original 103 block.

Q But you didn't do any fracture mechanics analysis, for example, of the type you did to determine the crack growth rate in the pistons? You didn't do that on the block top, did you, is that your testimony?

A (Witness Wells) That's correct, sir, we did not.

Q Did you start to do it?

A We conducted fracture mechanics calculations early in our work, particularly at this stage that I think you are about to refer to here that is represented by Mr. Taylor's deposition.

Q You knew what I was looking at.

JUDGE BRENNER: You gave him the exhibit number, remember?

WITNESS WELLS: It didn't take too much.

(Laughter.)

BY MR. DYNNER:

Q Well I gave you the exhibit number and that is in fact Exhibit 1 to Mr. Taylor's deposition, isn't that right?

A (Witness Wells) Yes, sir. That's correct.

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Q And Dr. Wells, you are familiar with this document and it was in fact circulated to the NRC and the other parties as an interim report, wasn't it, Dr. Wells?

A I believe so, sir.

Q In fact Mr. Taylor during that time frame was involved in performing a fracture mechanics analysis in order to predict crack growth rates in the block top, and Mr. Taylor's work didn't have anything to do and was not in fact based upon the cumulative damage analysis that you later did, was it?

A Not at that time, sir, that's correct.

Q And Mr. Taylor was involved in this fracture mechanics analysis, wasn't he?

A He did not make the calculations, as I recall, but yes, he was the task leader in charge of that work.

Q Who else was involved in doing that fracture mechanics analysis?

A There were many calculations performed prior to that period, Mr. Dynner. I would have to guess at the specific individual.

Q Anyone on the panel who knows can certainly state if they know who was working on the facture mechanics analysis.

A (Witness McCarthy) Mr. Dynner, I was involved with some of the iterative calculations; Dr. John Low; I

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recollect there was some peripheral involvement of Dr. Graham Fowler, and I believe Dr. Ernest Eason. Yes, that is correct, Dr. Ernest Eason as well.

JUDGE BRENNER: What are you going to do with that valuable information, Mr. Dynner?

MR. DYNNER: I was curious. I could have asked it differently of course, and I could have asked it as to whether any other members of the panel, and maybe I should have asked it that way. And I apologize if that is--

JUDGE BRENNER: I thought you had already established that it was persons other than members of the panel. Maybe I reached an inference that wasn't in the record.

There have been questions during the course of this proceeding as to who else, and then we get a long list of names, and unless you have something really special in mind, it is usually not material, although I can imagine circumstances where it might be. Howevr, I just didn't see it here.

Go ahead.

BY MR. DYNNER:

Q Now it was the purpose and intention of the fracture mechanics analysis that Mr. Taylor was working on to predict the remaining life on EDGs 101 and 102, given the cracks that they have. Isn't that true?

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A (Witness Wells) Not primarily, Mr. Dynner. At that time we were trying to explain the observed arrest of ligament cracks at the liner landing ledge. That was really the purpose of those calculations.

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Q But that was an objective, wasn't it, because Mr. Taylor testified in his deposition, as I think you know, "In my analysis we will predict the remaining life on 110 and 102 given the cracks that they have. At the same time that same analysis would predict the life of that same design starting from an uncracked condition."

MR. FARLEY: Judge Brenner, may I have the page reference?

MR. DYNNER: Page 64 of the deposition.

A (Witness Wells) Sure, that was the objective at that time of Mr. Taylor's deposition.

BY MR. DYNNER:

Q And it was the attention of and the analysis of the strain gage results that FaAA would be able to characterize the crack growth rate on EDG 103; isn't that right?

A (Witness Wells) It was hoped that with the strain gage data and the analytical models that we could predict the growth and arrest of ligament cracks and the observed behavior of the stud-to-stud crack at that time.

MR. FARLEY: Judge Brenner, I object to this examination. Unless I am seriously mistaken the County Exhibits which show the extracts from the deposition that they are relying on do not include the portions that Mr. Dynner is referring to. Obviously Mr. Dynner has a

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right to refer to any deposition but I understood that under the rules of this procedure I would be told about voluminous depositions so that I could have the information.

JUDGE BRENNER: Well, yes, you are right as to the general statement that if there was going to be cross examination from the extensive type documents parties would be told in advance. However, the concern I had and have had throughout the proceeding does not apply to that kind of use of that kind of document and I don't want to take a lot of time explaining the difference. I think you can see the difference between -- well, I'll try to state it briefly.

There is a big difference from that kind of examination from that kind of document as opposed to pulling out page 32 of a particular eddy current inspection report from a large volume of other inspection reports and then expecting witnesses to know very quickly what was done, how it was done, and so on. And it is the latter kind of concern that was most prominent. So I just don't see a prejudicial problem as to this particular line.

Nevertheless, your general statement is still true and I didn't draw a distinction in making the general statement. I don't see any reason to adjust at this time on that particular one.

BY MR. DYNNER:

Q Now, Dr. Wells, were any conclusions concerning

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the crack growth rates of the cracks in the block top reached from the -- what I will call the regular friction mechanics analysis that was being carried out by Mr. Taylor and others?

A (Witness Wells) Let me explain. That question is posed in a form that I can't answer yes or no.

We knew the behavior of the ligament cracks that were under investigation at that time. We were trying to understand the effects of the various types of loading and measured stresses on the propagation of the cracks and the apparent arrest of ligament cracks. What we concluded was that our modeling up to that time was not adequate to show the crack growth rates with any degree of accuracy.

In fact, our model, as Dr. Rau has testified, at that time consisted of a two-dimensional analysis and the calculated stresses were, in that model, too high to allow a crack to arrest at any particular time so that ligament cracks, in effect, were predicted to propagate rapidly through the material with no arrest.

And we knew that was not the case from looking at many, many ligament cracks and we knew of course from the stresses in the particular model that they were far too high, did not reflect the reinforcements of various other parts of the block top, the bosses, the webs, the restraints of cylinder heads, et cetera.

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In short, the model was not sufficiently realistic.

Q Your past behavior of FaAA has been, as it was in the pistons, for example, that when you had a finite element analysis that did not give you what you regarded as a viable result, you went back and refined the model and you did so in this case because, as you have testified, Dr. Wells, you did a 3-D model thereafter. Did you then carry forward using the 3-dimensional analysis in order to conclude Mr. Taylor's fracture mechanics analysis work?

A I believe so. We progressed to the point where we had not a complete detailed distribution of stress, that is, stress distribution adequate for Dr. Rau's fracture mechanics analyses, crack growth analyses if you will, that are comparing in this cumulative damage model.

A (Witness McCarthy) I would like to add to that that in the case of pistons our model with the eventual refinement just fit on a Cray computer and that was a far -- the piston was a far simpler geometry to analyze in the sort of detail we were able to analyze the piston than the block. Until the new Cray 2 computer comes on line at the University of Minnesota, we could not get a model of the block of the same detail as we did on the piston on any existing computer that we know of available anywhere in the world.

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Q Now, Dr. Wells, going back to your last answer you told me that the analysis was used in Dr. Rau's cumulative damage analysis. What I wanted to know was it used in Mr. Taylor's and company regular fracture mechanics analysis? In other words, was there an attempt made to apply that information to the analysis which had originally shown that the ligament cracks would propagate rapidly?

A (Witness Wells) No, sir, not in any great detail. I say the cumulative damage analysis based on crack growth that Dr. Rau performed were based on upperbound stresses that we obtained from the strain gage readings and through these models.

But I must explain that at this point the models are still not sufficiently accurate to perform a detailed fracture mechanics calculation. The reason for that is, as Dr. McCarthy applied, the size of this model would be enormous; much larger than a piston. What we learned since Mr. Taylor's deposition up to the end of last summer was that the stresses in the cylinder block are very a very complex combination of several structural elements. The block top is very complicated itself. It has a number of components reinforcing it which we did model. The cylinder head, however, exerts substantial effect on the block top. And as you know, we never even attempted a model of the cylinder head because of its complexity.

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So, the degree of detail that would have been necessary to perform the analysis that was suggested in Mr. Taylor's deposition was just beyond impractical.

A (Witness Rau) Let me add something to that, too. It was clear that it was unnecessary also -- not only was it impractical but it is also unnecessary -- to perform that level of sophistication. We had the most direct observations of what the stress distributions were from the block top which we knew from direct measurement with the strain gages and how that changed with depth, directly and explicitely demonstrated by the performance of the original 103 block. That was, in my opinion, by far the most accurate way to ascertain what that distribution was. And using the combination of the strain gage measured on the actual block and the performance as demonstrated by what the cracks did as they progressed from the block top downward in conjunction with the power levels, we were able to make a very precise determination of the crack progression from block top on down. That's exactly what we did with the cumulative damage model.

A (Witness Wells) Yes, our objective was to provide a reasonably cost effective minimum safe life for the client in this case.

Q Dr. Rau, if I am not mistaken, you were talking about your cumulative damage analysis, right, in the last

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part of your answer there?

A (Witness Rau) Yes.

Q What was the rate of propagation -- that is, how fast did the cracks propagate in the 103 block? Let me take a specific crack. How long did it take for the crack running from cylinder number 1, four-and-a-half inches down the front of the engine, to propagate once it had initiated?

A It took no less -- again, you can't answer it specifically because it is, in fact, dependent upon the way it's used. But it took no more than -- excuse me, it took no less than the amount of cumulative damage time, power levels that were seen by the original 103 block during the test period March through April, 1984. So we know -- given the fact you know how long it ran and you know how much the crack extended, that gives you the average crack progression rate over that period of time and given that amount of cumulative damage duty, if you like, which the parts saw during that time.

Q You say it took no less than from March 11 to April 14 for that crack to propagate down from cylinder number 1 four-and-a half inches down the front of the engine?

A Yes, that's what I said.

Q Mr. Youngling testified that nobody saw that there was any crack there on April 14 after the abnormal

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load excursion occurred.

So it's just as logical to say that that crack propagated down the front of the engine in something less than an hour and twenty minutes; isn't that right?

MR. FARLEY: Objection. Mischaracterization of testimony.

JUDGE BRENNER: Overruled.

WITNESS RAU: That's not correct.

BY MR. DYNNER:

Q Why isn't it?

A (Witness Rau) Mr. Youngling also testified that his people were not looking in that region of the engine before the unusual event or whatever they -- abnormal event. There is no evidence whatsoever that the crack was not there just prior to then.

Q Well, assume for me -- bear with me for a minute and let's assume, because we can all read what Mr. Youngling said yesterday --

A Let me just finish something, can I?

JUDGE BRENNER: Let him followup. I think we will get better precision. Go ahead, Mr. Dynner.

BY MR. DYNNER:

Q Okay, just assume for me for a moment, that the crack wasn't seen and although it wasn't especially looked for a crack of that size, as Mr. Youngling testified, where

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oil might collect, let's just assume for a minute that the crack wasn't there or couldn't be seen even if it were there.

JUDGE BRENNER: Mr. Dynner, could I suggest something? Why don't you ask him how he can be sure that it took no less than that time?

BY MR. DYNNER:

Q How can you be sure that it took no less than that time, that is, the time from March 11 to April 14?

A (Witness Rau) Well, there are several reasons for having that opinion. First, is the inspection results taken before the test period and after. The second is my knowledge of the -- from the strain gages of the relative stresses at the two locations. In other words, the stresses are lower at the number 1 cylinder location than they are at the 3 to 4 cylinder location. And the analysis of the performance between cylinders 4 and 5, as well as the observation that the other stud-to-stud cracks which had been reported prior to the test period, didn't extend anywhere near so far as to 4 or 5. All contribute to the opinion that that crack at the number 1 cylinder stud location would have taken at least as long as the period of observation. The reason I said less than was simply that it might have been smaller than the resolution limits of the non-destructive inspection at the start of that test

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period.

And therefore, it might have been growing for even longer periods of time, might have started before that March 11 test start.

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Q Dr. Johnson, if you look for a minute at Exhibit B-18 in its revised form, and if you look over at the stud in the four o'clock position on cylinder No. 1 on the intake side, there is a line indicating -- running outwards from the stud towards the front of the block with an asterisk and a 0 next to the asterisk. It says "Top surface indication depth not measured, length not recorded."

Is that the location from which the large crack propagated from cylinder No. 1 down the front of the engine?

A (Witness Johnson) At that time there was a penetrant indication of a crack, 0. --

Q Just can you answer the question? Isn't that the place where the large crack propagated down the front of the engine?

A You said an asterisk with a 0 after it. The answer is an asterisk with 0.4. Now maybe that's not on your copy.

Q Wait until I ask the question-- Just can you answer my question? My question is:

I have noted for you the location of that indication on the four o'clock position stud hole in cylinder No. 1. And I have asked you is that the location where the large crack propagated down the front of the engine during the qualification testing?

A Yes.

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Q Thank you.

Now my copy I don't believe has a .4 after it. Would you clarify that, please?

A Yes. The number is star 0.4, indicating it was .4 of an inch long coming from the stud directed towards the outboard edge.

Q And did you attempt to measure the depth of that indication?

This is all March 11th data.

A No, there was no attempt to measure the depth of that indication.

Q Why not?

A We had many indications that were much longer than that.

Q So because of its length, Dr. Johnson, you made the assumption that it must -- because of the relationship of length to depth, that it must necessarily be very shallow. Correct? Is that your testimony?

A There were also some ultrasonic evaluations done in those areas. I don't know the specifics of those.

Q You didn't answer my question. Again I would really like to request that you listen to the question.

Is it because of the relatively short length of that crack and your knowledge of the relationship of length to depth that you assumed that the crack must be a shallow

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one?

A We did not attempt to measure the depth of that crack.

Q Now let's try that question once again, and you couldn't--

JUDGE BRENNER: Why didn't you attempt to measure the depth of the crack? He is following up on your answer about two or three questions ago.

WITNESS JOHNSON: Because it being short on the surface would indicate it is not deep into the hole.

MR. DYNNER: Thank you.

WITNESS MC CARTHY: Just one additional correction on that exhibit. It says "Length not recorded." The "not" is superfluous. The depth was not measured but the length obviously was recorded, so the second "not" should be struck there.

JUDGE BRENNER: Well, be careful. I want you to think about that over the lunch break. I've observed the possibility at least on some of these crack maps, and I'm not sure about this one, that you've got multiple stars or asterisks and you're trying to -- for different indications at different locations of the crack map. And I think you've tried to use the asterisk notations to mean different things for different indications.

WITNESS MC CARTHY: Because of the superfluous

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"not" I can see how you would get that impression, Judge Brenner. It is not our intention. It is supposed to be the same admonition on all the crack maps, but the second "not" confuses that, and I apologize for the confusion.

JUDGE BRENNER: All right. I'll delete it if you want me to. It's your crack map.

WITNESS MC CARTHY: Thank you.

JUDGE BRENNER: You do not have uniform notations among the crack maps, and I had asked a question about one of them yesterday, but we'll put that aside.

Dr. Johnson, did you want to explain that?

WITNESS JOHNSON: Yes, it should not say "not" on this particular-- We did record the length. The length was recorded to be 0.4 inches, and the depth was not measured.

JUDGE BRENNER: All right.

WITNESS RAU: That's on Exhibit Number B-18.

JUDGE BRENNER: All right.

WITNESS RAU: I would like to add something, Mr. Dynner, if I might.

In the cumulative damage considerations of this location which you are asking Dr. Johnson about, I made the conservative assumption that the crack size at the beginning of the test period was -- the crack depth — excuse me -- was in fact zero, and that the maximum extent of crack extension, that is, from zero down to the depth of 4.4

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inches recorded after the test period, all occurred and even with that conservative assumption, neglecting whatever depth there was associated with that .4 inch, still demonstrated that there was even more margin between the required loop LOCA cumulative damage and that which had been demonstrated by the performance of the original 103 block during this test period.

JUDGE BRENNER: We can recess for lunch at this time unless you have a question or two that you want to follow up on.

MR. DYNNER: Just a couple of follow-ups.

BY MR. DYNNER:

Q Are the results-- You say you did use the cumulative damage index, you did use this crack that ran from cylinder No. 1 down the front of the engine, Dr. Rau. Is that in your testimony somewhere, where it talks about that crack?

A (Witness Rau) No. As I indicated to you previously, Mr. Dynner, the most conservative position was to consider the 4/5 position. That was the one with the least amount of margin.

We had considered this location and found it to demonstrate an even larger margin and the testimony reflected that position which was limiting or most -- was limiting.

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Q And this is the biggest crack in fact, isn't it, the one that goes down cylinder No. 1?

A Given the destructive measurement of 4/5, yes, this particular location would be the maximum amount of crack extension. However, the different stresses which are present at that location compared to the 4/5 location result in a larger margin when you go through the cumulative damage analysis than in the 4/5 stud-to-stud location.

Q And just to be sure you were consistent when you say that you considered this long crack running from Cylinder No. 1, am I correct that you assumed that that crack did not propagate in any less of a time than from March 11th to April 14th?

A Again it is demonstrated by the crack map, B-18, to have been present on the 11th and it grew during that period.

Now as I mentioned previously the reason I said "less than" is that obviously there is some crack propagation time prior to the 11th at which time the crack at that location grew from nothing to the .4 surface length and whatever depth corresponds to that .4 surface length.

Q So your answer is yes?

JUDGE BRENNER: We will put that one together ourselves and if you feel you need to follow up after lunch, you can.

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All right. Remember the one brief task for Mr. Dynner and Mr. Farley is to figure out what the situation is on that March 8th report. Just to get the two of you off on the right foot I want you to start out by agreeing that today is Wednesday, and the rest of it is up to you two.

We'll come back at 1:35.

(Whereupon, at 12:05 p.m., the hearing in the above-entitled matter was recessed, to reconvene at 1:35 p.m., this same day.)

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AFTERNOON SESSION

(1:35 p.m.)

JUDGE BRENNER: Good afternoon.

Whereupon,

ROGER LEE MC CARTHY,
HARRY FRANK WACHOB,
CHARLES A. RAU,
CLIFFORD H. WELLS,
EDWARD J. YOUNGLING,
CRAIG K. SEAMAN,
DUANE P. JOHNSON,
and
MILFORD H. SCHUSTER

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

JUDGE BRENNER: Mr. Dynner, do you now have what LILCO always believes to be the report of that March 8th eddy current inspection that you asked about I believe back on Monday?

MR. DYNNER: I do, sir.

JUDGE BRENNER: All right. So anything you want to do with it now is up to you in the first instance I guess, and of course the other parties, on further cross or redirect, can do what they want with it also.

You can continue your cross-examination.

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MR. DYNNER: Thank you, your Honor.

CROSS-EXAMINATION (Continued)

BY MR. DYNNER:

Q Dr. Johnson, what is the depth in the stud holes from the block top to the threads for any study hole?

A (Witness Johnson) What is the depth? You are seeking a definition?

Q No, a measurement.

A On what stud hole would you like?

Q Any stud hole at all. Do you know what the depth is from the block top to the threads, where the threads begin?

A From the top of the block to the threads is 1.5 inches.

Q Thank you.

MR. DYNNER: For the record -- and I'll do it now, Judge Brenner -- I have been given a copy of an Eddy Current Examination Report by Mr. Farley. It appears to be dated 3/8/84, and is signed by Don Johnson.

And this test report shows, under the column "Length of Indication," for cylinder No. 7 on EDG-102 for stud hole--

MR. FARLEY: For the record, I object to Counsel characterizing what the document shows.

JUDGE BRENNER: Yes. I'm not sure that we need

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that, Mr. Dynner.

MR. DYNNER: I will strike all that and I will let Mr. Farley take care of this. I was going to do it to clarify the record at this point.

JUDGE BRENNER: Okay. I just don't know what you were going to do.

MR. DYNNER: I can make a statement for the record that the Eddy Current Examination, given Dr. Johnson's testimony, does appear to show that the depths of the two stud holes in question by this Eddy Current Examination do substantiate the depths shown for those two stud holes on the crack map.

JUDGE BRENNER: Okay. Well, we can accept, if I can phrase it differently -- and tell me if I'm saying the same thing -- you are saying it is in effect a stipulation of fact that when Dr. Johnson testified that inspection report would show it in fact does show that.

MR. DYNNER: Yes, sir. That's all I was trying to put in the record.

JUDGE BRENNER: Okay.

BY MR. DYNNER:

Q Dr. Rau, it is true, isn't it, that your cumulative damage analysis calculations do not assume any particular sequence of loads for EDG-103. Isn't that right?

A (Witness Rau) That is correct, Mr. Dynner. The

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cumulative damage model does not take into account the relative sequence of the different power levels.

My experience with cumulative damage analyses over the years indicates that unless there are enormous differences in the stresses developed that the sequence of these kind of loads.... Let me back up a minute.

Unless there are enormous differences in the magnitude of the stresses, unless you're jumping around with your loads like you might on an airplane wing where it's bouncing up and down in the gusts back and forth from one load to another as opposed to continuously running at one power level for a certain amount of time, then continuously running at another power level for another period of time, that there would be no significant difference of the order of the sequence of the power levels.

Q Does the Cumulative Damage Index use what is commonly referred to as Miner's rule, or a variation of Miner's rule?

A Well, I can't answer that Yes or No. It is certainly not Miner's rule purely and simply. In a loose sense you might call it a variation.

To the extent you mean by Miner's rule just cumulative damage, Mr. Miner originally put together a linear cumulative damage which is associated with his name and sometimes called Miner's law or Miner-Pomigrin's law.

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What we did is not that, but it is a cumulative damage analysis.

Q If you had done your cumulative damage analysis on EDG-103 for the period from the time the engine went into service up until March 8th, 1984, that analysis would not have predicted the cracks that propagated during the period from March 11th to April 14th, would it?

A That question doesn't make any sense to me, Mr. Dynner. If you want to try again I'll try to answer it.

Q Dr. Wells, can you answer that question, if you understood the question?

If you had done your cumulative damage analysis using the state of the block top in this case as shown on Exhibit B-18 for the period of operation of EDG-103 from the time the engine went into service until March 8th, 1984, that analysis would not have predicted the crack initiation and propagation that occurred from March 11th through the time the block failed, would it?

MR. FARLEY: Objection on the basis of Dr. Rau's testimony.

JUDGE BRENNER: I'm sorry, I don't understand the objection, Mr. Farley. Can you explain it, please?

MR. FARLEY: Dr. Rau said he couldn't understand the question, it didn't make any sense to him. And now

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Mr. Dynner has switched to Dr. Wells.

JUDGE BRENNER: Well, that's acceptable. We'll allow the question.

WITNESS WELLS: I gather your question means did we or would we be able to predict the initiation and propagation damage as of the time the between-stud crack was observed. We made no attempt to do that. Whether or not we would have or could have or should have, I must defer to Dr. Rau.

WITNESS RAU: Mr. Dynner, the question you--

MR. DYNNER: Just a minute, please, because Dr. Rau has already said he didn't understand the question.

WITNESS RAU: You asked a different question the second time, Mr. Dynner.

BY MR. DYNNER:

Q All right. Go ahead and try to answer it, Dr. Rau.

A (Witness Rau) I can't answer it, and the reason I can' answer it and I don't think anybody can is you asked me to assume, or asked us to assume that the block started out with the cracks that are present in B-18 and then experienced all the duty which it has since the day it was first placed into service, and then to make predictions about whether or not things would happen thereafter. It doesn't make any sense.

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Q Well, wasn't the damage, Dr. Wells, that EDG-103 accumulated between March 11th and April 14th substantially greater than the damage as measured by the size of the cracks in the block that it had accumulated during its entire history of operation from the time it was put into service until March 8th or March 11th?

A (Witness Wells) I don't think so, Mr. Dynner. You're asking us to estimate the damage accumulated in initiation and in propagation up to the March 8th and comparing that with damage expended in propagation from March 11th through April 14th.

Again I must ask Dr. Rau, if he understands this situation, to respond to it.

A (Witness Rau) I can't respond exactly to it but I can indicate that qualitatively the total amount of cumulative damage which the origianal 103 block had seen through its duration of testing up until March of '84 is of the same order as the amount of damage which occurred during the test period from March through April of 1984.

Again I don't have the precise numbers in front of me but, you know, it's within a factor of two or three for sure.

By that-- As I said previously, I mean that the summation of the number of hours at the corresponding load levels and the stresses that result therefrom, when you add

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them all up, the number of hours times the stresses that go with a certain power level for all the testing up to March, is of the same order as that which occurred during that test period.

Q Yes.

What I was referring to is the magnitude of the actual damage; that is to say the size and depth of the cracks, and the nature of the cracks.

You couldn't make that kind of a comparison without some time spent, or can you have—

A The inspection records speak for themselves. The amount of damage accumulated physically as a result of a certain amount of duty, a certain amount of operation at power levels over a period of time speak for themselves. And you can compare that amount of damage with the amount of duty, power level, stress level, times, in any way you choose.

Q Dr. Wells, at page 52 you, among others, were asked a question about whether the cumulative damage analysis results show the ability of the original EDG-103 block to perform adequately during a postulated loop LOCA. Is that the standard for— If you know, is that the standard requirement for the General Design Criterion 17 for the diesel engines?

Anyone on the panel can answer that after you,

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Dr. Wells.

A (Witness Wells) I believe so, and I would like to ask Mr. Youngling for information.

A (Witness Youngling) Mr. Dynner, if you refer to page 74 of our testimony you will see a restatement of GDC 17, and basically the major attributes that we are trying to do there is the maintenance of the pressure boundary of the reactor coolant to keep the core cooled, and to maintain the containment integrity.

Q My question was is the ability to survive a loop LOCA the standard for the EDGs under GDC 17, in your opinion?

A GDC 17 sets forth the requirements for the power supplies, including the diesel generators. Certainly there are other General Design Criteria that discuss the response of the reactor, but the entire situation relative to the diesels has been interpreted that the diesels will be capable of supplying power for a seven-day period in response to a loop LOCA event.

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Q Dr. Wells, is the stress that the block top sees during operations of various loads linear. That is to say, would you expect to see a linear progression of if you went from 90 percent of load to 100 percent of load of the same amount of increased stress as going from 100 percent to 110 percent of load?

A (Witness Wells) You can, I think, best visualize that from the actual strain gage records that were obtained at different load levels. There you can see that the last measured load levels show a rather steep increase, to characterize it. So the answer would be the change from 90 percent to 100 percent -- the change in stress from 90 percent to 100 percent -- is not so large as the change from 100 to 110 percent of load.

JUDGE BRENNER: Dr. Wells, were you looking at one of the exhibits when you talked about the steep increase?

WITNESS WELLS: Yes, Exhibit 30, your Honor, or any of the strain gage records will show that. But 30 is the illustration we're looking at here.

JUDGE BRENNER: All right. Thank you.

WITNESS RAU: I think if I might add to that, with regard to strain gage 13 which is the one perpendicular to the directions where the stud-to-stud cracks formed between 4 and 5, what Dr. Wells said is completely true.

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And Exhibit B 30 does in fact show that it is not exactly linear?

There are two points that should be made, however. First of all, although there is an increase in the steady stress which is quite substantial between 35 and 3830 as illustrated by the change in slope of the lines in the upper right B 30, the difference between the maximum and the minimum which is -- that difference is the alternating stress or the range of stress which affects fatigue crack extension, that range is increasing much less slowly. It's not increasing as much as the steady or the mean stress is.

The second point that should be noticed is that there is a non -- things don't start at zero. There's a preload, which starts off at a positive steady stress or mean stress to start with. In the middle of that same Exhibit B 30, you can see that the points don't start where the engine load starts at zero stress. And so it's not linear but nor does it start at zero. And you have to be cautious about making ratios of power levels and extrapolating. You can make mistakes if you just do that.

BY MR. DYNNER:

Q Dr. Wells, on page 62 of your prefiled testimony as we have discussed previously, questions 83, 84 and 85 have been deleted in your revised testimony. And earlier you testified to the effect that the strain gage data from

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Delaval was -- I don't want to put words in your mouth, but my understanding is that you did not view it as reliable; is that correct?

A (Witness Wells) That's correct, sir. We could not verify it independently to begin with and on attempts to verify it we found there were certain discrepancies.

Q All right. Would you take me step by step? First of all, was the raw strain gage readings, was there something in it that you found that was wrong with the raw data, the readings from the strain gages?

We're talking for everyone's clarification. As I understand it, this testimony relates to the TDI strain gage of the cam gallery area.

A Well, in one case we found that one of the gage elements, I believe it was, a 45 degree element of a three gage rosette was not operating.

As another point --

Q Well, let me just followup on that if I may.

Were other gages operating?

A Other gages were in fact operating.

Q How many other gages were there?

A My recollection is that there were at least two rosettes and possibly three. I recall the gages were located on the cam bearing saddle support itself. And gages were located either side of the cam bearing saddle.

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Q That would be shown in the original Exhibit 54, isn't that correct, of LILCO's prefiled testimony?

A That's correct, Mr. Dynner.

Q Now, just help me out. Can you tell me which gage was not operating properly?

A I don't recall specifically which one was not operating at that time.

Q Anyone else on the panel can feel free, if you know, to chime in with an answer to these questions.

Dr. Rau, that includes you.

A (Witness Rau) I also do not recall the specific gage. I have to refer to detailed notes to find that.

Q All right.

Now, was there anything wrong with the data that was generated by the gages that were working properly, Dr. Wells?

A (Witness Wells) Yes. Although the ranges of the gage readings resulting from the application of firing pressure appeared reasonable and also appeared that there was some drift in the mean or the steady state values of the gages. So upon reviewing both of these apparent problems, and the fact that this gage that I indicated earlier had not been working was reduced with some assumed value rather than actually measured values. We concluded that we could not place any reliance on these gage readings.

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Q Dr. Wells, as I recall —

A (Witness Rau) Can I add something to that?

Q Certainly.

A There was one very specific problem identified that I recall and that was the -- they had a thermocouple which meausured the temperature in the vicinity where the strain gages were and that thermocouple recorded a temperature, I don't remember the exact number, but something like 100 degrees, in any case, well below the normal operating temperature of the block in that location. Which is definitive evidence, again to the extent that measurement is accurate, that the block had not reached thermal equilibrium and therefore, the instrumentation would be fluctuating as the temperatures changed.

A (Witness Wells) This certainly contributed to this problem of the shift in the mean reading on the zero reference. It is, of course, necessary to have careful temperature compensation with these gages which, of course, we have achieved in subsequent work.

Q You said the ranges appear to be reasonable, Dr. Wells. Can you explain what you mean by that?

A The ranges that were measured that are shown in the Exhibits 56 et cetera, show only that there was, if you will, a qualitative agreement, that is, the range seemed to go up with load in some places. But, however, at other

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places it appeared that it was a higher range at low values and we had no real explanation for that, either.

Clearly, since this is a simple matter of static equilibrium the higher the pressure range, that is, from zero to maximum firing pressure, the higher the stresses should be at the gage locations.

Q Are there any other problems that you found with the TDI strain gage information which you were, at one point, relying upon in your testimony?

A (Witness Rau) Are you asking Dr. Wells or --

Q Either of you.

A Dr. Wells may have others, but --

There was reported to us and later confirmed by us that there was a data reduction error, a simple out-and-out calculational procedure error, made by the TDI technician or engineer who was reducing the strain gage signals to stresses. It just plain was wrong.

Q What was the nature of that error?

A Again, I don't recall the details anymore but it was clearly just the mechanical engineering of the way he was doing it; it was just plain wrong. Again, I don't recall the details but clearly incorrect.

Q Do you know what data you're talking about that the error occurred in?

A I don't recall precisely whether it was limited

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to certain areas or generic. It was, again, a procedural kind of error, not slipping a number but just going about it with the wrong series of steps and equations. So, my recollection is to the extent we could ascertain it, this mistake was general to the reduction of the entirely of the data.

Q When did you discover this error had been made, approximately?

A My recollection is it was approximately early September.

Q How did you happen to discovery that error?

A We sent several of our engineers over to TDI. They sat down wih all the original data to the extent they had it, met with their current engineers and, again, I can't recall whether they first told us they were incorrect or whether we discovered it and then they confirmed it. But basically they told us it was incorrect it and we confirmed it was incorrect. I don't know which came first.

Q What prompted FaAA to arrange this meeting with Delaval at that time?

A (Witness Wells) We frankly doubted the validity of the data. It did not make engineering sense, on detailed consideration of it.

Q Did it make engineering sense when you filed your testimony on August 14?

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A I think it did from a standpoint of our conservative upperbound. We took at least what we thought was a documentable measured range of stress and applied that to an assumed crack depth and predicted there was, of course, no need for further consideration of this problem.

Q Well, what led you, Dr. Wells, to believe that it didn't make any engineering sense —

A (Witness Rau) Can I comment?

Q I'm following up with Dr. Wells.

What led you to believe that it didn't make engineering sense after August 14?

A (Witness Wells) Basically, it's Dr. Rau's story. But as I indicated yesterday morning, I believe, or rather Monday morning, if you just go through a simple analysis of the distribution of loading throughout the block of the engine, you reach the conclusion that there is no way a tensile stress can be exerted at any time, under any condition. Now, gage readings that show a tensile stress in the vicinity of the cam gallery are clearly at odds with the static equilibrium of the block, cylinder heads, and base.

Q So, is it your testimony that the TDI strain gage data reflected that there were tensile stresses in the cam gallery area?

A They did, in fact, indicate tensile stresses in the cam gallery area; yes.

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A (Witness Rau) I would like to add one thing, if I might, if you're done with that line of questioning?

Q And, Dr. Wells, just so I understand what you're saying, you're talking about tensile stresses as opposed to steady compressive stresses in that area; is that correct?

A (Witness Wells) No, I'm contrasting a stress state that, from static equilibrium, should vary from a mean value of deep compressive stress caused by preloading of the bolts that fasten the block to the base and then upper range of compressive stress which is actually a smaller negative value, if you will, caused by relief of some of that loading from the gas pressure forces applied to the underside of the cylinder head and transmit it from the underside of the cylinder head to the block top.

Q And instead of showing that, the TDI strain gage data showed that there were tensile stresses that were present during engine operation in the cam gallery area?

A During the application of peak firing pressure; that's correct.

Q Thank you. Dr. Rau, you wanted to add something?

A (Witness Rau) Yes, Mr. Dynner.

In addition to the reasonableness of the appearance of those results, they have been used initially because our belief was they were conservative. They did show small values of tensile stress and we utilized those as

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a conservative bound in the preliminary fracture mechanics calculations that were reported in the preliminary report in June.

I had a second point but I've lost it; I'm sorry.

Q If the results, Dr. Wells, were so unanticipated, why didn't you question the validity of the TDI strain gage analysis before you filed your testimony?

A (Witness Wells) Well, in fact, Mr. Dynner, we had realized from the start that cracks in the cam gallery were not a critical problem in the first place and, at least from my perspective, I viewed other areas of the block as being worthy of detailed consideration much more so than the cam gallery.

As we have testified I believe LILCO originally examined the significance of the cam gallery area before Failure Analysis Associates was brought under the diesel program and attributed the indications to fabrication and our preliminary analyses based on this small level of tensile stress Dr. Rau mentioned, and our understanding of the sizes of the indications confirmed that there was no significant problem in the cam gallery area whatsoever.

And, quite frankly, these problems were not fully uncovered until we began -- and Dr. Rau specifically -- began to go through the quality assurance review of the information for our final report.

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It was an unfortunate timing problem that the initial information found its way into our prefiled testimony.

A (Witness Rau) If I might just add, I remembered what I wanted to say that slipped my mind a second ago.

There is perhaps a bit of a misinterpretation of the sequence of things. Everything that has been said is correct but the sequence is not quite — at least as I understand what has come into the record, it is not exactly what happened.

The decision to do a detailed independent verification of the results that TDI presented in their strain gage report were part of the review of all of the input information that was going to form the basis for our testimony.

And the first thing that happened was that I could not obtain an inspection report which verified the depth of, the maximum depth of any indication in the cam gallery to be 3/8ths of an inch which is what had been reported to us. And it was my decision — at least my recommendation and LILCO's subsequent decision to destructively examine certain regions of the cam gallery to measure directly how deep those indications were.

And of course when we did that we discovered they were somewhat deeper than the 3/8th inch which had been

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reported previously. And as a result of having measured the cracks to be deeper than we had heretofore thought, we could no longer rely upon the what we thought were conservative results of TDI. We felt it was appropriate to independently review that and anything else that might go into an evaluation of those particular indications.

So really the inspection came first and then we started to do a detailed review of all of the input including the TDI strain gage and that's when we met with TDI and discovered the things we have already talked about.

Q Dr. Rau, approximately when did you measure these cracks in the cam gallery area, about what date?

A Well let's see. My recollection is that the first time I was aware that our inspections were out on the weekend I think, a weekend late in August, whatever the dates are, like the 25th, the 26th, something like that, and that Monday I got the report of the results. I had formulated a plan for the destructive inspection in mid-August, right about the time of the testimony preparation when I discovered we could not find any inspection records to verify the depth of those reported indications.

Q Dr. Wells, can you describe for me what is residual stress in a cast iron casting?

A (Witness Wells) Residual stress would be a

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stress that is balanced internally in a metal part through the result of differential heating or differential cooling, more correctly, during solidification which would leave, for instance, some tensile stress in some locations, that would be balanced by compressive stresses in other locations.

Q Would residual stress also arise because of differences in the geometry of a particular area?

A To the extent that the geometry affected the heat transfer and the solidification, it could.

Q And in the cam gallery area there are in fact, as you have testified in your testimony, some rather abrupt changes in the thickness of the material in the area, aren't there?

A That's correct, and we believe that the defects observed were the result of a fairly significant change in section.

Q You mean change in section geometry?

A Yes. Specifically that change in geometry that results in a thick structure immediately adjacent to a thin section.

Q Now in analyzing the stresses in the cam gallery area, did FaAA do an analysis of the residual stress in the cam gallery area?

A We did not include explicitly a residual stress. We assumed conservatively, in my opinion, that the stresses

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that were applied in the region adjacent to the cam bearing saddle were uniform through the walls.

Q So you did not do any analysis to determine the actual residual stresses in the cam gallery area, isn't that right, Dr. Wells, yes or no?

A No, we made no analyses of residual stress. In order to do that one would have to know the precise history of solidification and cooling. Had we known that, I think we would have assumed that there was a gradient of stress which was tensile at the outer wall of the casting and either decreased more or less rapidly through the wall toward the inside of the casting, since this is the normal variation of solidification and heat transfer that takes place in the cooling of a large casting.

In other words, the location at the outer part of the cam gallery could have been -- would be expected to have a slightly higher tensile stress perhaps than the region on the inner wall.

I would like Dr. Rau to amplify on that, please.

Q Well I'm not interested and my question didn't go to what you might have assumed. My question was a very simple one and you answered it, and that is that you did not perform an analysis of the residual stresses in the cam gallery area, so I don't need an amplification on an answer to a question that I didn't ask.

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MR. FARLEY: I object.

MR. DYNNER: I would like control of this, Judge Brenner.

JUDGE BRENNER: I will give you control in this instance.

WITNESS RAU: Your Honor --

JUDGE BRENNER: No, we will get it on redirect if you think it is still important.

Go ahead, Mr. Dynner.

MR. DYNNER: Thank you.

BY MR. DYNNER:

Q It's true, isn't it, Dr. Wells, that you did not -- and I mean you, FaAA -- did not perform an analysis of the residual stresses in the block top, isn't that right?

A (Witness Wells) No, to my knowledge we did no analyses of residual stresses in the block top.

Q Who is Stewart Parker?

A Stewart Parker is an analytical engineer at Failure Analysis.

Q And you are aware, aren't you, that Stewart Parker recommended that FaAA consider measuring the residual stress in the cam gallery area.

Are you aware of that?

A Yes, I'm aware of that.

Q Can you explain to me why you did not accept

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Stewart Parker's recommendations?

A We believed it was unnecessary, that the residual stresses resulting from the solidification of a casting would show a conservative gradient. The effects of residual stresses were in fact considered by Dr. Rau. There may not have been detailed analytical calculations of the effects of those stresses, however, the effects of residual stress were in fact qualitatively included in our engineering evaluation of the cam gallery. After careful consideration we decided it was unnecessary to perform any experimental measurement of residual stress, which would have meant having to drill holes in or cut up a fairly large unwieldy piece of material.

Q It's true, isn't it, Dr. Wells, that the residual stress would not be measured or taken into account by strain gage experiments, would it?

A That's correct, it could not be measured by strain gages.

Q And it is also true that if you --

A (Witness McCarthy) I'm sorry, there is a little clarification that needs to be given to the last answer. It would not be measured by strain gages on a part in the form we use them. Residual stresses are customarily measured by strain gages, by putting them on a part and then drilling a hole or by sectioning.

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The way Dr. Wells meant was correct but it can be measured by strain gages in other ways.

Q Thank you.

And it is possible, isn't it, that the residual stress in the cam gallery area could be such that it could turn out that, rather than have only the compressive stresses that you have testified you believe are in that area, there could actually be tensile stresses when you took into consideration residual stress: isn't that right, Dr. Wells?

MR. FARLEY: Objection, speculation and conjecture.

WITNESS WELLS: Mr. Dynner —

JUDGE BRENNER: Wait a minute.

(The Board conferring.)

JUDGE BRENNER: I am going to overrule the objection. I don't know enough to agree with you, Mr. Farley, and since I don't know enough to agree with you on that objection I am going to overrule it and we will let the witness handle it.

WITNESS WELLS: Mr. Dynner, insofar as what might or might not be the residual stress distribution in a casting of this sort, Dr. Rau actually made that evaluation and I must defer to him.

BY MR. DYNNER:

WRBagb

Q My question was in fact, just to clarify the record, my question was in fact a hypothetical one which we often use in discussing these scientific areas and it is that given X amount of residual stress, which you don't know what it is, the impact of that residual stress could be that there really are tensile stresses in the cam gallery area, isn't that true?

MR. FARLEY: Same objection.

JUDGE BRENNER: Same ruling.

WITNESS WELLS: No, I disagree, Mr. Dynner, that is not a yes or no situation. It would have to be specific about what location and under what conditions and a variety of other matters. It is a more complex situation than can be answered simply yes or no.

Obviously one stress distribution can be added to another distribution. But again so far as the engineering evaluation of this type of situation, this is Dr. Rau's field.

BY MR. DYNNER:

Q Dr. Rau, you may find that that question is familiar, because I think I asked it in my deposition so why don't you try to answer it for me again.

A (Witness Rau) Do you want me to refer to my deposition?

Q No, you don't have to do that. I want to see

whether you are going to say the same thing.

A Well I think I have the right to look at my deposition.

What were you referring to?

Q I am referring not to the deposition now, I am referring to the question.

JUDGE BRENNER: I tell you what, Mr. Dynner, since you thought it was so interesting and entertaining to rephrase the question the way you did, now you give him the reference.

MR. DYNNER: I will give him the exact reference: page 74 of the deposition, and I will read into the record my question:

"Question: Is it possible that residual stresses would have an impact such that you would find that all of the stresses in this area were not compressive?

"Mr. Farley: Object to the form of the question, speculative and conjectural."

MR. FARLEY: I still do.

MR. DYNNER: "Mr. Dynner: Go ahead, answer, it is all allowed.

"Dr. Rau: Well again if you are going to make the hypothetical" --

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MR. FARLEY: I object to this form of examination. This is not the way you impeach somebody or attempt to impeach him.

MR. DYNNER: I'm not trying to impeach him now --

JUDGE BRENNER: He is not trying to impeach him now, Mr. Farley, he is doing this because the witness preferred it and I agree with the witness because -- and I stated why.

MR. DYNNER: And I agree with you, Judge Brenner.

JUDGE BRENNER: It's not necessary, do it anyway.

BY MR. DYNNER:

Q "Dr. Rau: Well again, if you are going to make the hypothetical that residual stresses can shift to steady stress from what is measured there to something which would include some positive, yes, the answer to that is of course, yes. You have to specify what magnitude and all that sort of stuff."

And that is the answer I was referring to --

MR. FARLEY: That is not the complete answer, your Honor.

JUDGE BRENNER: All right. Do you want to read more of it into the record?

MR. FARLEY: Yes, sir.

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JUDGE BRENNER: "Stuff" was within the quote?

MR. DYNNER: Yes.

MR. FARLEY: The conclusion to the answer on page 75 was:

"...but the evidence again from the old 103 block is -- and there is one which had very severe cracks introduced by the shrinkage during fabrication -- clearly the evidence of that having run for more than -- I have forgotten the number, 1200 hours over a wide range with 400-plus full power and having no indication of crack extension at all, is indicative that the loading conditions -- even if they are not all compressive, which I believe them to be -- even if they are not all compressive, are still well below the conditions under which those cracks would extend. That is clearly demonstrated. Again, this is in 103, the old 103 which had these terrible degenerate properties: cracks grow so much more easily than they do in conventional gray iron. And there is another conservatism built into that whole conclusion."

JUDGE BRENNER: Dr. Rau, is that the same answer you would make to that same question today?

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WITNESS RAU: Hopefully I would be a little more articulate, but yes.

(Laughter.)

1 WRBeb

JUDGE BRENNER: Whenever you have transcripts read back of anything you say -- and I've had the experience also -- it is usually not pleasant, but you are not alone. -- I meant in substance.

WITNESS RAU: Yes, sir.

JUDGE BRENNER: When the lawyers start quoting you in orders as to what you have articulately said in the transcript it is even more fun.

WITNESS RAU: Your Honor, could I add what I was going to add to the question just before that? I didn't get a chance.

JUDGE BRENNER: All right.

WITNESS RAU: Mr. Dynner was asking about residual stress evaluations and analyses, and in fact I have considered residual stresses in both the cam gallery and also in the block top region.

Dr. Wells is correct in that we have not made explicit calculations attempting to get the exact magnitude of the residual stress. That is not precisely possible. But in the case of the cam gallery, there are very specific pieces of physical evidence which provide certain bounds on that the residual stresses could be.

In particular, the casting defect that is present in the cam galleries, the shrinkage cracks, the fact that they didn't extend entirely through the wall thickness at

1 WRBeb

that location is definitive evidence that the residual stresses are compressive or, at the very least, very, very low. Had they not been the crack would have-- As the crack gets bigger, if the stresses stay the same and the crack gets bigger, it doesn't stop. The only thing that stops a crack as it gets bigger is that the stresses have to die down or go away.

And for that reason it is my belief that the very fact that they stopped is clear evidence that the residual stresses from the casting are compressive at the point where the crack finally stopped and in fact are probably compressive -- it is more like a bending field -- somewhere before the crack actually stopped.

In addition to that, as you know, there was a repair weld put over the top or the surface of these shrinkage cracks in the cam gallery. These welds are different depths but it is of the order of 3/8ths, 1/2 inch deep. And when that repair weld was put on some time after the original fabrication, the subsequent cooling solidification of that weld introduces additional residual stresses.

But again the details of that weld and its location are such that tensile residual stresses will be produced in the weld, that is over the first -- the size of the weld, the 1/2 inch or 3/8ths, and beneath that depth,

WRBeb

there must be the balancing stresses Dr. Wells made reference to, that is, compressive stresses.

So if anything, the subsequent weld repair would have added compressive residual stresses to the locations where the tips of the casting defects exist.

So for both those reasons we have reason to believe that the residual stresses, if they are there, are compressive, and in our analyses we made the conservative assumptions that they are zero. And I believe that to be very conservative.

Now with regard to the block top, it again is true we made no explicit compilations of residual stress, but I would like to state for the record that the cumulative damage approach which makes use of the performance, the actual performance of the original 103 block top, takes into account residual stresses should they be there.

The 103 block top, if there are residual stresses, has residual stresses just like 101 or 102, and to the extent they are there, they are part of the performance of the block, given the cumulative damage experienced, power levels, times. And so that is an integral part of the cumulative damage assessment of margin against possible loop LOCA requirements based on the actual performance of the 103 block during testing.

BY MR. DYNNER:

1 WRBeb

Q Would you turn to page 28, please, gentlemen, of your testimony?

I noted, Dr. Wells, since you were the sponsor of this testimony, that you have deleted the testimony of Questions 35 and 36. Why?

MR. FARLEY: Your Honor, I want the record to show that I object to that, and I understand your ruling is that you are going to allow it.

JUDGE BRENNER: I guess I don't have to say anything.

(Laughter.)

WITNESS WELLS: Mr. Dynner, in the analysis of the block top strain gage data provided by TDI, the reason for striking those two answers is that the strain gage information could not be verified independently by our quality assurance program.

BY MR. DYNNER:

Q Do you have any reason to believe that there is anything wrong with that strain gage data?

MR. FARLEY: Objection. Asked and answered.

JUDGE BRENNER: I am going to sustain that unless you can convince me otherwise, Mr. Dynner.

BY MR. DYNNER:

Q Well, what attempts were made to verify whether or not the TDI strain gage data was reliable or not?

WRBeb

MR. FARLEY: Objection. Asked and answered.

JUDGE BRENNER: You know you've covered the area at different times, Mr. Dynner.

MR. DYNNER: This is a different strain gage, a completely different strain gage test, Judge Brenner. Just so we don't avoid confusion, the strain gage tests that they've been testifying about as being unreliable and incorrect were the strain gage data that were done on the cam gallery area of the DSR-46 engine.

I am now questioning the witness about the deletion of TDI strain gage tests that were done on the block top, and as you can clearly see by looking at Exhibit B-32, which shows the location of these strain gages, they aren't anywhere near the cam gallery area. It is a totally different set of tests.

JUDGE BRENNER: I don't happen to have the exhibit and it is unfortunate and I regret now that I allowed the exhibit book to be recast in such a way that those that were deleted were actually deleted rather than struck through.

MR. DYNNER: I will show it to you if you like.

JUDGE BRENNER: You don't have to. I'll accept your representation. I don't know if the answers are going to be any different but I will allow you to pursue it. I was confused. I believed that this was also strain gage

WRBeb

data of the cam gallery area.

WITNESS WELLS: In general, our problems with verification of the tests conducted in the past by TDI have been the same. We have not been able to confirm the calibration of instrumentation, the accuracy of recording, and in some cases, the reduction of strain data to stress data. Therefore I think all these gage readings are essentially tarred with the same brush.

BY MR. DYNNER:

Q Well, do you know when these particular strain gage tests that you referred to in your answers 35 and 36 were done?

A (Witness Wells) I don't have those dates with me now, Mr. Dynner. They are in our records. They are certainly much-- They predate our analysis of the block.

Q Do you have any reason to believe that this-- Other than the general statement you made about not relying on Delaval in general, do you have any reason to believe that this particular strain gage data is wrong?

MR. FARLEY: Objection. He mischaracterized what the witness said.

JUDGE BRENNER: I will sustain that objection.

MR. DYNNER: All right.

BY MR. DYNNER:

Q Do you have any reason to believe that this

particular strain gage data is wrong?

A (Witness Wells) I don't recall any specific violation that would suggest that we should discount the measurements. However, I have little faith in the mean stress values. The situation here I think is analogous to the situation in the case of the cam gallery strain gage tests.

I recall that in discussions of this data there were references made to problems with the shift of the mean value of strains. As you know, these are important to our understanding of the thermal contribution and the preload contribution to the block top stresses.

Again these have been variously -- at various times attributed to the lack of calibration or compensation, I should say, for temperature effects, and in that regard I think these measurements suffer from the same problems that the cam gallery did, only in the case of this location we are dealing with higher temperatures and more complex heat transfer situations. So I am doubly pessimistic about the validity of the results.

Q The placement of the two stream gages, Nos. 3 and 4 as they appear on Exhibit 32 which has been stricken, is in fact one directly above the counterbore landing and one directly below the counterbore landing. Isn't that true?

A Approximately so, yes.

2 WRBeb

Q So that if one had an accurate reading of the strain from those areas, one would know what the stress in the area where the circumferential cracks had initiated, wouldn't one?

MR. FARLEY: Objection. There has been no evidence of that.

JUDGE BRENNER: Well, maybe we'll get some when we hear the answer.

WITNESS WELLS: I don't believe there is any connection between those gage readings and the stress that is directed perpendicular to the corner of the liner landing where we're concerned about the initiation and growth of circumferential cracks.

WITNESS RAU: Can I add to that, please?

I perceive another difficulty in trying to answer that question is that the gages, although they are in the general vicinity of above and below the liner land, are a substantial distance away from that sharp corner where the liner land reaches the counterbore of the cylinder.

Our analyses have shown that there are very severe stress concentrations right at that corner. It's a very localized but very high elevation of the stresses above those that would be anywhere near the gage locations compared to those stresses that are right at the corner.

So even if you had valid gage readings at the

2 WRBeb

positions where they were located, you could not infer by any way, shape or form what was present at the corner of the counterbore to liner land where these shallow circumferential cracks have been observed.

BY MR. DYNNER:

Q Well, isn't it true, Dr. Wells, that the stresses that cause circumferential cracking are both stresses of the liner hoop against the counterbore as well as the stresses of the cylinder liner squashing down on the landing?

A (Witness Wells) The primary stresses on that particular corner do result from, as you call it, the squashing effect of the liner collar against the liner landing, and also result from the radial pressure of the liner collar against the landing -- rather, the vertical walls, the cylindrical walls above and below the landing surface.

The components of stress that one is concerned about contributing to the initial and growth of these circumferential cracks, though, could not be measured at the locations of those gages.

JUDGE BRENNER: Gentlemen, as long as Mr. Dynner is pausing:

The TDI strain gage data discussed in the portion of your testimony deleted, starting on page 28, what engine did TDI place the pages on? I have lost my reference point

WRBeb

now in mind.

WITNESS WELLS: It was an R46 six-cylinder in-line test engine. I don't have the specific designation of the engine, Judge Brenner.

JUDGE BRENNER: That's sufficient for my purposes.

Now did TDI perform those strain gage tests at approximately the same time period as TDI's cam gallery strain gage tests? What I'm trying to find out is if it is part of the same test series on the same engine, if you know.

WITNESS WELLS: I think the block top stresses were-- I'm fairly sure the block top stresses were measured before the time of the cam gallery stress measurements.

WITNESS RAU: I think, your Honor, -- I don't know the precise dates exactly, but I do know from my recollection of reading the memoranda in the TDI strain gage report that -- for the cam gallery that that was done in response to some certain specific observations and was not an integral part of a block top test program for which this other strain gaging might have been part.

Although they may have been at the same time, it is also my belief that the cam gallery strain gaging came later, and it certainly was independent.

WITNESS SEAMAN: Judge Brenner, perhaps I can add

1 WRBeb

something.

The cam gallery tests that were performed by Trans-American Delaval were done at LILCO's request in response to our investigation of the cam gallery indications we found at Shoreham.

This other block test was not done at our request, so I don't know the exact time it was done but it certainly was not done at our request.

JUDGE BRENNER: Okay. Thank you.

BY MR. DYNNER:

Q Dr. Rau, when did you first discover that the cam gallery cracks had been welded? And when I say "you" I'm referring to FaAA and/or LILCO?

So anyone on the panel really can answer that.

A (Witness Rau) I can give you my recollection.

I personally became aware of it I believe on the Monday after our inspectors did the destructive examination and perhaps over that weekend, I may have had a telephone call. I can't recall at this time. But it would have been late in August.

Perhaps the LILCO people, Mr. Schuster, would like to comment about when LILCO became aware of it.

A (Witness Schuster) The August date frame would be consistent with our first awareness of the weld repair in that area.

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Q And how did you come to find out that the cracks contained weld material?

A During examinations of the original DG-103 block by Failure Analysis. They were non-destructive examinations that were performed in the fillet gallery area of the cam gallery.

Q What prompted those examinations in August?

A Further examinations of -- and evaluations by Failure Analysis of the fillets in that original block. And I think Dr. Rau would probably be able to add more to that at this point than I can.

A (Witness Rau) Yes, Mr. Dynner. As I said previously, in our attempt to obtain the definitive documentation for the deepest cam gallery crack indications, not being able to locate an inspection report confirming that in fact the deepest crack was 3/8ths, I asked that LILCO make the original 103 block available for our destructive examination.

I established a plan for how that should be done and part of that plan was to perform -- basically to make sure the paint was off to perform a non-destructive penetrant inspection of the surfaces prior to the actual cutting of holes, the replicating and the subsequent cutting of samples for removal to the laboratory.

And it was those inspections done as part of that

1 WRBeb

plan for independent evaluation of the depth of those indications that the presence of the weld was revealed by porosity and just the liquid penetrant inspection reports.

And we then asked the LILCO people to make additional confirmatory measurements with -- they called them I think a "material gage," but basically it's-- I am sure Mr. Schuster and Dr. Johnson will have a more definitive description of what that is, but a measurement that the material was in fact weld material and not the original cast iron.

1 WRBpp

A (Witness Johnson) The approximate date of that inspection was 8-24-84. And I believe in addition the reason it was so evident is that the block had been out in the rain and cast iron rusts and weld material doesn't. And so you could very -- up until that point they look extremely similar, but at that point after the cast iron had rust, you could see the differences. So it's also a visible, visual, result.

Q There were in fact a number of other inspections of the cam gallery area of the EDGs prior to August of this year; isn't that right, Mr. Seaman?

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

Q Can someone explain to me why none of these other inspections disclosed the nature and extent of the cam gallery cracks and the fact they contain weld material.

A (Witness Schuster) I think I can help in that area.

When we looked at the 103 block, the original, when Failure Analysis did their examinations on it, we did not have all the paraphernalia et cetera, that would be normally bolted up an area, the cam shaft, the push rods, et cetera. The area geometrically, when the engine is assembled, does not provide the same overview that you would have when it's completely stripped down.

In addition, Failure Analysis, when did they

1 WRBpp

their examination, had all the paint stripped from the engine block. And the surface in that area is ground surface. We're looking at a fillet area and maybe you could help me with that sample we have.

JUDGE BRENNER: It's acceptable to use the sample, Mr. Schuster, but be as descriptive as you can because you remember after this all we'll have is the transcript for the record.

WITNESS SCHUSTER: Yes, sir.

The fillet is in approximately this position in the engine. (Demonstrating.) The bearing saddle is in this area here. (Indicating.)

What you're looking at down in the engine is this curved surface which is about three inches across. And that's all the area that is really visible when you look at it with an assembled engine.

In addition to this, we have painted both sides of it and the through bolt is in this area here adjacent to it. (Indicating.)

When the examinations were done by Failure Analysis we had none of this additional, you know, the additional components of the engine, the cam shaft, the push rods, the through bolting, or the paint in that area. And the surfaces are very similar because of the grinding, et cetera, that is done. And that's part of the reason why

1 WRBpp

that weld repair would not be totally evident, you know, in that location.

The other thing is, too, that welds commonly exhibit the same types of discontinuities of casting stone, porosity, et cetera, and it's not, you know, not unusual that you would see that type of discontinuity in any cast material or weld material. That area was not considered to be a problem from the point of view of a weld repair. And that would be as much as I could contribute without any further question.

MR. DYNNER: In order to assist the record, I will refer to the fact that the area in question, that is the cam gallery bearing saddle area, appears in photographs on the County's Supplemental Testimony filed October 18, 1984. In, for example, S3 there are three photographs of that area.

JUDGE BRENNER: Thank you.

BY MR. DYNNER:

Q Mr. Schuster, you could very easily have discovered whether there was weld material in those cracks simply by passing a magnet over that area, couldn't you?

A (Witness Schuster) No sir, it is not true because the weld deposit is magnetic, sir.

MR. SCHUSTER: Your Honor, I would like to add one other thing to the previous question and that is during

1 WRBpp

our time of examination of the engine we also had plastic and covering around the area that would be adjacent right and left of this, which was a clean area requirement that we had for the work that was going on in the engine. It furthe restricts the area that you're focusing on when you are doing the inspection.j

BY MR. DYNNER:

Q Dr. Rau, did FaAA conduct an inspection of the cam gallery area prior to August?

A (Witness Rau) I don't know the answer to that, Mr. Dynner. I know I personally was not involved but Dr. Johnson, manager of our nondestructive examination efforts might know.

A (Witness Johnson) We witnessed some inspections, I believe. I think Cliff can answer that -- Dr. Wells probably answer that best.

A (Witness Wells) Yes, Mr. Dynner. We witnessed some of the inspections. I also recall several of us making our own visual examination. I cannot dignify what they were with the word inspections because we're not, you know, qualified inspectors but we did examine the blocks of all three engines during their disassembly and reassembly.

Q And is it true that up until August you thought that the longest crack in the cam gallery area was 4 1/2 inches long and 0.375 inches deep?

1 WRBpp

A We had no basis to disagree with the inspection records.

Q Is your answer yes?

A I would have to see the inspection records that indicate those dimensions, Mr. Dynner.

Q Take a look at the block report on page 4-6. You might also look at your own testimony, Exhibit B52 which has since been stricken?

JUDGE BRENNER: I don't mean to be picky but it was deleted unilaterally by LILCO.

MR. DYNNER: Of course.

JUDGE BRENNER: And the only reason I say that is after many weeks go by and people look at old transcripts it sometimes is hard to keep separate what the Board may have ordered be struck as opposed to the unilateral withdrawal.

MR. DYNNER: Yes, sir.

BY MR. DYNNER:

Q Does that refresh your recollection, Dr. Wells?

A (Witness Wells) Not adequately, Mr. Dynner. I must remind you that this draft report to which you refer has not -- was not subjected to our QA review. And the information at hand at that time would have to be traced back to the inspection reports that Dr. Johnson and Mr. Schuster have reviewed.

Q Well, let me help you further.

1 WRBpp

Look at page 63 of your own testimony that was deleted. At the top of the page you say, "The size of the largest postulated defect was determined by surrounding disc continuous indications. The largest indications were found in EDG 103 and were 4 1/2 inches long."

Does that refresh your recollection?

A I have no personal basis to agree or disagree with the length of the indications. I must refer this one to Dr. Johnson or Mr. Schuster.

Q Except, Dr. Wells, you're the sponsor of that testimony, which is question 84 and answer --

MR. FARLEY: Objection.

BY MR. DYNNER:

Q The only other person to sponsor that was Mr. Taylor who is not here.

JUDGE BRENNER: The objection is sustained.

MR. DYNNER: All right.

JUDGE BRENNER: He is not the sponsor of any testimony.

MR. DYNNER: He was the sponsor of the deleted testimony.

JUDGE BRENNER: Well, they deleted a witness and then they deleted the testimony and there's a lot involved, so your characterization is incorrect and that's why the objection was sustained.

1 WRBpp

BY MR. DYNNER:

Q Dr. Johnson, can you help us?

A (Witness Johnson) I believe that the inspection records show that the length of the defect is of the order of 4 1/2 inches but I don't remember the exact number of the largest defect at that time: possibly Mil Schuster would know the number.

Q I think we've been with Mr. Schuster already.

JUDGE BRENNER: Not for that one, I don't think.

(Laughter.)

He can pivot and pass to somebody else if he wants.

Mr. Schuster?

WITNESS SCHUSTER: 4 1/2 inches is a reasonable estimate of the crack length, sir.

JUDGE BRENNER: And he wanted to know whether that was, I guess, 3/8 of an inch.

MR. DYNNER: .375 inches as known.

WITNESS SCHUSTER: If I can refer to the testimony that he's talking about, if I go down to the next sentence, it says the postulated defect shape is shown in Exhibit B 52. Postulated, to me, means -- does not necessarily mean accurate or the same as. There are certain crack characteristics that would give the appearance on the 103 engine of the defect depth of being 3/8 of an inch.

WRBpp

.375. But, again, I have to refer to, you know, the characterization here.

BY MR. DYNNER:

Q You didn't know, did you, before August of this year that some of the cam gallery cracks were as deep as 8/10 or 9/10 of an inch; did you, Dr. Wells?

A (Witness Wells) No, I didn't.

Q FaAA didn't know that and LILCO didn't know that, is that right, gentlemen? One person can answer and if nobody disagrees the rest of you don't have to answer.

A (Witness Schuster) LILCO did not know that the crack indication depths were 9/10 or 9/10 of an inch.

Q FaAA didn't know that; did they, Dr. Wells?

A (Witness Wells) FaAA did not know, Mr. Dynner.

Q And when was the first time that you discovered there were circumferential cracks in EDG 103?

A (Witness Wachob) Those were found in about the second week in September.

Q Of what year?

A 1984.

Q And that area had been subjected to inspections prior to that time, hadn't it, nondestructive inspections; isn't that right?

A What area and what block, sir?

Q I'm talking about the area where the

2 WRBpp

circumferential cracks were later discovered.

A (Witness Johnson) Those areas had been subjected to penetrant inspection and other inspections prior to that time in -- I believe the first inspection of that order was conducted March of '84.

Q And were those inspections done on all three of the EDGs?

A (Witness Schuster) The liner landing circumferential inspections were done on all three diesel generators, DG 101, 102, and 103.

As I indicated -- I believe it was Monday or so when the question was asked -- that the first engine that the inspections were done on was DG 102. And then subsequently -- that was in February and subsequently in March DG 101 and 103, and then again -- we repeated the inspection again for 103 in April. On DG 102, we also did the 100 start examination on, sir. I'm sorry, no. We didn't do a circumferential on that one because the liners were installed, as I indicted the other day.

MR. DYNNER: Judge Brenner, this might be an appropriate time for the afternoon break: if you will.

JUDGE BRENNER: Okay. If you want to, we'll take it now.

MR. DYNNER: It will be a convenient time for me to see whether I can conclude this afternoon.

WRBpp

JUDGE BRENNER: All right. Do you want more than just 15 minutes?

MR. DYNNER: I think -- why don't we do it until 3:30?

JUDGE BRENNER: Okay.

(Recess.)

1 WRBagb

JUDGE BRENNER: Back on the record.

During the break I was able to pass on to Mr. Brigati something I wanted to say to you on the record, Mr. Dynner and forgot to as to the time and that is you indicated you might finish today and what I said was that if in fact you do finish before the end of the day we will adjourn and I would still give you the opportunity to come back Monday morning and say you have considered things and want to still take advantage of the time up until the noon break on Monday on reflection, even though you might have originally thought you were finished before the end of the day today.

Off the record.

(Discussion off the record.)

JUDGE BRENNER: On the record.

MR. DYNNER: Judge Brenner, before I go back on the cross-examination, we had admitted into evidence the County's Diesel Exhibit 75, which consisted of a number of pages of eddy current examinations. We have now taken those pages and put them together in a package which I would like to give to the Reporter and the parties so that can be placed into evidence.

JUDGE BRENNER: Fine. Thank you.

And you have checked that they are pages 11, 12, 21, 23, 27 and 39, have you?

WRBagb

MR. BRIGATI: Exactly, Judge, at least I think so.

JUDGE BRENNER: Go ahead, Mr. Dynner.

BY MR. DYNNER:

Q Dr. Wells, would you please turn over a moment to page 66 of your written testimony?

Would you please tell me whether you now wish -- and Dr. Wachob also -- to delete the last sentence of your Answer 91 that appears on page 66? It refers to the FaAA's fracture mechanics analysis which earlier was -- portions of that on the cam gallery area, earlier portions of that, were deleted because in part they depended upon the TDI strain gage data. And I wondered whether there was an oversight and you wished to delete reference to that last sentence now.

A (Witness Wachob) The statement that we have a fracture mechanics model and we still believe its conclusions are correct, the thing that has changed is we have now changed the crack depth to make that analysis and you have received copies of that before. So our conclusion is that from a fracture mechanic point of view the cracks do not propagate.

Q This analysis you are talking about on the bottom of page 66 does not -- is it your testimony that it does not depend in any way upon the fracture mechanics analysis that

1 WRBagb

is referred to in question 83 on page 62?

A (Witness Rau) Mr. Dynner, the bottom of 66, where are you referring?

Q The last sentence. I thought by the way this document is written that on page 62 you talk about, in question 83, "...a fracture mechanics analysis was performed to evaluate fatigue crack growth of the cam gallery indications."

Now that's the only place in this testimony where you talk about a fracture mechanics analysis performed to evaluate the fatigue crack growth rate of the cam gallery indications. And I think if you look at that you may come to the conclusion that that is what you are talking about at the bottom of page 91 in the last sentence -- on page 66, answer 91.

A Mr. Dynner, I'm confused with regard to exactly what you are asking. I understand you want to understand whether our statement at the bottom of 91 still stands but I don't understand your reference to question 88, what kind of comparison you are asking for.

JUDGE BRENNER: I think you have got the wrong reference, it is not 88.

MR. DYNNER: It is question 83 on page 62.

JUDGE BRENNER: Okay.

WITNESS RAU: Mr. Dynner, if I might, I think

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your statement is not correct, that the mention in question 91 is the only mention to fracture mechanics analyses of the indications or the defects in the cam gallery area. They are in fact addressed in the answer to 91 as you have indicated, they are also addressed in the answer to 88.

For clarity I think I should indicate that the reference you made to deleted question number 83 had to do with the preliminary fracture mechanics analysis that was based upon the 3/8th inch deep postulated depth, whereas the analysis referred to currently, that is, by questions 88 and 91 and perhaps elsewhere but at least those two, have to do with the fracture mechanics analysis that was performed after the deeper cracks were identified and which we talked about extensively during my deposition.

BY MR. DYNNER:

Q I put to you that that is totally impossible because your testimony is dated August 14 and you didn't even discover the nature of the cracks and the depths of the cracks in the cam gallery area until after August 24. So let's try to look exactly at what you said in this testimony on August 14.

I put to you that the only fracture mechanics analysis regarding the cam gallery that this August 14 testimony is talking about is the fracture mechanics analysis first mentioned on page 62, answer 83, sir.

1 WRBagb

A (Witness Rau) That's not true, Mr. Dynner. When we did the additional analyses and provided the supplementary testimony we obviously reviewed all of the testimony which had been submitted in the initial response in the middle of August.

To the extent that that testimony was still precise and accurate it was left intact, and to the extent it required modification it was supplemented by the supplementary testimony. I would certainly agree at the time we drafted those words we had not done the new fracture mechanics analyses but, as they read and as they were, I addended or amanded by the supplementary testimony they are completely accurate at this time, the words referring to the fracture mechanics, the current fracture mechanics analysis.

A (Witness Wells) I would like to add to that, Mr. Dynner, if I may, that our current engineering evaluation would predict no fatigue crack propagation will occur under any conditions in any of the three blocks.

MR. DYNNER: I am moving to page 44 of the cross plan, Judge Brenner.

JUDGE BRENNER: On the last one you took, the last answer referred to the cam gallery, is that right, Dr. Wells?

WITNESS WELLS: That's correct, I was referring to the cam galleries of the DG 101, 102 and the new 103.

1 WRBagb

JUDGE BRENNER: Mr. Dynner.

BY MR. DYNNER:

Q Gentlemen, if you will look to page 68 of your testimony, you say that the replacement block for EDG 103 is the current production model.

When was the current production model of this block first introduced by TDI?

A (Witness Wells) The pattern changes to the block top, which is the only area that is different at all between the new DG 103 block and the DG 101 and 102 blocks was made in October 1979.

Q Is that block made in a single casting?

A As far as I am aware, yes.

A (Witness McCarthy) Excuse me, just to make sure the record is clear, what we have been referring to as "the block" is indeed a single casting. There is a little different makeup in terms of the number of pieces that forms what people normally think of as an engine block in one of these big diesels. It is not like the engine block on your car but the block is a single casting.

Q You testified earlier that the thicker the material in the cast iron there is less ultimate tensile strength.

Does the fact that this block is at least a half-inch -- the block top is at least a half-inch thicker

WRBagb

than the previous block reduce the tensile strength in the block top?

A (Witness Rau) Well to the extent, Mr. Dynner, the casting -- the original casting rather than the final machined part were in fact thicker in that region, it might have some small effect on the reduction in the ultimate tensile strength.

If you look at Exhibit B-12, which we have talked about previously, you will see that by the time you get out into thicknesses in the order of 2-1/2, 3-3/4, 3-1/2, the slope is pretty shallow. So we are not getting substantial reductions in ultimate tensile strength based on small changes in thicknesses out at that particular portion.

In addition to that, of course, the higher class of the replacement 103 block at the higher measured B bar strength would indicate substantially higher ultimate tensile strengths, much in excess of the small differences that perhaps a half-inch in thickness might make.

Q What is the difference between the cold clearance gap between the cylinder liner and the cylinder block on the replacement 103 block as compared to the existing 102 block?

A (Witness Wells) The diametral clearances were reduced both above and below the landing on the new DG 103 block.

I must emphasize this was not a change in the

2 WRBagb

block but it was a reduction in the liner diameters. The collar and the interference that fit below the liner landing in addition to the liner collar itself were reduced in diameter.

The block is the same dimension, both the upper and lower pilot diameters.

Q My question was what is the difference in the clearance between the block and the liner in the replacement block as opposed to the existing 102 block, if you know?

JUDGE BRENNER: Are you looking for a measurement or a description of what is different about it?

MR. DYNNER: A measurement, the difference in the gap.

WITNESS WELLS: There are two gaps here, Mr. Dynner. Let me give you the upper one first -- and this is a radial gap, I am not going to give you diametral gap.

The current DG 101 and 102 gaps above the liner landing are specified to be in a range of 4-1/2 to eight thousandths of an inch. That has been increased in the DG 103 block to a range of seven- to ten-and-a-half thousandths radial clearance, and those dimensions apply to the gap above the liner landing.

There was the same reduction in the liner diameter and the same increase in the gap below the liner landing. If you would like, I can read you those

2 WRBagb

tolerances.

In the DG 101 and 102 blocks, the gap is in a range of one-half of one thousandth of an inch to two thousandths of an inch.

In the replacement DG 103 block, the current range is four thousandths to six thousandths of an inch radially.

BY MR. DYNNER:

Q Dr. Wells, you are aware, aren't you, that the clearance between the liner and the block was also increased in the R-5 engine, isn't that right?

A (Witness Wells) Yes, that's my understanding, Mr. Dynner.

Q And you remember that as a result of that increase a piece of the liner broke off and fell into the cylinder on the R-5, do you remember that?

A What I remember is that the wrong liner was put into one cylinder on the R-5 development engine which did in fact have -- result in a very large radial gap and a lack of support, and I don't know what else contributed to it, but there was a liner failure.

Q Do you know what the gap was between the block and the liner that failed in the R-5 engine?

A Again let me state that this was a liner failure, Mr. Dynner. That had nothing to do with the liner landing

WRBagb

area of the block top.

That gap I would have to dredge out of my notes here. The dimension of an old liner and the new block pilot diameter.

The R-5 test engine had an increase in the diameters, both above and below the liner landing, of one-eighth of one inch. Therefore the old liner would have had an excessive clearance diametrally in this case of one-eighth of an inch below one-sixteenth of an inch radial gap. Therefore this particular cylinder had an extremely loose fitting liner, one which, in my opinion, would not have been supported at all by the block and therefore subject to the full firing pressure and hoop stresses, the resulting hoop stresses, without any reduction from the support of the liner. And of course this would have contributed to cracking and failure of the liner collar.

There was no failure of the block.

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Q Dr. Wells, was the replacement block tested before it was delivered to LILCO?

A I'm sure some tests were performed on it.

What type of tests?

Q What is the basis for your being sure that some tests were performed?

A Certain inspections had to be performed.

Q What inspections were performed?

Just a minute, Dr. Rau. You'll get your chance.

What inspections were performed on the replacement block before it was delivered to LILCO?

A Well, I am not the authority on this at all. I am aware of visual examinations. I am aware I think of B Bar Properties. But LILCO obviously is the authority on what was done in the acceptance of the block, so I would ask Mr. Youngling to respond.

Q Well, I'm referring to your testimony, Dr. Wells. Maybe you can explain that on page 70, Answer 95, where you say:

"The few changes that have been incorporated into the replacement block have been tested extensively in the R-5 engine and been shown to be of benefit."

Can you tell me what you mean by that extensive testing?

WRBeb

A Mr. Dynner, we're talking about modifications to the design, not the specific block that was delivered to LILCO. I thought you asked me previously whether the 103 block delivered to LILCO had been tested.

Q Yes.

A And I just ask you again in what way? The block design has been tested and evaluated and its integrity confirmed in many tests, as represented by service experience in numerous other engines.

Q All right.

Will you describe those tests to me, these extensive tests that you're talking about?

JUDGE BRENNER: You two are not communicating.

Mr. Dynner, I think you're going to waste some time. Maybe I'm misunderstanding where you want to go and if so, I apologize.

As Dr. Wells just testified, the answer to 95 is not directed to the particular 103 replacement block. Are you clear on that, Mr. Dynner? He's talking about tests on something else, and you keep coming back, "What tests?" And I think you have a particular block in mind.

Why don't you start again and see what you want to do.

MR. DYNNER: All right.

BY MR. DYNNER:

2 WRBeb

Q Let me refer you to page 70, your Answer 95, and the statement from your answer that I read to you regarding extensive testing of those few changes, I guess.

Now could you tell me what were the extensive tests that you're referring to?

A (Witness Wells) We're referring in 95 to the evaluation of blocks that have been assembled into other engines such as the R-5 development engine and in addition, about 38 or 39 other blocks that have gone into service without any known distress. That is what we meant by tested.

I think there may be a semantic problem. Some of these blocks have been inspected after operation, some have not. But by "testing"-- Perhaps a better word would have been "evaluated."

Q All right.

Which blocks that contained the few changes that you have referred to did you evaluate?

A Well, we have information confirmed by telephone communications with operators of several engines that have precisely the same block top details as the new DG-103 block. Admittedly these are V engine designs, and the V block differs in respect to its overall height, of course, from the in-line 8 block.

As I think Dr. McCarthy pointed out, the V

WRBeb

engine design consists of a shorter block with an intermediate crank case.

Q All right.

Dr. Wells, let me interrupt for a moment just to ask you, did you personally get this information from these telephone conversations?

A I have not personally discussed the block top experience with operators of other ships or plants, but individuals under my supervision have done so and reported that to me.

Q Are any of those individuals on this panel so they can be cross-examined?

A No, they are not on this panel.

MR. DYNNER: Judge Brenner, I am going to have to move to strike the sentence that says:

"Those few changes that have been incorporated into the replacement block have been tested extensively in the R-5 engine and have been shown to be of benefit"

-- on the grounds that Dr. Wells did not get this information personally and I am unable to conduct any effective cross-examination of the persons who received this information, as he has testified, on the telephone.

WITNESS WELLS: May I please correct my statement?

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I had been talking about operation of engines other than the R-5 development engine. We do have personal knowledge, because we have reviewed the data logs. We have had first-hand examination of records of the R-5 engine, as you can recall perhaps from the piston testimony. We have documented performance of the R-5 test engine at TDI in Oakland. We have similar information concerning the structural integrity of the blocks, the two blocks that were operated in the R-5 engine.

So I must ask that you differentiate between the R-5 development engine history and the history of other marine and stationary engines.

MR. DYNNER: With that clarification, and if Dr. Wells is only talking about the testing of the R-5 block, I will withdraw my motion.

BY MR. DYNNER:

Q Now, Dr. Wells, what do you mean when you say the concept of the deeper stud hole with the thicker block top to accommodate the deeper stud hole has been employed by the R-5 engine and tested thoroughly? What do you mean when you say there that that was tested thoroughly?

A (Witness Wells) The R-5 development engine has a deeper boss and a deeper thread placement, the same as the replacement DG-103 block. And the R-5 engine, as you have heard before, has been operated through many thousands of

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hours at low levels higher than that of the engines at Shoreham. It is rated at a higher BMEP and has been operated for over 5,000 hours at these conditions without any problems.

And that is what we refer to as the favorable experience and the successful testing, adequate testing of this particular design detail.

Q Has FaAA conducted an eddy current examination of the block top of the R-5 engine that you're referring to subsequent to its testing?

A I will have to ask Dr. Johnson or Mr. Schuster or Mr. Seaman for the inspection results, as to who performed them and what they showed at TDI.

Q Well, I note for the record this is your testimony and Mr. Taylor's testimony in Answer 95. But go ahead if the other gentlemen can help you.

A You asked if we had performed--

JUDGE BRENNER: It doesn't matter. Let the other people answer.

BY MR. DYNNER:

Q The question was, gentlemen, so I can refresh your recollection:

Did FaAA conduct an eddy current examination of the block top of the R-5 engine that you're talking about here after it completed its test runs?

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A (Witness Johnson) This is another question, because I think you said "or any other inspections." But we did not conduct any eddy current tests of the block top of the R-5 engine.

Q Did you conduct an examination by means of a dye penetrant of the block top of the R-5 engine?

A (Witness Schuster) We did not, sir, no.

Q Did you conduct any other non-destructive examination of the block top of the R-5 engine? I'm talking about FaAA now.

A (Witness Johnson) FaAA has not done any non-destructive examination of the block top of the R-5 engine.

Q Well, based upon those answers, Dr. Wells, how can you testify that there has been no problem with the concept of the block top on the R-5 after it was tested?

A (Witness Wells) We are not aware of any problem experienced in the operation of the R-5 block top whatsoever through inspection data reports generated by TDI with one exception, that there was a single ligament crack reported on one block which was associated with the loose liner collar that we had mentioned before.

Q You mentioned TDI inspection data. What data is that that you're referring to, Dr. Wells?

A Referring to the results of TDI's own

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inspections, and I must ask if Dr. Johnson has the documentation, or Mr. Seaman, or anybody else.

(No response.)

Q Hearing no one speak up, am I to assume that you don't have the Delaval inspection data present at this time?

JUDGE BRENNER: Wait. Now you've changed the question. Let's see what the answer is to the other question, which was what TDI inspection data.

MR. DYNNER: Yes.

JUDGE BRENNER: All right. You have no answer to that question so I take it you can assume the answer to your next question without having to ask it.

BY MR. DYNNER:

Q Gentlemen, am I right, you don't know what inspections you're talking about at TDI? Is that right?

A (Witness McCarthy) The problem we're having pulling the documentation together here is that Dr. Swanger, who appeared on a previous panel, is the person who went over to look at the block, and we don't have the documentation here.

JUDGE BRENNER: That wasn't the question, or at least it wasn't-- He asked two questions, and that may have confused you.

The question I would like answered is what inspection data are you talking about the last few minutes?

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We've got no evidence in response to questions attempting to elicit that evidence as to what TDI inspections on the R-5 engine block is being relied upon for either the written testimony or Dr. Wells' oral amplification of that testimony.

WITNESS WELLS: Judge Brenner, the inspections were dye penetrant inspections of the block top. Whether we have that documentation here with us or not, I am just not sure. I have to go back and check.

We know that the work was done. It was witnessed by Dr. Swanger, and we know what the results of those inspections were. But whether we can produce the documentation--

JUDGE BRENNER: I didn't ask you that, and I don't think Mr. Dynner did initially.

Can I ask one clarifying question?

There is reference here and elsewhere in the testimony to the block of the R-5 development engine. Is that one block or-- It's a series of development test engines. Are we talking about one block, ten blocks, two blocks?

WITNESS WELLS: There are two blocks. The V engine of course has two, and there are another two pieces in addition to what you would expect that result in a--

JUDGE BRENNER: I knew the V engine had two

1 WRBeb

blocks. I wasn't clear. It is just one engine? There is only one R-5 development engine that is being referred to any time you see a reference to the TDI R-5 development test engine?

WITNESS WELLS: That's correct, sir. The same two blocks were involved in the complete development history of the R-5.

BY MR. DYNNER:

Q And do I take it that FaAA and you, Dr. Wells, are relying upon this Delaval dye penetrant inspection of the block top for your answer?

A (Witness Wells) Yes, Mr. Dynner, we're relying on their inspections as witnessed by our engineer for these conclusions.

Q And that engineer is not a member of this panel, is that correct?

A That's correct.

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MR. DYNNER: Well, now I am going to renew my motion to strike on the basis that we don't have anybody here for me to cross examine about these inspections. The person is not a member of this Panel. This is rank hearsay as far as I can tell and is unsupported.

JUDGE BRENNER: Mr. Farley?

MR. FARLEY: I object, your Honor.

JUDGE BRENNER: Go ahead, give me your reasons.

MR. FARLEY: Under the testimony as given and the rules of practice of this Commission, I think we have established a sufficient foundation for the admission of this particular testimony.

JUDGE BRENNER: What's the foundation.

MR. FARLEY: The testimony that Dr. Wells has given.

JUDGE BRENNER: You'll have to tell me particularly why.

MR. FARLEY: Well, I don't think that the witness is required --

JUDGE BRENNER: Let me back up and tell you what I mean.

Mr. Dynner, I think, accurately summarized the testimony of these witnesses. And in his view it supports his motion to strike. So instead of just referring to the same testimony, you'll have to tell me why it supports not

WRBpp

striking it.

MR. FARLEY: Well, I cannot cite any other testimony and I don't think the motion is well-founded. Otherwise, we would have to bring 25 people here.

JUDGE BRENNER: I'd like to hear a little more about what Dr. Swanger, what his involvement was that your involvement wasn't. Now, did Dr. Swanger do anything other than to over to TDI and gather up their inspection reports. Was he involved in the inspections?

WITNESS WELLS: It's my understanding, Judge Brenner, that Dr. Swanger did observe the block tops himself.

JUDGE BRENNER: You mean the inspections of the dye penetrant tests of them, or just looking at the block tops?

WITNESS WELLS: I can't honestly say that he did witness the inspections.

We did reveal the logs of the operation.

JUDGE BRENNER: Would I be correct in assuming that -- am I correct that there the only TDI tests that you're referring to are dye penetrant tests?

WITNESS WELLS: I believe that's correct, Judge Brenner.

JUDGE BRENNER: Would I be correct in the belief that such tests would not have been conducted in the stud

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holes for the reasons you previously testified. That -- I guess it was Dr. Johnson who testified on that.

WITNESS WELLS: These tests would have been conducted on the block top only, I believe.

JUDGE BRENNER: On the top itself?

WITNESS WELLS: On the top.

These cracks, they exist such as the ligament crack that was reported and generally can be seen on close scrutiny without the aid of penetrants if one knows what to look for.

WITNESS RAU: If I could add, too, Judge Brenner, the examination of the ligament cracks as well as the stud-to-studs indicate their presence of the block top. And the reliability of the visual and liquid penetrant to detect the cracks present on the block top if, in fact, there are cracks there.

JUDGE BRENNER: Why do you feel you should rely on TDI's test of this, given the problems in TDI's other tests such as this strain gage test, not one test series but, apparently, two test series that you later found not to be reliable.

I'm asking you as experts in the course of -- you know, forget about the legal trappings in this proceedings as experts going about your work and trying to reach conclusions. Why would you be willing to base some of your

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expert opinion on tests conducted by TDI given some of the problems that you, yourselves, ascertained to some of their other tests?

WITNESS WELLS: In my opinion, Judge Brenner, the problems of strain gage testing involve a much higher level of technical expertise in electronics and in the reduction of data which requires engineering knowledge. It certainly requires a rather high degree of skills strictly from an electrical instrumentation standpoint.

The observation of block tops whether by penetrant or unaided by any penetrant, while I do not wish to cast any aspersions to the nondestructive testing community these cracks are, in fact, as visible to the eye as the particular sample that you have seen here. If there had been extensive cracking, if there had been more ligament cracks or any stud-to-stud cracks -- and recall that in every case that we have seen or, for that matter, heard about, these cracks do start at the top corners of the block. Such cracking would not have escaped the careful scrutiny of an inspector or a technician with a relatively low skill level.

WITNESS JOHNSON: I would like to add that the ligament cracks were first detected visually and that's why this whole rest of the more extensive nondestructive program was put into place on the Shoreham block tops.

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JUDGE BRENNER: Is that true for the stud-to-stud cracks also?

WITNESS SCHUSTER: Yes, it is, your Honor.

WITNESS RAU: If I could also add to your question, I also think that the nature of the reliance here is quite different. Perhaps it's a restatement of what Dr. Wells has said. But to rely upon the engine logs which record simply the number of hours and the power levels and how long they ran a certain engine with our own inspection -- observation of the fact that the engine was there and a review of those logs, and to rely upon the fact that it ran a certain number of time -- extensive amount of time -- and didn't create any major, any operational, problems associated with the block I think, as a professional engineer, it's very easy for me to rely upon that kind of information as opposed to detailed, technical considerations which might, in fact, require additional sophistication.

JUDGE BRENNER: Dr. Wells, I believe you testified that you thought Dr. Swanger observed the tops of the blocks. Does anybody in the Panel know one way or the other whether he saw the blocks in a condition that he could look at them. That is, without the heads, I guess, and without anything else that might be in the way? If you know?

WITNESS WELLS: I recall a discussion with

2 NRBpp

Dr. Swanger and that's my recollection of what was done, Judge Brenner. But under oath I cannot really say with certainty that he did witness inspections or --

JUDGE BRENNER: I didn't ask you whether he witnessed the inspections on this last question. I was referring back just to the portion where you said you thought he observed the tops of the blocks. And I don't know what to make of that for two reasons: Number one, the fact that you were tentative in the way you expressed it earlier and, number two, I'm not clear what he was looking at. Whether he was looking at an engine with everything on it such that the heads and anything else that might be in the way or, whether you were trying to tell me that he was looking at an engine in a condition that, if he was somebody who would recognize cracks when he saw them -- and I could draw my own opinion on that - whether or not there was an absence of obstruction such that he could see it.

WITNESS WELLS: It's my understanding that Dr. Swanger did look at the block with the cylinder heads removed. But I really would have to confirm that with Dr. Swanger, Judge Brenner.

JUDGE BRENNER: Okay.

(Board conferring.)

1 WRBagb

JUDGE BRENNER: We agree with you partially, Mr. Dynner. but we don't agree that we are actually going to strike any words, and I will tell you why, just to try to make clear what we will not rely on the testimony for.

We agree with you that you have been deprived of effective cross-examination on the point as to whether or not there have been any cracks in the block top of the R-5 engine based on the testing performed by TDI. I tried and I couldn't get there also and Dr. Wells was very candid in explaining what his basis was and we appreciate that.

However there are other things being testified to: the way the written testimony was drafted in answer 95 it has not focused on absence or presence of cracks, it is broader than that. And we are going to allow the testimony to stand for the fact that these witnesses are testifying that in their view there has been extensive running, if you will, of the R-5 engine.

And another reason that we would not strike it is that we see enough of a connection and cognizance of LILCO and FaAA with what was done on the R-5 engine to believe that if there had been any catastrophic, obvious type things that occurred with that engine that they would have been informed of it in the course of their inquiries and investigations and work. As experts they are entitled to rely on other persons.

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Mr. Farley, you are correct that if we carry it to the extreme you have to bring many, many people in here. However the persons, the other side of the limit is that a party cannot be deprived of the right to cross-examine and we believe as to the presence or absence of cracks that Mr. Dynner has been deprived of that.

I am sorry we cannot make a clean excise of some particular words, it would be easier for us to do that, but you know what you cannot write any findings toward based on this answer at least.

BY MR. DYNNER:

Q Dr. McCarthy, does FaAA believe that EDGs, the blocks of EDGs 101 and 102 are capable of being operated in those engines continuously at 3500 Kw for one year without experiencing cracking to the extent that the operation of those engines would be impaired, yes or no?

A (Witness McCarthy) That question can't be answered yes or no, at least by me.

JUDGE BRENNER: Well can anyone answer it yes or no?

WITNESS MC CARTHY: We haven't done the analysis but someone can express an opinion.

JUDGE BRENNER: All right, as part of the answer you explain why it can't be answered yes or no, presumably we will hear that as part of the explanation.

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WITNESS MC CARTHY: We haven't analyzed a year at 3500 Kw operating experience. The test of the GDC 17 and the criteria we were looking at is can the blocks perform effectively the requirements of supplying on-site power for seven days in the load profile of loop LOCA. That is unquestionable.

Now whether I would go on for an additional year, if any of my colleagues have an observation...

BY MR. DYNNER:

Q Dr. McCarthy, have you performed an analysis --

MR. DYNNER: I am sorry, I was asking the questions of FaAA specifically. I think I know what LILCO thinks. I am exploring FaAA and FaAA's analysis now.

JUDGE BRENNER: All right. You don't want an answer from LILCO?

MR. DYNNER: No, sir, I don't need that answer.

JUDGE BRENNER: All right.

MR. FARLEY: I think Mr. Youngling ought to be permitted --

JUDGE BRENNER: Well you do it on your redirect time I suppose is what Mr. Dynner has in mind and I agree with him.

BY MR. DYNNER:

Q Dr. McCarthy, am I correct then that you, FaAA, has also not done an analysis which would allow it to come

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to a conclusion that the EDGs with the EDG 101 and 102 blocks are capable of operating at 3900 kilowatts for two hours in any 24-hour period over a one-year period, is that right?

A (Witness McCarthy) If I understand your question, which is as I understand it: two hours out of every 24 hours for a 365-day year continuously, once again the answer is no.

Q And Dr. McCarthy, do I understand FaAA's position to be, in effect, a guarantee that none of the EDG blocks can possibly fail during a loop LOCA?

MR. FARLEY: I object to the form of the question, speculation and conjecture.

It is not the right criteria. "Possibly," anything is possible.

JUDGE BRENNER: All right. Why don't you rephrase it?

I missed your initial point, Mr. Farley. Now that you have clarified it, I agree with you.

BY MR. DYNNER:

Q Does FaAA guarantee, in effect, that the blocks on EDGs would not fail during a loop LOCA?

MR. FARLEY: Same objection.

MR. DYNNER: I am probing the extent of their certitude as to the -- and I think that is perfectly valid

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to do. I haven't asked him to speculate in any question.

JUDGE BRENNER: All right. Let's make believe that their answer to your question is anything is possible, and now why don't you go on to ask what you have to ask next in order to prove their certitude.

BY MR. DYNNER:

Q Given the fact that anything is possible, is FaAA assured -- has it assured itself that the EDG block will not fail during a loop LOCA?

A (Witness McCarthy) Applying our normal professional standards and understanding the gravity of the situation, the importance to public safety of the operation of these engines and the conservatism that all of these dictate in the analysis, we have as much confidence in these predictions as I think science permits and the sum total of our engineering skill allows. We are highly confident, we would not be here in no small part, staking the reputation of the firm on our predictions -- as you do any time you make a prediction of this gravity and this visibility -- you can be sure we wouldn't be here unless we felt very good about these predictions.

JUDGE BRENNER: Well I don't know, you might be here for Suffolk County.

(Laughter.)

Go ahead, Mr. Dynner. I'm just kidding.

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BY MR. DYNNER:

Q Let me shift for a moment and ask you to take a look at your supplemental testimony.

JUDGE BRENNER: Mr. Dynner, I just wanted to let you know we do want to adjourn promptly at 5:00, not 5:01, so keep an eye on the clock and pick a convenient time.

MR. FARLEY: Judge Brenner, if I may, in connection with that, Mr. Ellis is here and I think he has something to report.

JUDGE BRENNER: I don't want to take it now. We have been talking about taking other things all week and we have been here. We can pick up whatever he wants to do in a future session, presumably.

Is it in relation to the agreement on the heads?

MR. FARLEY: Yes, sir.

JUDGE BRENNER: Somebody could provide a written agreement to it at our offices tomorrow or Friday. Friday would be acceptable. And then any oral presentation that you feel is necessary could be accomplished at the next convenient time for him.

I had assumed we would be given something to read in advance before an oral presentation in any event.

Go ahead, Mr. Dynner.

MR. DYNNER: Thank you.

BY MR. DYNNER:

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Q Can you describe in what manner you believe that the cam gallery cracks would be bathed in oil after initial engine start-up?

This is your testimony, Doctors Rau and Wachob, on page six, answer nine.

A (Witness Rau) I'm not sure what kind of detail you want, Mr. Dynner, but basically the cam gallery area and, in particular, the saddle area of the cam gallery -- the cam shaft support, which is where these indications -- and the subsequent destructive examination has confirmed there are shrinkage cracks -- is a region which is oiled, if you like, during operation. The oil is pumped into that region and, if you like, bathes or coats in a continual way these regions. So it is not a region which is oiled once and then left alone.

Q Well is there a continuous flow of oil into that region?

A Yes.

Q What kind of oil?

A It is a diesel lubricating oil. I don't have the chemical composition and stuff in front of me but it is a conventional lubrication oil.

Q Have you ever examined —

A Mr. Youngling may have the specific designation, if that is important to you.

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Q Have you ever, Dr. Rau, examined the chemical composition of this conventional diesel lubricating oil?

A Yes.

Q What is it, do you know?

A I don't have it memorized, no, sir, it is a hydrocarbon lubricant. Perhaps Dr. Wachob remembers more than I. He also examined it.

Q Does it have anything added to it?

A I don't know what you mean. What do you mean, added to it?

Q Is there anything in the lubricating oil beside plain old, conventional lubricating oil? Are there any additives?

A (Witness McCarthy) Once again in deferring to Mr. Youngling, who will have exact knowledge, typical lubricating oil will have added to it anti-oxidants and anti-foaming what are called detergents. It works like a surfactant to cut down foaming in the oil. These would be components in this oil.

Q Do you know that for a fact, Dr. McCarthy, that this particular lubricating oil has that additive?

A I would be mildly flabbergasted if it did not.

Q Do you know it? Do you know it? It's Yes or No, either you know it or you don't.

A I have not done a chemical analysis of the

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specific oil used. I don't think oil.... Well, I would not know where to go purchase oil without it for this purpose.

Q But you didn't analyze this particular oil, did you?

JUDGE BRENNER: He answered that particular one.

MR. DYNNER: All right.

BY MR. DYNNER:

Q Mr. Youngling, everybody is looking to you to help us out on this one.

Can you tell us whether there is any additives to this particular oil that Drs. Rau and Wachob say bathes the cam gallery cracks?

JUDGE BRENNER: Mr. Dynner, is there a particular additive you're interested in? We can shorten things up if you asked about it.

MR. DYNNER: I just want to know if there is an additive. I don't know. I'm asking this panel who is giving this testimony, and some of them who haven't given this testimony.

WITNESS RAU: Mr. Dynner, if you have something specific in mind--

JUDGE BRENNER: All right. We've tried that.

MR. DYNNER: It is the Judge's job, Mr. Rau.

JUDGE BRENNER: Let's see what Mr. Youngling has to say.

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WITNESS YOUNGLING: The lubricating oil meets the requirements of the TDI Instruction Manual, Appendix No. 6, which is Suffolk County Exhibit Number 9. It is a Grade 40 oil.

In addition, at the recommendation of FaAA and Dr. Pischinger, as we testified earlier, he has recommended a high detergent oil which has now been placed into the engine, a higher detergent oil.

BY MR. DYNNER:

Q What kind of oil is that by grade, if you can specify for me, Mr. Youngling?

JUDGE BRENNER: Wait a minute. I'm sorry. I'm losing the materiality of this. I thought you were interested in the oil that was used in the oil 103 block. Am I wrong?

MR. DYNNER: No, that is not correct.

JUDGE BRENNER: Okay, I'm sorry.

MR. DYNNER: The testimony that I'm referring to.... Well, all right. I'm interested in both, for obvious reasons.

BY MR. DYNNER:

Q First of all, what oil--

JUDGE BRENNER: Wait. Why are you interested in oil that will be used or is used in the engine after the examination of the layers on the cracks? I take it.... Why

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don't you tell me the materiality?

MR. DYNNER: I'm sorry, I misspoke. You are correct. I am interested in the oil that was used in the original EDG-103 engine.

JUDGE BRENNER: We all want to find out what caused the oxidant -- the layer and when it was there. Right?

MR. DYNNER: Yes. I thank you for that correction, Judge.

WITNESS YOUNGLING: Okay. The oil in the original engine met the requirements of the Instruction Manual that I cited.

BY MR. DYNNER:

Q And was that the Grade 40 oil? Is that what you said?

A (Witness Youngling) Yes, AC Viscosity Grade 40.

Q Is there a particular brand that was used?

A We used Mobil Delvac.

Q And did it have an additive in it?

A Yes, but I can't cite them.

Q You don't know what kind of additive was in that oil?

A No, not without having the spec sheets in front of me, no, I can't cite those.

Q Do you know whether there was any additive at

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all?

A As Dr. McCarthy testified, I would be surprised if there weren't additives. But again I can't tell you without the spec sheets. I just don't have those facts in my head.

Q Does anybody on this panel know— As opposed to speculating or guessing or having an educated guess, does anybody on the panel know for sure whether or not there was an additive in this oil that would have retarded or protected against corrosion, or oxidation, I should say? Does anyone know for sure?

A (Witness Rau) The oil itself protects against oxidation, Mr. Dynner. I don't understand what you mean.

Q My question is not that, because there is going to be some testimony on that if there isn't already. I'm asking about additives.

(No response.)

I take your silence to mean nobody knows for sure.

Will someone please say that's correct?

A (Witness McCarthy) Mr. Dynner, I am almost certain that you have to specify additive oil if you are going to run the bearings of the type that are being run on the connecting rod. Otherwise you will risk oxidation reactions pulling the copper out of the alloy.

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I would have to check that but I have a very high degree of confidence.

Q I specifically said I would like an answer to the question: Does anybody know for sure? I told you that I'm not interested in educated guesses or speculation.

JUDGE BRENNER: They don't know for sure.

MR. DYNNER: Then I assume that the answer is nobody knows for sure.

JUDGE BRENNER: They don't know for sure, by the way you've defined that term.

MR. DYNNER: Yes.

BY MR. DYNNER:

Q Now, Dr. Rau, you were about to say that you think--

JUDGE BRENNER: Now we may later find that what they know is good enough for us, but that's another story. I just want you to get on to the next question instead of having us sit there while there's silence.

BY MR. DYNNER:

Q Is it your testimony, Dr. Rau, that oil would retard oxidation even without an oxidating retardant additive?

A (Witness Rau) Yes.

Q Would it prevent oxidation?

A You will have to define the limits. It is going

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to retard it to such an extent that compared to oxidation at, say, 1,000 degrees Fahrenheit, it is virtually preventative, but obviously individual molecules of oxygen can still react with iron on the surface if there is oxygen in the oil.

Q So if all you had in there was some Grade 40 ASE Mobil oil without any additive, you might have some oxidation over some period of time. Is that right?

A You'll have to be a little more specific, Mr. Dynner, with regard to temperatures and times. But the answer, in a very, very general sense, is you might get some oxidation unless you are at absolute zero in temperature. But whether it's significant, whether anybody can measure it or see it is a whole different issue.

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

JUDGE BRENNER: Okay.

As I said, you can tell us on Monday morning when we continue, which will be at 10:30, if you in fact change your mind and have more questions up until the noon lunch break. If you know you are going to have more questions it might be courteous for you to tell the other parties, but I am not going to require that.

Does the Staff have any idea how much it has of questions for this panel? If you don't want to answer now,

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that's okay, but if you have some idea I would like to get it.

MR. GODDARD: Probably one to two hours.

JUDGE BRENNER: Mr. Farley, do you have any idea on redirect? If you don't know that's okay. I was just wondering.

MR. FARLEY: I don't know, Judge Brenner.

JUDGE BRENNER: Okay. We will probably ask you on Monday morning.

MR. FARLEY: I'll know then.

JUDGE BRENNER: All right.

We have a few minutes. If you have the written settlement agreement document, is that what you wanted to do, Mr. Ellis? Why don't you just give us the written document? I would like to read it before we hear any discussion of it. And then whenever it is convenient to you or whoever else wants to do it on any day when we're here in the future, we can come back to it.

MR. ELLIS: Yes, sir. I had three things I was going to give the Board if I may.

One was the cylinder head agreement that has been signed by all the parties now.

JUDGE BRENNER: All right.

MR. ELLIS: The second was just the SNRC letter and the FSAR change that you would ordinarily get in the

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mail that I will give you here for convenience.

And thirdly, the piston supplemental testimony involving the polishing in the boss area. And I hope all this won't be necessary. We are going to try to settle the pistons with the County as soon as Mr. Dynner has an opportunity to turn his attention to it.

JUDGE BRENNER: Okay.

I didn't know you were going to have testimony in the latter category. I remember the bases as to why you might. I just didn't know what your decision had been on that.

All right, we will take all that now, and while you're doing that, we will recess. And I hope everybody has a more relaxing time the rest of this week and over the weekend than they probably have had this week so far.

We will resume at 10:30 a.m. on Monday morning.

(Whereupon, at 4:50 p.m., the hearing in the above-entitled matter was recessed to reconvene at 10:30 a.m., Monday, October 29, 1984.)

CERTIFICATE OF OFFICIAL REPORTER

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

NAME OF PROCEEDING:

LONG ISLAND LIGHTING COMPANY
(Shoreham Nuclear Power Station)

DOCKET NO.: 50-322-OL

PLACE: Hauppauge, Long Island, N. Y.

DATE: October 24, 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

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