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UNITED STATES
NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF: LONG ISLAND LIGHTING CCOMPANY
SHOREHAM NUCLEAR POWER STATION

DOCKET NO: 50-322-OL

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY & LICENSING BOARD

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In the matter of: :

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

Long Island Lighting Company) :

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State Office Building

Veterans Memorial Highway

Hauppauge, New York

Tuesday, September 11, 1984

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

BEFORE:

JUDGE LAWRENCE BRENNER,

Chairman, Atomic Safety & Licensing Board

JUDGE PETER A. MORRIS,

Member, Atomic Safety & Licensing Board

JUDGE GEORGE A. FERGUSON,

Member, Atomic Safety & Licensing Board

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P R O C E E D I N G S

JUDGE BRENNER: Good morning. Are there any preliminary matters before we continue the County's cross-examination? Has the dispute over documents gone away or does it still exist?

MR. DYNNER: Judge Brenner, I spoke yesterday with counsel for LILCO and we're confined, given the amount of time we had. We confined our discussion to the documents we've requested on the pistons and the crankshafts because they're most immediately needed. We have agreed —

JUDGE BRENNER: The only ones I mention right now are pistons.

MR. DYNNER: Yes. I was about to say to the extent the documents exist we reached an agreement on their being furnished and we expect to get them a little bit later this morning

JUDGE BRENNER: All right. I cut you off. Does that statement apply to crankshafts also?

MR. DYNNER: Yes, sir.

JUDGE BRENNER: All right.

I won't worry about any others unless and until you tell me I'll have to worry. But if I'm going to have to worry could I expect you to give me more than one minute's notice, because I'll have to go back and do some more homework.

Off the record for a minute.

(Discussion off the record.)

JUDGE BRENNER: Do you have a time estimate you can give us, a reliable time estimate?

MR. DYNNER: Yes, sir. I believe that I will be able to finish the cross-examination on the pistons by tomorrow afternoon, assuming that the witness's answers are directed towards answering the questions and not repeating the direct testimony.

JUDGE BRENNER: You say tomorrow afternoon. You mean the end of the day tomorrow?

MR. DYNNER: It's hard for me to be more precise but, yes --

JUDGE BRENNER: That's a long time. I didn't expect your estimate to be that long, frankly.

MR. DYNNER: I hope it will go faster than that. I hope to be as realistic an estimate as I can under the circumstances.

JUDGE BRENNER: We have your estimate. I don't know if we'll give you that much time. We'll discuss the situation again at the end of the day today. Maybe even earlier than the end of the day today, depending on circumstances.

Why don't you proceed. Orient me in your cross plan.

MR. DYNNER: Start on page 11 of the cross plan where we left off yesterday.

Whereupon,

DAVID O. HARRIS,

DUANE P. JOHNSON,

ROGER L. MC CARTHY,

FRANZ F. PISCHINGER,

CRAIG K. SEAMAN,

LEE A. SWANGER,

and

EDWARD J. YOUNGLING

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

CONTINUED CROSS-EXAMINATION

BY MR. DYNNER:

Q. Gentlemen, yesterday we were discussing matters concerning the peak firing pressures in the EDG's and I'd like to have a few follow-up questions on that subject matter.

If you will, for a moment, please turn to Exhibit P-5 which is the gas pressure versus crank angle document in LILCO's exhibits.

JUDGE BRENNER: Mr. Dynner, excuse me a

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moment. I left those exhibits in the other room.

Q. Dr. Pischinger, given this document. would it be possible for you to calculate its BMEP of the engine on the basis of this document?

DR. PISCHINGER: Not on this document because the accuracy -- if you think of paper distortion and so on, it is impossible.

Q. Well, let me say --

JUDGE BRENNER: I can't hear you, doctor. You've got to bring the microphone closer. Could you repeat the answer again.

DR. PISCHINGER: Excuse me. This document is -- cannot be the basis of evaluation of the BMEP. One reason is distortion of the paper. You cannot -- the accuracy is not enough. It's just to show the principal shape of the pressure trace. Of course, digitalized data which are the background of such a drawing will enable to give the BMEP.

Q. If you had the original tracing of this document, would you be able to calculate roughly what the BMEP of the engine was? By roughly I mean within two percent?

DR. PISCHINGER: Yes.

Q. Given the distortion of this document in the Xerox copy, do you think you'd be able to calculate the BMEP from this document within two or three percent?

DR. PISCHINGER: No.

Q. Excuse me, may I finish, please, with the follow-up, before you have your discussion?

Dr. Pischinger, given the distortions shown on this paper, approximately what would be your estimate of the percentage, plus or minus percentage of accuracy, of a calculation of the BMEP of the engine from this document?

DR. PISCHINGER: There is one second reason why this is not possible from this paper, because the accuracy and the scale of the degrees of crank angle needed for such a calculation is not there.

If you shift one or two degrees of crank angle which you cannot read easy from such a paper, there is a lot of shift in the value, more than ten percent.

Q. More than ten percent shift?

DR. PISCHINGER: Yes. Maybe there was a mean effective pressure. We are talking on mean --

Q. Brake mean effective pressure is BMEP?

DR. PISCHINGER: Brake mean — well, of course, what you can read from this is the indicated pressure that's here. Of course. Wait a minute.

Maybe I should clarify.

JUDGE BRENNER: Wait a second. There was no question. I don't know what you want.

MR. ELLIS: I'm sorry, Judge Brenner, I thought Dr. Pischinger was finished. He's not and I was just going to remind Mr. Dynner that Dr. Swanger was eager to say something.

DR. PISCHINGER: Yes. Maybe I should define the difference between the indicated mean effective pressure and — they had indicated mean pressure and mean effective pressure. The mean effective pressure is a mean pressure which can be calculated from braking the engine and relating -- relating the braked torque to the swept volume. The diagram itself only can give you a reading of the gas work from which you can calculate the indicated mean pressure, and the difference between the two is friction work of — within the engine.

Of course, engines of such size, the mean friction pressure has a certain value that you can get out of experience and try to take into account.

MR. DYNNER: Dr. Swanger, did you want to add something now?

DR. SWANGER: Professor Pischinger has

addressed my concerns.

BY MR. DYNNER:

Q. Do you have copies of the digitalized data that you referred to?

A. Yes. Certainly. This was digitalized.

Q. Do you know where that data is located, anywhere on the panel?

MR. YOUNGLING: We have it right here.

MR. DYNNER: Could the County be furnished with a copy of that digitalized data?

MR. YOUNGLING: Surely.

MR. ELLIS: Judge Brenner, I'd like to object to that request. I think it comes late. He hasn't done it and asked questions concerning it or shown that it's material and what we've seen in the last day is discovery all over again here at the hearing stage, and I would object to production of any further documents, especially after talking to Mr. Dynner to reach an agreement with him.

JUDGE BRENNER: I'm shocked. This is something even beyond the listing that we -- we wasted all that time discussing conference calls yesterday.

MR. DYNNER: We had assumed when we saw this document that it was a complete and accurate document and that at any time that would be able to to be generated from it and we have just learned from this cross-examination that in order to make those calculations according to Dr. Pischinger there would have to be some other data which indicates that this document by itself does not accurately represent what it purports to represent in the testimony because in order to have accurate data, there could be variations by as much as ten percent given the way this document is reproduced.

And one would need the digitalized data and I don't -- it's not something we could have been able to find out during discovery and it's not something that we were able to know about in advance.

I think it's follow-up from the cross-examination answers.

JUDGE BRENNER: Give me a moment. We're not going to require LILCO to turn that data over to you. This is information that should have been obtained by you on general discovery, certainly after the testimony was filed.

Moreover, it doesn't come within my view of the Appeal Board's balances in the Clinton case, which case I alluded to yesterday. There's been no showing that this is so particularly material that

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if at this time it isn't obtained there is some void in the record.

The witnesses have been able to answer questions about the subject and if you would have desired to have some of this data in an attempt to undercut the witness's expert testimony on the subject, you should have obtained that by now.

We don't have a situation here where the witnesses said "I simply can't answer your questions unless I have the data." nor do we have a situation where what we have presented in the testimony is just a sampling of some conclusions without -- and a lack of recollection by the witness as to how the data was averaged or otherwise looked at, which was the situation I perceived yesterday.

We've got the answers. If you would like to challenge the witness's judgment as to what the conclusions are and what's represented, it's up to the County to do little homework before walking in here, and the information was available from which it could have been apparent to the County, as apparent as it is now, as to what is presented in the testimony and the exhibits.

So your request is denied. If LILCO wants to turn it over, that's their business. If we get to the findings and you show us contrary to our view now that there's a void in the record on a material point, well, LILCO has the burden to prove and they will then suffer the consequences of that.

Apparently they're not worried about that on this point, given their objection. Let's proceed with the question.

BY MR. DYNNER:

Q. Gentlemen, at the top of page 19 of your testimony, there's a statement "Measurements were also taken simultaneously at the pressure cocks at the side of the cylinder using a Kiene gage to measure the cylinder firing pressure. Exhibit P-5 is the pressure crank angle diagram developed by FaAA."

It's true, isn't it, that Exhibit P-5 pressure diagram was not developed from the measurements taken using the Kiene gage that are referred to in the immediately prior sentence; isn't that true?

DR. SWANGER: The measurements depicted in Exhibit P-5 were taken with the Piezo electric transducer which is placed in the air start valve in cylinder number seven.

Q. So it's true then that the P-5 diagram was not developed from the measurements referred to in the sentence at the top of page 19.

DR. SWANGER: I believe that's what I just said, yes, P-5 was developed by the other technique, by the Piezo electric transducer in the air start valve.

Q. Yesterday I believe I asked you whether you could tell me what the measurements were that were referred to in the first sentence at the top of page 19 and you were unable to do so.

Have you since been able to refresh your recollection as to what those measurements are?

DR. SWANGER: I was able to refresh my recollection on this point by speaking with Dr. David Mercaldi of Failure Analysis Associates who was the test director for the tests performed at the end of December and in early January.

He was able to refresh my recollection that a better gauge than a Kiene gage was used for the auxiliary measurements. In fact, it was a Piezo electric transducer operating on the same principal as the Piezo air start valve which was attached to the pressure cocks on the sides of the cylinders. And that data from these more accurate, more

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reliable Piezo electric transducers was simultaneously recorded on the magnetic tape that recorded data during that test.

I believe that Professor Pischinger further address this in discussing the relative accuracy of the Piezo electric transducer relative to the Kiene gage.

Q. My question, do you know what those measurements are now?

MR. ELLIS: Which measurements, if I could have the question clarified?

MR. DYNNER: Measurements referred to at the first sentence at the top of page 19 as we've been discussing.

DR. SWANGER: No. We don't have that at any time at a hearing.

DR. PISCHINGER: May I, perhaps, for clarification, add something. I used at the time -- I'd to make sure what this Kiene gage is because that are different makes of such sort of gages.

This is a pressure gage which only gives the peak -- the varied peak pressure reading and -- of, of course, accuracy is lower compared to a quartz transducer which gives the whole pressure traced for each individual cycle and the functions that way that pressure — mechanical pressure reading device is pumped up by the gases out of the cylinder to the degree of the highest pressure which is present.

That means it tends to show the highest peak pressure of — during a lot of cycles. So it has a tendency to do some overemphasizing of higher pressures.

Q. Dr. Pischinger, what do you mean that it overemphasizes the peak pressures?

DR. PISCHINGER: During — following cycles in a diesel engine, the peak pressure is not always the same, and if you get a reading from a quartz transducer, you can follow these variations. Here you cannot follow. You get the very maximum reading one value.

In addition, the piping needed which is. in such a gage tends to be — rise to a higher pressure because of the reflection of the pressure wave. The rising pressure in the cylinder is a very quick rising pressure during combustion which generates a pressure wave into the piping and it's well-known that the reflection of this pressure wave gives a higher pressure than which is present in the cylinder; but these Kiene gages are very useful when comparing the reading in different cylinders. So they are used to compare cylinder one, two, six --

Q. Did you mean, Dr. Pischinger, Kiene gages or were you talking -- I thought you were talking about the Piezo electric transducer?

DR. PISCHINGER: Yes, the Kiene gages. The Kiene gage is usually used to compare the pressure level in the different cylinders of the multi-cylinder engine. It has a -- if there's a deviation, large deviation, then this could be a sign of overfueling one cylinder or underfueling.

Q. I'm confused, Dr. Pischinger. Is the instrument that you've been describing as giving only the highest maximum peak firing pressure the Kiene gage -- or is it the Piezo electric transducer?

MR. ELLIS: I object to that question. I think it mischaracterizes his testimony. It can't mischaracterize --

JUDGE BRENNER: He's asking -- it's the Kiene gage, Mr. Dynner, as we said.

Q. And the Piezo electric transducer in your judgment is more accurate than the Kiene?

DR. PISCHINGER: Yes. This is general knowledge, written in a lot of textbooks.

MR. YOUNGLING: The Kiene gage is

basically used by the operations personnel as a maintenance diagnostic tool to assess the general pressures in the engines. It's also used to implement the recommendations of TDI that the peak firing pressures between any two cylinders be no more than 200 pounds. It's certainly not the kind of instrument to be used in an analysis like this.

JUDGE BRENNER: Dr. Swanger, answer 25 is yours in the testimony. Can you tell me, given the question there, what the importance to you as a witness answering the question was, including the fact that the measurements were also taken simultaneously at the pressure cocks using the Kiene gage?

DR. SWANGER: The significance of that is the plural of pressure cocks. The simultaneous readings which were, with the Piezo electric transducer were taken on all eight of the cylinders by moving the Piezo -- we had two Piezo electric transducers -- by moving them from cylinder to cylinder to demonstrate that the measurements taken with the air start valve in cylinder number seven were characteristic of all the cylinders and, therefore, could be used as a basis for analysis.

MR. SEAMAN: Excuse me, Judge. Perhaps I

could add one thing to that.

Maybe it's important to put into perspective why we use this Piezo electric transducer. There were concerns expressed by our test personnel regarding --

JUDGE BRENNER: I know. You told us yesterday. I didn't mean to cut you off but once in a while we remember the testimony from the day before. Don't let that stop you when you think we're not remembering it.

Dr. Swanger, for the diagram in Exhibit P-5, is that from just the Piezo electric transducer which was used directly in the chamber?

DR. SWANGER: Yes, this is from the Piezo electric transducer we have been referring to that was installed in the air start valves which is directly in the combustion chamber.

JUDGE BRENNER: Dr. Pischinger, in discovering relative accuracies referred to a quartz gage, is the Piezo transducer referred to in answer 25 a quartz gage?

DR. SWANGER: Yes. It is. Quartz is one of the materials that exhibits the Piezo electric effect. That is, it develops a electromotive force across it which subjects it to pressure, and thus we're using the quartz gage and Piezo electric gage interchangeably.

BY MR. DYNNER:

Q. Gentlemen, I direct your attention to page 19, question 36, where you referred to the County's Exhibit 46 document 6, as detailing the measurements of the TDI furnished in factory tests.

Does the County's exhibit contain all of the peak firing pressure measurements provided to LILCO as a part of the TDI instruction manuals?

DR. SWANGER: Which County exhibit are you referring to, Mr. Dynner?

MR. DYNNER: As stated in your testimony 46, document 36.

MR. YOUNGLING: Mr. Dynner, TDI provided factory data on the engines.

I do not know whether this is a complete duplication of all that data. I would have to check that.

BY MR. DYNNER:

Q. Mr. Youngling, in the next question, question 27, beginning on page 19 and going to 20, on the top of page 20 you refer to LILCO Exhibit P-9 as including firing pressures measured before and after the crank shaft replacement.

Does Exhibit P-9 include all of the measurements taken for the peak firing pressures during the pre-operational qualification tests, or is it only a sampling?

MR. YOUNGLING: These are the data which are required to be taken as part of the official pre-operational testing program. Other Kiene gage measurements were taken in restoring the engine after the rebuilding operation.

Excuse me. I'd just like to say that those additional data were taken as part of the set-up of the engine and making sure that it was timed and properly balanced.

Q. Were those additional data part of the pre-operational activity?

MR. YOUNGLING: No, sir.

Q. So is it your testimony that Exhibit P-9 does include all of the peak firing pressure data taken during the pre-operational tests?

MR. YOUNGLING: These are the data required to meet the requirements of the pre-operational test documents.

Q. And it's all of those measurements that were taken; is that correct? There weren't any more during the pre-operational tests?

JUDGE BRENNER: Mr. Dynner, it seems to me this question and the question before, is getting repetitious. We've got the situation and you are causing him to repeat his immediately preceding answer.

MR. DYNNER: I don't think that's the answer to the question. I am just trying to get clear whether this is all of the test at any time that the firing pressure is taken or whether it's just representation. I don't think he's answered that.

JUDGE BRENNER: I thought he did, but we'll give it one more shot in deference to the possibility that you're right.

MR. YOUNGLING: The pre-operational test documents required that a certain number of data be taken. These sheets that you have represent those requirements.

MR. DYNNER: I still don't know what you said. You said they represent. Are they all of the data or are they part of the data? Yes or no.

MR. YOUNGLING: They are all of the data that needed to be taken.

MR. DYNNER: Thank you.

Q. All that was taken or all that needed to

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be taken?

MR. YOUNGLING: All that needed to be taken as part of the pre-operational test documents.

Q. Are they all the data that was taken as part of the --

JUDGE BRENNER: Mr. Dynner, he said he had other data. I mean, you got that in the first question or two. The reason I'm interrupting is to point out areas where you're spending too much time so if you run out of time on areas you didn't get to, it's going to be your fault.

He said this was the data for the pre-operational test requirements.

Now, you may have some disagreement as to how much data he should have reported for the pre-op test requirements and you can probe that. You may have some interest in what the other data showed and you can probe that. He said there's other data.

BY MR. DYNNER:

Q. Gentlemen, on page 20, question 28, you referred to static experimental procedures considering pressures as high as 2,000 psig.

Did the finite element analysis performed on the AE piston skirt consider pressures as high as 2000 psi?

DR. HARRIS: The finite element analysis that was performed was a linear elastic analysis. Once you have the results for one pressure it is applicable to any other pressure and we did a benchmark calculation at 1,670 psig, but the results obtained can be applied to any other pressure and indeed the results have been applied to numerous other pressures including pressures as high as 2,200 psi.

Q. Dr. Harris, when you say that it's linear, is that an a arithmetical progression?

DR. HARRIS: Could you please define for me what you mean by an arithmetical progression?

Q. Well, is the linear -- if you have the figure for 1600 psi, for example, you just draw a straight line and go up the graph to a higher psi.

DR. HARRIS: Let me rephrase.

Q. Let me rephrase the question for you, Dr. Harris. What do you mean by a linear progression? Could I have your answer please and then you can consult with your colleagues.

DR. HARRIS: I believe I said a linear relationship, not a linear progression.

Q. Could you describe what you meant by a linear relationship.

DR. HARRIS: By that I mean if you plot the peak stress as a function of the pressure on the piston, you obtain a straight line. This is somewhat complicated by the crown skirt interaction and you can get a change of the slope of the line when the gap closes as was discussed in the thermal distortion report of the failure analysis as provided. When you get a change of slope, you call that a bilinear relationship, two straight line segments.

Q. Does this linear relationship mean that if you know or if you have calculated stress at 1600 psi that you can easily figure what the stress will be at 2,000 psi?

May I have your answer and then your colleagues can consult with you.

JUDGE BRENNER: Well, Mr. Dynner, help me out. Why isn't that the kind of question that we can just direct to the whole panel for efficiency?

MR. DYNNER: We could but I'm exploring what Dr. Harris's testimony is describing, the linear relationship and how it works.

JUDGE BRENNER: That went beyond just his definition and it will be efficient to let them get together on something like that. When you need to eliminate, you certainly can, but if you don't have to. It would be efficient not to.

DR. HARRIS: Could you please refresh my memory by repeating the question.

DR. HARRIS: Knowing the proper bilinear relationship, you can calculate the stresses at 2,000 psi from information obtained at 1600 psi. It's a combination of the linear relationship obtained from the finite element analysis and the crown skirt interaction analysis that tells you when the slope changes and by how much it changes. These two put together give you the bilinear relation between the stress and pressure that can be used to calculate the stress at any pressure.

Q. Now --

DR. MC CARTHY: Just one thing I want to add, in completeness to the last answer. It's the stress at any pressure as long as the -- there's no permanent deformation of the cylinder. This is a linear elastic model and even up to 2,200 psi there was no plastic deformation or any permanent set in the cylinders. All the linear cylinders were perfectly accurate even up to that pressure.

DR. HARRIS: My statements were all in regards to a linearly -- to a stress calculated using linear elasticity theory and are not to be extrapolated over to additions of which you can get plastic deformation in the material. That's another aspect of the problem that I was not addressing in my earlier answer.

Q. What do you mean by plastic deformation?

DR. HARRIS: Deformation that occurs within the material that permanently changes the shape of the material even on a low — in this particular instance it's a very localized phenomena.

Q. Is a crack, an example of plastic deformation?

DR. HARRIS: Not to my way of thinking it is not.

Q. Now, in your answer to question 28, still at page 20, you stated that the static experimental procedures considered pressures as high as 2,000 psig. By that do you mean strain gage readings that were actually taken at TDI?

DR. HARRIS: By that I mean strain gage readings were taken at various pressures including pressures as high as 2,000 psig.

Q. And when were those readings taken approximately?

DR. HARRIS: When in time?

Q. Yes.

DR. HARRIS: Roughly February 1984.

Q. In your answer 28, you referred to figures 3-5 through 3-8 of the piston report.

It is stated that these figures were included in Exhibit P-10.

Now, how does that information which concerns, I believe, among other things, rosette, how does that information get translated into Exhibit P-14 which is entitled strain readings and calculated stresses for AE piston skirt for the complete stud boss rosettes at 1600 psig with a conventional crown.

MR. ELLIS: Judge Brenner, I know the question assumed that something was -- maybe it's true and I don't know, but the question assumes that certain data on P-10 is -- I think he said translated or transformed to P-14 and I didn't hear any testimony about that.

JUDGE BRENNER: The witness can handle that by his answer.

DR. HARRIS: Mr. Dynner, a more correct interpretation of the relationship between exhibits P-14 and P-10 is that Exhibit P 14 provides you with the strain gage data from rosette C, D, E, F and H, so we have five different rosettes here.

The first three rows of Exhibit P-14 provide the strain readings at 1600 psig obtained directly from the measurements. The strain readings at each location consisted of readings from a three-arm rosette, a three-arm rosette being a group of strain gages that are put down at the same point in different orientations.

The results of measurements from this three-arm rosette then provide you with sufficient information to completely characterize the stresses at that point.

The first step in the calculation is to transform the measured strains, the Epsilon sub Z, Epsilon sub theta and Epsilon 45 to the principal strains which is Epsilon I and Epsilon II. This is accomplished through standard techniques in the strength of materials for the treatment of strains in solids.

Then knowing the principal strains you can calculate the principal stresses using Hook's law which is an underlying assumption in linear elasticity.

Taking the elastic constants and the principal strains you can then calculate the principal stresses that are shown on the last two rows of Exhibit P-14.

The data which is presented in Exhibit P-14 is only for 1600 psig so it's a small sampling of the measurements that were taken because measurements were taken at a large variety of pressures.

You can see on the bottom column, the bottom row of the column headed by the letter C the number minus 43. It's also -- that is absolute value, the largest principal stress.

You then turn over to the plot that is provided on the first page of Exhibit P-10, and on the horizontal access you come into 1600 psig, you go up vertically and you'll see a group of data points up there that those -- that group of data points represents redundant measurements that were made. We pressurized the crown skirt assembly a number of times to many -- pressures as high as 2,000 psig to check on the reproduceability of the results.

If you go from the data point at 1600 horizontally then over to the absolute largest principal stress, you obtain the number of about 43, which is the number that I alluded to a moment ago from Exhibit P-14.

That's the relationship between the two exhibits and as long as we're on the subject, I would like to point out the bilinear nature of the relationship between the stress and the pressure.

If you look at the top half of the figure that's on Page 1 of Exhibit P-10, you can see the solid line coming up from pressure equal to zero up to a thousand psig. It approximately follows the data points. At a 1000 psig the solid line changes slope.

If it didn't change slope, it would move along the vertical line -- the dash line. The dash line being an extrapolation of the slope from the lower pressures.

This shows the bilinear relationship between the stresses and the pressure, and the change in slope is associated with the closure of the gap on the outer rim between the crown and the skirt as is discussed more fully elsewhere and demonstrated by other portions of the exhibits.

This can be shown quite clearly by comparing the top half of the first page of Exhibit P-10 with the bottom half.

In the bottom half the -- you can see

that there is a single straight line that's solid all the way up to 2,000 psig. This is the result of tests that were performed using a modified crown, and this modified crown we machine the crown back at the outer contact ring -- to a sufficient degree that we knew that the gap would not close at 2,000 psig.

We then pressurized the modified crown skirt assembly to pressures as high as 2,000 psig and saw this linear relationship between stress and pressure, and this demonstrates then that the bilinear nature seen on the top half of this page of the exhibit is due to the gap closure, because the difference between the two halves of this page is simply the closure of the gap at the outer rim.

Q. What I was curious about, Dr. Harris, or anyone, is that if you turn -- the first page of Exhibit P-10, which corresponds, incidentally, to figure 3-5 of the piston report, it refers to information from the stud boss rosette C; isn't that correct?

DR. HARRIS: Yes, Mr. Dynner, that is correct.

Q. Now, the following two pages of Exhibit 10, the following three pages, I should say, which correspond not incidentally to figures 3-7, 3-6 and 3-8 of the piston report, give the information for the rosettes R — or give the information for rosettes R, P and N, according to their titles, but Exhibit P-14 does not give any information for the rosettes R, P or N, and I was wondering why.

DR. HARRIS: I'd like to point out, Mr. Dynner, that the information included in Exhibit P-10 and the information included in Exhibit P-14 are only a sampling of the total data that was taken during the piston testing on the AE skirt.

If you refer to Exhibit P-12, you can see that this exhibit shows the location of the strain gage rosettes that were applied on the AE piston skirt. There were, as you can see, there were numerous strain gage rosettes placed on this component, and data was taken from each of these rosettes, each rosette being three channels of data, that taken from each of those rosettes at a wide variety of pressures so that the volume of information obtained is quite large and the material that's included in these exhibits and also material included in the original Failure Analysis Associates piston report is only a sampling of the total data that was taken. The data that's included in the —

in both these exhibits and in our reports we feel to be the data that is most relevant to the conclusions that we wish to draw from the experimental results.

Q. Well, Dr. Harris, does Exhibit P-14 represent the highest stresses that were measured in any of the rosettes?

DR. HARRIS: The information included in Exhibit P-14 is, as I mentioned, taken at 1600 psig. Of course, at 2,000 psig where we also took data the stresses were higher.

Q. Sure. But my question is at 1600 psig does the data on P-14 represent the highest stress for all of the rosettes that were taken? We've got a sampling of rosettes here, and you've pointed out that there were many other rosettes including R and P and N, that I've alluded to previously, and my question is, are the stresses at 1600 psi in the rosettes that R, P or N or any of the other higher than the stresses that are shown on P-14?

DR. HARRIS: As shown on Exhibit P-12, which I alluded to a moment ago, this shows the location of the numerous strain gage rosettes that were placed on the skirt.

In table 3-1 of the piston report, which is one of the County's exhibits, Exhibit 8, page

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3-15, there is a description in words of each -- of each of the rosette locations. There were eight strain gage rosettes that were mounted on the stud boss region and the stud boss region did have the highest stresses of any location in the piston skirt. This was verified by the stress coat test as well as by the finite element analysis. A stress coat test was performed using a brittle laquer. This is a standard technique for determining the location of maximum stress in a part. The results of the stress coat test are summarized in the piston report and we can get into that, if you so desire, but to keep on the track of strain gage measurements, we had eight rosettes in the stud boss region. The results in Exhibit P-14 summarize the measurements at 1600 psig for five of these rosettes, so there were an additional three rosettes.

The results obtained from these additional three rosettes are summarized in table 3 of County's Exhibit 8 which is on page 3-17. These three additional rosettes were rosettes in which one of the gages in the rosette element was not operative at the time the skirt was installed in the piston test fixture.

Please keep in mind, we had on the order of 50 strain gages that were mounted on this piston skirt. Out of those 50, 47 of them operated properly. Three of them did not.

However, we still have information on the stresses in those — from those other three rosettes because two out of the three arms were working. Using procedures that are enumerated in the piston report, we made estimates on what the stresses would be in those other three rosettes, and I might add that the other three rosettes were just redundant to the five that were complete rosettes.

Using the procedures that we outline in the report, we make estimates of what the principal stresses are at the locations of the rosettes that did not work, and we obtained numbers as large as in absolute value 48.4. The number 48.4 is larger in absolute value than the absolute value of any of the numbers on the bottom row of Exhibit P-14. So the answer to your question is, I believe, no, Exhibit P-14 does not give you largest stress of anywhere in the skirt, but, however, it's very close to the results that were obtained by estimates using the incomplete rosettes.

Q. If you had used the 40 ksi I number rather than the 43, would it have changed your

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results at all of your — or the conclusions of the piston report?

DR. HARRIS: Absolutely not. It would have had no influence whatsoever. If you had used the 48 ksi instead of 43.

Q. Dr. Harris, other than what you've just explained about the rosettes that didn't give you correct information, on the rosettes that you did -- that you were able to read, did any of them have higher strain readings than outside the boss area -- outside the boss area than those within the boss area?

DR. HARRIS: Other than the rosettes that were incomplete, no other rosettes that were included on the piston skirt gave stresses higher than those that are reported in Exhibit P-14.

MR. YOUNGLING: Mr. Dynner, we'd like to consult.

DR. HARRIS: The three rosettes that I discussed a moment ago that are on page 3-17 of County's Exhibit 8 are incomplete results, but using the procedures that I outlined in the piston report, I consider these results to be accurate.

I consider all of the strain gage results to be accurate and provide representative values of

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the stresses in the piston skirt. There were no strain gage rosettes outside of the stud boss regions that gave strains larger than those that were observed in the stud boss region itself.

Q. And these strain readings were all taken at ambient temperatures; isn't that correct?

DR. HARRIS: Yes. Mr. Dynner, it's true that strain gage measurements were taken at room temperature. Perhaps a more appropriate characterization of the test conditions were isothermal. We believe the isothermal measurements to be relevant to an operating piston for a variety of reasons. One of them is based on measurements that were made by TDI and supplied to Failure Analysis Associates that are shown in Exhibit P-11, the maximum temperature point. This exhibit shows pointwise measurements at the maximum temperature in a crown under operating conditions of an engine.

At the bottom of the figure you can see temperatures like 202, 205.

At the top of the crown you see numbers like 681, so the crown is certainly not operating under isothermal conditions. There are large temperature gradiants in the crown as you can see simply by looking at these numbers.

If you look at the bottom of the crown the numbers are like 202, 205. These changes are not significantly above the temperatures of the cooling oil that is circulated through the piston during operation of the engine.

Therefore, the temperature of the skirt during engine operation is going to be somewhere between the cooling water temperature and the 200 degrees Fahrenheit everywhere in the skirt. And the cooling water temperature is, perhaps, as low as a 160 degrees Fahrenheit.

Mr. Youngling can correct me on this if I'm wrong. Therefore, the temperature differences in the skirt have to be significantly less than 40 degrees which is very close to isothermal compared to the crown, which we have temperature differences approaching 500 degrees Fahrenheit.

Additional confirmation of the isothermal nature of the operation of the piston skirt in an operating engine is provided by the results of finite element calculations that had been performed by a variety of organizations other than Failure Analysis Associates, including some results that Dr. Pischinger could show us in regards to calculations and I suppose measurements of operating piston skirts, two piece skirts in large diesel engines.

MR. DYNNER: I would like to respectfully remind the witness my question was, were these readings made at ambient temperature. I did not ask you to give the history of why it's appropriate to do so.

My questions will take us there, but I would appreciate it if I could get some assistance in having the answers responsive to the question.

JUDGE BRENNER: That was a fair comment by you, Mr. Dynner, on that question and answer. Keep the question in mind and give the answers to the question and not just put in everything you think may be of interest on the subject from your perspective. We'll make Mr. Ellis work a little bit on redirect. Go ahead, Mr. Dynner.

BY MR. DYNNER:

Q. Dr. Harris, when you were describing the linear relationship of the firing pressure -- well, let me ask you, the linear relationship you were speaking of, was that the linear relationship of the firing pressure to the stress?

DR. HARRIS: The bilinear relationship that I mentioned earlier is the relationship between the peak firing pressure and the maximum stress in the stud boss region.

Q. Yes. Now, would that linear relationship be affected by temperature changes?

DR. HARRIS: That linear relationship would not be affected by temperature changes if the -- in many instances that linear relationship would not be altered by temperature changes.

Q. Well, in what instances would it be --

DR. HARRIS: Under the assumptions of linear thermo-elasticity, which is the theory that we are using in this particular case, it is the theory we believe to be applicable in this case, there will also be a linear or in this particular instance bilinear relationship between the pressure and the stress.

Q. Regardless of temperature changes in the skirt, is it your testimony -- what I'm getting at, Dr. Harris, to try to clarify my question, is that the data that you -- that we were discussing previously that's attached as Exhibit P-10 which shows the line going up on these graphs, my question is if there had been changes in temperature, would that affect the way these lines look?

MR. ELLIS: Judge Brenner, I object, because the answer that he gave before shows that

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there were changes in the skirt and so the question is a hypothetical question as to which of the facts aren't here in the record, and, therefore, I don't think the question is relevant.

JUDGE BRENNER: I'm a little confused as to what changes he's talking about because the testimony was that, at least in Dr. Harris's view, the temperatures were basically isothermal on a particular measurement and he gave the limits of what he considers isothermal, about 40 degrees, and I'm not sure that Mr. Dynner is asking about to certain temperature deltas in the piston skirt for a given point in time of measurement or if he's talking about variationin temperatures that might occur at different firing pressures notwithstanding the fact that the range might be the same. I don't understand what you're asking. I was going to let it go because you were still following up.

On that basis you might want to retract the question as you asked it and ask it a little more precisely. I'm a little confused, Mr. Ellis, and I'll let him go for a question or two to see where we're headed. Maybe I'll be less confused.

Q. Dr. Harris, what was the temperature of the engine when these readings were taken, the temperatures of the strain gage rosettes?

DR. HARRIS: Mr. Dynner, perhaps I could clarify the procedures that we used in the experimental work.

Q. Can you just answer the question. What was the temperature of the engine when these measurements were made?

DR. HARRIS: No, I can't answer that question.

JUDGE MORRIS: What part of the engine, Mr. Dynner? I mean, the engine is a huge thing.

MR. DYNNER: The pistons.

DR. HARRIS: At the time that -- the measurements were not performed in an actual engine.

Q. So the temperature of the pistons at the time these measurements where taken is under what circumstances?

DR. HARRIS: As I testified to a short while ago, at room temperature.

Q. And what is the temperature in the pistons at the time the engine is operating at full load?

DR. HARRIS: The operating temperature of the piston skirt is close to 200 degrees Fahrenheit, as I also testified to a short while ago.

Q. And at 200, is it your testimony that at 200 degrees Fahrenheit the strain readings would be the same as at the room temperature that you did your experiment at?

DR. HARRIS: Do you mean the pressure/stress relationship?

Q. Yes, with respect to the linear relationship that you've been talking about.

DR. HARRIS: The relationship between the pressure and the stresses would be the same for the skirt at 200 degrees Fahrenheit as it would be at room temperature, keeping in mind the influence of the operating performance of the engine on the thermal distortion of the crown and the closure of the gap on the outer contact ring.

Q. So if you go back now a minute, just to clarify on Exhibit P-14, for rosette C, where it shows at 1600 psig 43 ksi stress, it's your testimony that at 200 degrees Fahrenheit you would also get a reading of 43 or close to 43 ksi; is that correct?

DR. HARRIS: Under operating conditions in the engine, you have the large temperature gradients in the crown that I spoke of a moment ago.

When these large gradients occur in the

crown, the crown actually distorts due to these large temperature gradients and closes the gap on the outer contact ring. The effect of this is to actually reduce the stresses at a given pressure once the gap is closed, reduce the stresses at a given pressure below those that would be measured under isothermal conditions.

So making the measurements at room temperature under isothermal conditions is actually -- actually provides a conservative estimate of the stresses at a given pressure.

So there are differences between the room temperature results and results that would be obtained on an operating piston skirt, but we can analyze these differences and we find that the cyclic stresses or the peak stresses we're talking about here are actually lower under the operating conditions.

Q. Have you tested that theory by actually taking strain measurements of the piston skirt while the engine is operating?

DR. HARRIS: No, we haven't, but you don't need to, and the reason you don't need to is we have the results of finite element calculations, we have the results of the isothermal strain gage measurements. We have studies of the interaction between crown and skirt both from our crown skirt interaction model and from the experiments that were performed with various size gaps. And putting all these pieces of information together, along with the measured temperatures and the calculations performed by use of these measured temperatures, we can calculate and analyze what the cyclic stresses would be in an operating piston. And we don't feel that it's necessary to perform actual measurements on an operating engine.

I might point out such measurements would be of great difficulty to perform. It would be possible to do such measurements, and perhaps Dr. Pischinger would care to comment on this regarding the difficulty and possibility of measuring stresses in the operating engines, in the piston skirt.

JUDGE BRENNER: If Mr. Dynner wants him.

DR. PISCHINGER: Yes, do you want me?

MR. DYNNER: Go ahead.

DR. PISCHINGER: We have done such measurements already. The problem is to transduce a measured value from the moving piston to standing equipment, and, of course, this apparatus which is necessary reduces accuracy of such measurements; so in my mind, the way which was followed up here, combination of measurement and using measured temperatures in the piston crown, is a precise way which could not be very much improved by actual measurement in a running engine.

Q. Dr. Pischinger, is it difficult to measure the temperature of the piston skirt while the engine is operating?

DR. PISCHINGER: The temperature of the piston skirt is not difficult to be measured.

What is difficult is to measure the strains because the strains are varying with time so you have a time variable signal which you have to transmit from the piston to any measuring equipment.

JUDGE BRENNER: We're going to take a break in a moment. I'm just a little confused on one point.

Dr. Harris, you talked about the possible difference that would occur when the gap is closed. And you said that might account for differences in the result of direction you indicated between the experiments at ambient room temperature and what you might expect in terms of stress results at an operating temperature of an engine.

I also inferred, perhaps wrongly, from

some of the information and from that exhibit, LILCO Exhibit P-13, that the gap that you were talking about between the crown and the skirt, closed air pressure and, therefore, I thought that the experiments represented — or some of the results of which are represented in LILCO Exhibit P-10, once they saw that gap closed pressure wouldn't close the gap, notwithstanding the fact that there was ambient temperature. Am I going wrong somewhere? ?

DR. HARRIS: No, Judge Brenner. I don't believe you are going wrong. Under ambient conditions you can close the gap simply by pressure. However, when you go to operating conditions in an engine, an additional deformation of the crown is — results from the temperature gradients in the crown so there are components — two contributors to the deformation in the crown. One is the pressure and the other is temperature.

Even in the absence of any temperature gradients, the pressure alone can close the gap.

JUDGE BRENNER: Now, when you did the experiments, some of the results showed that there was a crown on the skirt; correct?

DR. HARRIS: Yes, that's correct.

DR. MC CARTHY: There's an additional --

one can ask the question, apart from this, does the crown actually touch the skirt during normal operation, and it's clear from our tests that the pressure will make the crown touch the skirt. So the question is, is it touching it all the time because of thermal effects or is it only touching it occasionally for pressure effects?

If you know and look at operational pistons there was a substantial gap, there was close firing pressure and you would expect the crown to be hammering on the skirt and you would see a Brinelling effect on the crown skirt interaction line. If you look at the piston lines you do not see evidence of the Brinelling effects of it close up pretty well.

DR. HARRIS: I'd like to amplify on Dr. McCarthy's answer briefly.

JUDGE BRENNER: You've answered — I've got the answer I wanted on my original question or two. Why don't we leave it at that. That's part of the problem of where we guess we might be going or what we might be thinking, and the way it's played out is to try to direct your answer to the question.

DR. MC CARTHY: There may be —

JUDGE BRENNER: Clear it up if you want

to through your counsel. He can come back if he wants. Just on this one example I'll tell you more than I want, but I'm trying to judge and taking in questions to be concluded. I want the answers to the questions and Mr. Dynner is going to come back and talk about his time took three times as long because the answers were three times as long as necessary, and he's going to have a good case.

The fact I was interested in was solely whether or not I should put much stock in the fact in your testimony that the pressure results in an actual operating engine would be lower because the experimental results in P-10, some of which is also in P-14, is conservative of the sense of gap closure, and I was wondering whether there was not in fact some gap closure, even during the experiments and you've answered the question.

Now, if you may have something else in mind beyond that. You may think I'm confused on another point. That may you be true and you can talk to Mr. Ellis and he'll fix it up all for you. We'll be back at 10:50.

(Recess 10:30 a.m.)

JUDGE BRENNER: Mr. Dynner, you can pick up on your cross-examination.

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BY MR. DYNNER:

Q. We're on page 12, Judge Brenner.

JUDGE BRENNER: I was able to progress from 11 or 12 this morning.

Q. Gentlemen, you've referred in your testimony to -- that's on page 21 of your testimony, you referred to peak temperatures in the crowns measured by DeLaval and those are set forth, you've testified, as exhibit P-11. Does the measure set forth as Exhibit P-11 represent the only crown temperature measurements that were furnished to LILCO, FaAA or the owners group by DeLaval?

DR. HARRIS: I don't recall precisely whether the information provided in Exhibit P-11 is the only information on crown temperatures that TDI supplied to LILCO FaAA.

I do know, however, that all of the data that was supplied to us was supplied to us at one time. My memory is fuzzy on this. There might have been two sets of information supplied both at the same time and the two sets were very similar to one another and the results that were used as shown in exhibit P-11.

MR. DYNNER: Judge Brenner, I'd like to pass out and have marked for identification a document showing the temperature measurements of the crown.

JUDGE BRENNER: You're in the pretrial exhibits which of course we have not yet identified or entered into evidence on the record. Your last number is going tc be 67, is that correct? So this is going to be 68. Diesel Exhibit 68 for identification.

MR. ELLIS: May we know where this is from so we can identify it?

JUDGE BRENNER: Have you given copies to the reporter?

MR. DYNNER: We're going to need more copies of that, so I'm having someone make additional copies so I'm having someone go on to a related area.

JUDGE BRENNER: Answer Mr. Ellis's question in any event, so you can be more prepared later as to where this is coming from.

MR. DYNNER: This is one of the documents which was obtained during the discovery and to our knowledge it represents TDI measurements of the temperature of the crown of the AE piston

JUDGE BRENNER: You're going to have -- you're introducing it for identification on cross-examination. You're going to have to ask some questions so the witnesses know about it. Let's hold off identifying it at this point then. When you come back I'll let you get your foundation in and then I'll hear your motion.

BY MR. DYNNER:

Q. Gentlemen, what did FaAA do, if anything, to independently verify whether or not the temperatures given by DeLaval for the crown were accurate.

DR. PISCHINGER: May I shortly address this? The range of temperatures given in this piston crown is very reasonable and similar to similar measurements in comparable piston crowns. So I feel that these measurements are in a reasonable scope of experience.

Q. What do you base that on, Dr. Pischinger?

DR. PISCHINGER: For instance, similar measurements by German piston manufacturers taken in engines which gives quite similar readings, comparable readings.

Q. What engine would that be?

DR. PISCHINGER: Well, this is a piston -- little smaller piston, but with higher BMEP. So I rather feel if these values would deviate or should deviate they should -- should deviate, they should be in reality a little lower.

Q. What was the engine that you're referring to?

DR. PISCHINGER: I cannot give you the engine. I only can give you the piston. The diameter of the piston isn't --

Q. Is that the person that will take the temperature readings?

DR. PISCHINGER: No, it's published.

Q. Where is it published?

DR. PISCHINGER: It's published in a German -- in a German technical newspaper so that it could be made available.

Q. And was this engine -- what was the BMEP of this engine that you're referring to?

DR. PISCHINGER: This was 23 -- the highest BMEP was 23.5 bar which is -- well, a lot higher than --

Q. What was the RPM of that engine?

DR. PISCHINGER: 800. It all means severe conditions.

Q. How many horsepower did that engine put out?

DR. PISCHINGER: I don't have it in my mind. I could --

Q. Sorry?

DR. PISCHINGER: I cannot tell you at the moment.

Q. What was that piston made of?

DR. PISCHINGER: Cast iron, same material as this piston.

Q. Who was the manufacturer?

DR. PISCHINGER: Karl Schmidt.

DR. MC CARTHY: An additional check --

MR. DYNNER: I would like to follow up with Dr. Pischinger.

Q. What were the dimensions of that piston?

DR. PISCHINGER: A little smaller, possibly 300.

Q. And you think that -- what evidence do you have that the temperatures of that piston that you're referring to, the Karl Schmidt piston were adequate -- would be adequate for determining whether temperatures of the DeLaval EDG's piston skirts were proper?

DR. PISCHINGER: Well, there is a certain similarity rule that which an engine of this piston design, the same design, two part piston, the crowns from below, the same cool from below, the same way of cooling the piston, that the temperatures adjust -- the temperature field is about the same.

What I wanted to say that if there would have been this measurement deviation to, let's say, 400 degrees centigrade or 200 degrees centigrade to the maximum, I would say it's too low or too high, but this is -- this was in the reasonable region of my experience with such pistons, and also this very recently measured and published result.

Q. Did the Karl Schmidt piston that you're referring to have a temperature variation in the crown of over 400 degrees from the top of the crown to the bottom?

DR. PISCHINGER: Now we have to tell both degrees.

Q. Fahrenheit.

DR. PISCHINGER: Fahrenheit. 400 degrees Fahrenheit. It's even more. It's -- sorry, I have to convert.

MR. ELLIS: My son is struggling with the metric system. It may spur him on to success.

JUDGE BRENNER: Don't tell him he can get the answer with a calculator. He'll lose his incentive.

DR. PISCHINGER: Yes. It's a little higher from Karl Schmidt.

Q. What is your number?

DR. PISCHINGER: Oh, it's just the same. It's just the same.

Q. Just the same. 400 degrees Fahrenheit.

DR. PISCHINGER: Yes. 220 degrees Celsius.

Q. What was the peak firing pressure of the Karl Schmidt piston.

DR. PISCHINGER: I don't remember but considerably higher.

Q. Do you feel that the comparison of this data to the Karl Schmidt piston is sufficient in your mind to verify the accuracy of the temperature measurements taken by DeLaval for the AE piston crown?

DR. PISCHINGER: Well, what I can say, the method that was used was a templug method which is a usual method. Karl Schmidt did it. DeLaval did it. It's the same method and this method gives you a lot of independent reading at different points of the piston crown so you do not rely on only one point, and it's very unlikely that a large set of templugs is basing wrong in such a piston all in the same direction. So I have a lot of reasons to say that these readings are reliable and they are also in the range of experience of similar pistons, so I think it would be a very good pace. The only thing you can think of that DeLaval would have done this test with a completely different load, but this is unlikely in view of the temperatures and the temperature differences.

JUDGE BRENNER: Mr. Dynner, I've lost the thread of materiality again.

Why is the differences or potential greater or lesser differences in the temperatures of different portions of the piston crown relevant to anything before us?

MR. DYNNER: Well, because as I understand the testimony of the witnesses, they calculated or extrapolated temperatures in the piston skirt based upon the DeLaval measurements made of the temperatures in the piston crown, and we're talking now as to whether or not the temperatures of the DeLaval measured in the piston crown were or were not accurate, and were or were not validated.

JUDGE BRENNER: But your last series of questions for about the last ten minutes went to differences between the highest temperatures and the lowest temperatures on the crown and the testimony we also have is that -- and in the view of these witnesses -- it is reasonable to take the temperature at the bottom of the crown and realize that that is somewhat higher than the coolant temperature, and to use some temperature around that or, perhaps, even a little lower for the skirt temperature, and you also have the testimony as to the variations you might expect within the piston skirt, and unless you're going to do a number of things, that is give some evidence somehow and I don't recall the County's testimony, I may be wrong, that, A, that is wrong, B, that there are some great differences at different portions of the piston skirt in temperature in contradiction of what these witnesses have testified, and, C, all that makes a difference in the way they have applied it in their finite element analysis, then we're not going to do anything with this mix of information. So there are quite a few links missing if you are talking about differences between the temperatures at the top of the crown and the bottom, in terms of any usefulness to us.

Do you want to comment on that?

MR. DYNNER: No. I'm going to try to follow up with questions that may answer the comment that you made.

JUDGE BRENNER: I'd like you to start thinking about where you're going with some of these questions as opposed to the immediate interest that you or anybody else might have in view of the particular question in isolation.

BY MR. DYNNER:

Q. Gentlemen, concerning the calculation you made or the conclusions you reached about the temperature of the piston skirt, based upon the TDI measurements of the temperatures in the piston crown, would it have made any difference to your conclusions if there were much larger variations in the temperature between the top of the crown and the bottom of the crown than shown on Exhibit P-11.

DR. SWANGER: Our conclusions about the isothermal state of temperature distribution in the skirt are affected only by the temperatures at the bottom of the crown.

The temperature gradient across the crown would not have any effect on temperatures within the skirt. Only that portion of the crown in direct contact with the skirt would influence the temperature of the skirt, so as long as the measured temperature at the bottom of the crown is about 200 degrees Fahrenheit, we think that the operating temperature of the skirt would be about 200 degrees Fahrenheit.

DR. MC CARTHY: Now, it is important, of course, the absolute temperature gradient from the top of the crown to the bottom of the crown with the thermal distortion that's going to occur with the crown and the closure interaction, and in answer to your previous questions where you were talking with Dr. Pischinger and I didn't -- your question was what checks had we done on the numbers, and Dr. Pischinger talked about about his experience. But I did not get a chance to add to that other checks the Failure Analysis did.

Dr. Gail McCarthy, who is a consultant in heat transfer was asked by me to do confirmatory calculations or analytical calculations of the temperature gradient provided to us by TDI, and there are some absolute checks on the accuracy of, or reasonableness of the gradient, that is, if there's more heat flowing through the top of the piston than is being removed by the oil, you've got a problem.

So there's an absolute check on if your gradient is higher, more heat flows through the top of the piston must be removed by the oil.

As I think Dr. Pischinger indicated, these numbers — this temperature gradient might be a shade high. I think our analysis confirmed they are reasonable, perhaps a shade to the high side, because the heat flux through the pistons would account for 93 percent of the temperature loading in the oil, it's the heat load to the oil, so, once again, another independent physical bound on the reasonableness of the numbers confirms that they are in a reasonable range, perhaps a slightly higher gradient than actually exists.

Q. Is it your testimony on P-11 that the temperatures shown there of 205 and 202 degrees Fahrenheit at the very bottom of the crown are uniform throughout the circumference of the bottom of the crown?

DR. MC CARTHY: We do not have, to our knowledge, circumferential temperature measurements; however, the geometry and by the nature of steel itself, we do not believe there are any significant temperature variations.

There are going to be small differences introduced by the presence of the wrist pin around parts of the -- wrist pin around the periphery of the piston will introduce a small assymetry into the temperature field, but nothing that would approach a level which I think one woulo term significant, something you'd be concerned about.

DR. PISCHINGER: May I add, this is the experience with this type of pistons before: there is no larger circumferential deviation in temperature.

That means --

Q. You're referring to the crown or to the skirt?

DR. PISCHINGER: The crown. Of course, the skirt is usually, even with those German piston manufacturers, tested as thermal, also, the same way it was done -- this is industrial habit because it has no influence of temperature and for the crown it's usually the temperatures do not vary in the circumferential direction.

Q. Dr. Pischinger, are you familiar with instruments produced in England by Welworthy for the measurement of stresses in a piston while the piston is operating?

DR. PISCHINGER: No. We have our own methods.

Q. When you say, "We have our own methods," to whom were you referring?

DR. PISCHINGER: If anybody wants to have a piston tested, I can do this.

Q. Do you know how long the engine had been running when the temperature readings in the crown were made by TDI?

DR. HARRIS: I was not supplied precisely with that information, but I was told that the engine had been run long enough that the temperature measurements were representative of steady state conditions in the engine.

Q. Do you know what the load was?

DR. HARRIS: Yes. Approximately. The BMEP was some -- as I recall, somewhat below the 225 applicable to Shoreham. As I recall, it was 213 BMEP.

Q. Can you translate for us that BMEP of 213 into what the horsepower per cylinder would be for that load, or don't you know? I'm not trying to make you do a ten-minute calculation here, but --

DR. HARRIS: More like a ten-second calculation.

Q. Judge Brenner, we have some extra copies of this exhibit marked for identification which we can now show the witness. I don't know how much I'll going to pursue in view of your remarks.

JUDGE BRENNER: If you're not going to pursue it, don't mark it.

MR. DYNNER: I haven't decided yet

JUDGE BRENNER: Hold off then. We've got the copies. As of now we have no exhibit identified as 68. You decide what you want to do with it and since it's cross-examination, you'd better get a few questions in before you even ask to mark it so we get the context.

If you want to come back to it, you can.

DR. HARRIS: The 213 BMEP for which the temperature measurements are applicable and the 450 rpm operating condition in the engine translates to 577 horsepower per cylinder which for an eight cylinder engine would be 4,620 horsepower.

DR. SWANGER: I might point out that horsepower is 95 percent of the rated horsepower of the Shoreham engine; therefore, the thermal loading would be within five percent of the thermal loading of the Shoreham engine is at the rated horsepower, and given the heat transfer properties of the steel, I feel that the evidence shown in Exhibit P-11 is reasonable for use in Dr. Harris's calculations.

MR. ELLIS: Judge Brenner, if we're now

going to introduce this piece of paper, my Xeroxed copy has some figures up at the right-hand corner that I cannot read. If Mr. Dynner can read into the record what those are --

JUDGE BRENNER: I don't know if we're going to do that. I don't know if he's going to use it. He had that discussion. He's got a problem and if he can't get to it before the lunch break, he can get a better copy and give it to you but if he does get it before the lunch break he'll get it for you and we'll mark it. Are you going to use it or not?

MR. DYNNER: I'll find out in minute.

JUDGE BRENNER: One at a time. Dr. Harris, what were the units for your 213 BMEP?

DR. HARRIS: Psig -- pounds per square inch.

DR. PISCHINGER: 213.

JUDGE BRENNER: All right, thank you.

If we want to convert the B bar units, is that 14.7 psi?

DR. MC CARTHY: 14.504. Go ahead.

Q. Gentlemen, we've handed you a document and it is in the bottom right-hand corner, it says DeLaval and you have crown with templugs and then under that RD-2145.

Has any of you seen this document before, if you recall?

MR. ELLIS: Again, Judge, I object to it unless I can be sure that their document and my document I think is a Xerox but I have some figures around the piston that I can't read and also some figures in the right-hand corner that I can't read

JUDGE BRENNER: I can't read all the figures either.

MR. ELLIS: I think they may be very pertinent.

JUDGE BRENNER: Do you have a good original on this?

MR. DYNNER: I have a copy that -- the right-hand corner it says 213 BMEP; under that 450 rpm.

MR. ELLIS: : Go ahead.

MR. DYNNER: 1500 oil it says under that. --

JUDGE BRENNER: Can you read it?

MR. DYNNER: it looks like an O I L, 1500 -- it's a pretty educated guess on my copy.

JUDGE BRENNER: 1500 something.

NRC STAFF MEMBER: Seconds read is probably --

MR. DYNNER: Something IO, looks like IO.

JUDGE BRENNER: Let's go off the record:

(Discussion off the record)

JUDGE BRENNER: Mr. Dynner, ask the questions you want to ask.

Q. Have any of you seen this document before that you can recall?

DR. HARRIS: To my knowledge, Mr. Dynner, I have not seen this document before.

DR. SWANGER: Nor have I, Mr. Dynner.

BY MR. DYNNER:

Q. Nobody has seen it on the panel. Okay, we're not going to use it.

JUDGE BRENNER: So it's never been marked.

MR. DYNNER: That's fine then.

Q. Gentlemen, instead of making this extrapolation or conclusion that you do in answer 29 on page 21 concerning the temperature in the skirt, and following in 30, why didn't you just measure the temperature of the skirt during operation of the engine as Dr. Pischinger has suggested would be fairly easy to do.

DR. HARRIS: Because it wasn't necessary, Mr. Dynner.

Q. It wasn't necessary. For what reason do you make that conclusion?

DR. MC CARTHY: Basically, the temperatures and any possible differences from these temperatures -- were, first of all, so small, and second, so unlikely to have any even probably detectable effect on our results that it just made no sense to go forward with elaborate tests like this when the results are going to be so insensitive to temperature. First of all the elastic modulus of the material which determines the rate it stretches which are insensitive to temperature at this range. Insensitive not sensitive. Even if there is small differences in temperatures, even if there exists small differences in temperature the behavior of the material is still elastic. You have to get to temperatures in the skirt equal to those temperatures in the crown before you begin to see any measurable -- at the top of the crown, before you begin to see even measurable effects on the modulus of the material. It would effect its elasticity, affect its slope. There were no effects that would have affected our conclusions.

DR. SWANGER: I can go into some more detail as to the significance of these measurements as well.

We had made the statement that the skirt is in our opinion essentially isothermal. The only concern that we would have if it were hypothesized to be not isothermal is that there might be an effect of thermal stresses in the skirt; however, the temperature in the skirt would be essentially uniform during operation of the engine. It would not fluctuate at 225 cycles per minute as do the stresses from the firing pressure. Rather the only effect it might have if it possibly exists would be a slight offset in the mean stress and no effect at all on the cyclic stress. The finite element analysis and the fracture mechanics analysis takes into account the cyclic stresses, primarily the cyclic stresses in assessment of the propagation of hypothesized cracks in these pistons. Thus even even if we relax the assumption that the skirt is essentially isothermal which we believe is a reasonable assumption, it can be demonstrated by a number of methods, it would have no effect at all on the cyclic stresses in the stud boss region or any other region of the skirt.

Q. Well, if you measured the temperature of the skirt in an approach of to 400 degrees, which is some of the temperatures that I see in P-11 near the top of the crown, would that have any influence or effect on the stresses in the skirt that were measured by strain gages?

DR. SWANGER: We believe that the premise in your question, that the temperatures in the skirt could even reach 400 degrees Fahrenheit is within -- without foundation.

The reason we belie at that premise is without foundation is that the oil coolant of the piston is very effective in that there is a large drilling up through the connecting rod which delivers copious quantities of oil into the region between the crown and the skirt and that oil then drains back out of that area and bathes the skirt in an isothermal oil bath.

We know that the lubricating oil temperature into the engine is 155 degrees Fahrenheit and that the maximum lubricating oil temperature out of the engine is 180 degrees Fahrenheit.

As Dr. McCarthy had said, our bounding calculations show that the vast majority of the thermal load on the oil, which means where the source of heat in the oil is that comes out of the engine is through the piston crown; therefore, that oil leaving the piston crown will be very close or no more than 170 to a 180 degrees Fahrenheit and the skirt is bathed in this oil maintaining it isothermally.

If we accept what I think are the absolutely unfounded premises of your question that the skirt might reach 400 degrees Fahrenheit as Dr. Harris had testified earlier, linear elasticity still applies. The loads are still the same and the stresses in the areas would still be the same.

JUDGE BRENNER: Dr. Pischinger, wait, because Mr. Dynner is talking to one of his consultants.

In addition, I think that question was answered.

Mr. Dynner, unless you're going to give evidence that contradicts the two points that Dr. Swanger has answered just now, I think you'd better move on to another question.

MR. DYNNER: I was about to say that we're going to move to cross-examination at page three, at the bottom of page three.

JUDGE BRENNER: Just in case it wasn't clear, Dr. Swanger's answer which has not been contradicted by any evidence orally and by any, to my recollection, any direct written testimony, that the County has provided is that the series of questions on the data and the reasonableness of it as to temperature of the crown and also the skirt does not matter for the reasons he's just indicated. The bounds on the piston skirt temperature provided by the lubricant, the oil, and also the lack of effect in his view of even the higher temperature or assumption on the finite element analysis, so that's the evidence and you're going to have to contradict that in order to ask any other questions about it, make a representation that you've got evidence that contradicts that. And you can think about that.

You want to try sooner rather than later to narrow the areas that are potentially in controversy, and I don't think you're doing that as quickly as you can and I have some opinions as to why that's not happening. So I'll save them in my own mind for now unless I have to give them out loud at a later point. Let's proceed.

BY MR. DYNNER:

Q. Gentlemen, referring now to testimony if you will, at page 14, of your testimony, now, regarding the fracture mechanics analysis that was performed, you stated in your testimony at the top of page 14 that the fracture mechanics analysis would also determine growth behavior from any possible initial imperfections in the skirt.

Does your fracture mechanics analysis also predict cracked growth behavior from the initiation side of the crack into a sand inclusion or other imperfection that might occur very near to the initiation site?

DR. HARRIS: The fracture mechanics analysis in the AE piston skirt was performed for hypothesized cracks as deep as one half an inch. Even cracks of this extreme depth were predicted to never propagate; therefore, any initial defect of size up to a half an inch is also predicted not to propagate. I might add that a crack is very severe type of defect and the half inch depth is very large compared to any features of the microstructure or any grains of sand that were used in the casting process. I believe Dr. Swanger has some additional words that he'd like to add in this regard.

DR. SWANGER: Yes. My inspection and evaluation of the manufacturing techniques that I testified to yesterday allows me to conclude with a very reasonable degree of certainty that the kind of defect that is alluded to in the question could not exist in the subsurface of the highly stressed crown skirt attachment boss in the AE pistons.

We have taken samples of material from two actual AE pistons for our mechanical properties testing, and we have sectioned AE pistons for metallographic graphic examination and in all of these cuts through the highly stressed areas of these pistons we have not found any evidence of such internal inclusions.

My opinion is that in a sand cast product such as the AE piston, the vast majority of any potential defects that might be attributed to the manufacturing process would occur at the surface of the piston and they would be the result of the kind of occurrences which can occur in a foundry but for which inspections were done.

Also, I testified why there was a grit blasting operation performed on these pistons to make such an inspection of the surface.

DR. JOHNSON: All the piston skirts which were supplied to Shoreham AE piston skirts supplied to Shoreham were inspected by two independent inspection methods, one, penetrant, and, one an eddy current. In shipment to Shoreham all indications were -- all evidence and all indications were removed from the piston skirts. There were no indications by either technique of imperfections in this area of the piston skirt.

Q. Did you say all indications were removed, Dr. Johnson?

DR. JOHNSON: The source of all indications were removed, yes.

Q. Could you explain what you meant by that

DR. JOHNSON: In the --

Q. I'd like Dr. Johnson to please answer the question.

JUDGE BRENNER: Yes.

Q. It's a follow-up to his testimony.

JUDGE BRENNER: Yes, Dr. Johnson, just you for now.

DR. JOHNSON: In the washer landing area, there were some machine indications which were ground out per TDI procedure. All of the pistons which were shipped to Shoreham had no eddy current indications, nor penetrant indications.

Q. What was the nature of these machine indications that you say were ground out?

DR. JOHNSON: They were linear indications in the lip of the washer in the landing area.

Q. Can eddy current and die penetrant inspection detect subsurface flaws in the casting?

DR. JOHNSON: Both penetrant and eddy current are not directed at subsurface flaws.

Q. So the two inspections that you say were carried out on all the skirts would not be able to detect any subsurface flaws; isn't that true?

DR. JOHNSON: Both the PT tests and the eddy current tests are sensitive to surface connected defect, not deep subsurface defects.

Q. So my question to you is it's true, isn't it, that those techniques would not disclose subsurface flaws, that's true, isn't it?

DR. JOHNSON: I believe I answered that question.

JUDGE BRENNER: You didn't, Dr. Johnson. I was going to make the same point that Mr. Dynner made. What's the answer to the question?

DR. JOHNSON: The answer to the question is that penetrant and eddy current are not designed to detect subsurface flaws.

JUDGE BRENNER: The question is would they detect subsurface flaws?

DR. JOHNSON: I do not believe so.

MR. SEAMAN: I would like to add one thing to that discussion.

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with Failure Analysis and Stone & Webster and other NDE experts did consider performing in sort of subsurface or some sort of NDE that could determine subsurface flaws and, basically, due to the physical configuration of the head it's really not possible to perform adequately a volumetric inspection of the pistons in this area.

Q. Did you say heads, Mr. Seaman?

MR. SEAMAN: Excuse me, pistons.

Q. Is that the only way in which you could detect subsurface flaws or could you use x-ray techniques, Mr. Seaman? Or anyone?

DR. JOHNSON: In this particular area there is a large variation in thickness which precludes a meaningful x-ray examination of the area for subsurface defects.

DR. SWANGER: I'd like to follow up on the logic that went into FaAA's recommendations to LILCO about the need for nondestructive testing.

At the time of the purchase of the AE piston skirts, the metallurgical failure analysis of the AF piston skirts was well in progress and one of the primary features that we were looking for in the cracks in the AF skirts was to see if they were in any way associated with subsurface defects, manufacturing defects or casting flaws.

I think that the statistics that we pointed out yesterday that 23 out of 23 AF pistons did have the cracking in them showed that that was related to the design of the piston and not to its manufacturing.

We investigated a number of these cracks in the AF pistons and we found coincidentally that one of the cracks did pass through a small preexisting surface-connected flaw on that AF piston, but from examination of the fractured surface we saw that even that flaw in the AF piston had no effect on the fracture mechanics.

Gaining this confidence in the manufacturing techniques used for both the AF and AE pistons, it contributed to our opinion that the surface related NDE inspection techniques were the appropriate ones for the AE pistons.

DR. HARRIS: If I could further amplify on our answer to the question, there are fracture mechanics and stress analysis reasons for concentrating on surface cracks. A crack of given size is much more severe when it's connected to the surface than when it is a subsurface defect, even given that the stress were equal throughout the volume of the material.

The very severe stress gradients that the finite element analysis showed existed in the stud boss region tells us that the stresses are highest at the surface and, therefore, that's the region that we should be most concerned about. The stresses die out very rapidly as you progress away from the surface of the highly stressed region in the stud boss area. Therefore any subsurface defect would be less likely to grow because the stresses on them are considerably lower.

Q. Moving to page 4, paragraph D of the cross claim.

Gentlemen, if you'll turn now to page 22 of your testimony, concerning the strain gage test which we've discussed previously, how many pistons were subjected to the strain gage measurements

DR. HARRIS: How many AE pistons?

Q. Yes.

DR. HARRIS: One. However we had each of the four stud boss regions in that one piston strain gaged. So we had redundant measurements of the strains in the stud boss region of the AE skirt.

Q. Is it difficult to obtain accurate measurements from the strain gaging that you did on this piston?

MR. ELLIS: Objection. I don't know what he means by difficult. If he wants to talk about the billions that we paid for having all this done, I can address it to that or there could be -- I just don't understand what the word difficult means in this context or how it's -- whether it's material. You can ask him what the -- ask her to describe it, but I simply don't think difficult is an appropriate question.

JUDGE BRENNER: The question is not so imprecise that I would grant the objection.

However, I think in the name of efficiency, it would be helpful if you could just more precisely get to whatever it is you want to get to in some of these questions, Mr. Dynner. As an example, if you have something in mind, why don't you ask him directly about whatever it is you have in your mind. I'll leave it up to you. But don't complain to me about the length of the answers if you keep asking questions like that one. It's your move.

Q. Is it your testimony that the measurements of the strain gages that you took on this piston are a hundred percent accurate in their readings?

JUDGE BRENNER: Mr. Dynner, I'm interrupting only because I hope it will be helpful for the future here. That, too, is the same type of general question, you changed the wording. If there is something you have in mind as to the accuracy of their measurements, ask them about it.

MR. DYNNER: Well, I tried to do that.

JUDGE BRENNER: You said is it difficult and then you changed difficult to the accuracy of the readings, it's still the same --

MR. DYNNER: I said is it difficult to obtain an accurate reading.

JUDGE BRENNER: That's still very generally. That's still a question to the procedure. Is there something about the procedure that you believe you can adduce evidence on that will help us? Placement of the strain gage, the --

Q. Is there a predictable accuracy for the strain gage measurements that you made?

DR. HARRIS: Like any engineering tool, the strain gages are capable of providing accurate results. In my own 20 years experience in applying experimental techniques to measurements of stresses of bodies I can confidently say that strain gage techniques are capable of providing results which are of suitable accuracy for making engineering judgments. I believe that the strain gage techniques that we used are general state of the art and have been applied very widely in other industries, and have been applied very widely by myself and other people in Failure Analysis Associates. And once again I believe that the strain gage techniques are capable of providing the results of suitable accuracy for our purposes here.

I believe, if I had to put a number on it, I would say that the results we obtained were accurate to within approximately plus or minus five percent. I would expect accuracy actually would be better than that.

Q. Well, you had a concern, didn't you, as to whether you really got your strain gage down to the region where the stresses are highest in the AE piston, isn't that correct, Dr. Harris? Did you have that concern as to whether you got the strain gage down in the region where the stresses are highest in the AE piston?

DR. HARRIS: In the general application of strain gages to experimental stress analysis if you are looking for regions of highest stress, one need always be concerned to have the strain gage down in the region of highest stress and this is precisely the reason that we did the stress coat test in order to accurately find the location of the maximum stress. Then once that region was identified, we put redundant strain gage rosettes in that region. We had eight independent measurements of the stresses and strains in the stud boss region and all eight of those measurements agreed quite well with one another which to me indicates that we were indeed close to the region, if not precisely on the region of the maximum stress in the stud boss.

Q. And fairly small inaccuracies in the placement of your strain gages could cause some inaccuracies in the strains that you measure. And in the strains that you want to compare with your finite element runs; isn't that true?.

MR. ELLIS: Object again on grounds that it is imprecise. Fairly small. I don't know what he means by fairly small.

JUDGE BRENNER: Well, we'll let the witness handle that one.

Q. May I have your answer, Dr. Harris?

DR. HARRIS: Inaccuracies in the placement of strain gages in the region where there are high stress gradients can cause inaccuracies in the results that you obtain thereby. However, the stress coat test showed us that the region of high stress is quite small, but precisely identified it and allowed us to put the strain gages in that region. Once again we put eight rosettes and obtained eight nearly — very nearly the same results and this indeed indicated to me we hit very closely to the high stress region. There's further evidence in the finite element analysis that provides guidance in the placement of these gages but we rely primarily on the stress coat test for that purpose.

DR. SWANGER: The finite element analysis further gives us confirmatory evidence that the strain gages were placed in the areas of highest stress.

If you'll recall, we discussed yesterday the two different assumptions about two different wrist pins in the finite element model. These were two boundary conditions which were selected to be extremes of boundary conditions which bracketed what we believed to be the actual situation. The first runs were done with a rigid wrist pin, that is, one which does not deform. The second finite element done which was done with a soft wrist pin, one which completely conforms its surface mathematically to the bore of the wrist pin boss.

We felt that the -- we know that the actual wrist pin which was used in the experiments is an elastic wrist pin which was somewhat in between these two assumptions, and the results came out the same way. The rigid wrist pin which we expected to give us high conservative values from the FEM analysis did give us high conservative values relative to the strains and stresses measured by the strain gages.

The other boundary condition, soft wrist pin gave us strains and stresses lower than the experimental values. Thus, we feel that both finite element runs give us confirmatory evidence that the strain gage readings were accurate for the purposes of the analysis.

Q. Exhibits P-12, you testified, shows the location of the strain gages.

In fact, were all of the strain gages placed in the same plane?

DR. HARRIS: I assume you mean the same plane perpendicular to the axis of the cylinder, vertically.

JUDGE BRENNER: You mean the same horizontal plane?

Q. P-12 as I looked at it is the cutaway looking down from the top of the skirt; is that correct? So you wouldn't be able to tell from P-12 whether all the strain gages were placed in the same horizontal plane.

DR. HARRIS: Yes, that is right. You wouldn't be able to tell from that.

Q. My questions is, were all in the same horizontal planes or were they on different planes?

DR. HARRIS: No, they were on different planes.

Q. What was the extent of those variations? Well, let me rephrase the question.

Would it matter in terms of the readings that you got whether there was any variation -- whether there was a variation in the planes of the strain gage placements?

DR. HARRIS: Well, of course, the strain in the piston skirt depends on where you are vertically along the height to the skirt. So where you put the strain gage down is going to have an influence on the strain that you measure. The strains are not the same everywhere in the skirt obviously.

Q. Is there someplace where you have identified the location of the strain gages up, shall I say up and down the skirt?

DR. HARRIS: Perhaps the clearest identification of the horizontal plane on which the strain gages were mounted is provided in the table that I discussed earlier this morning. Table 3 won't help us on that answer.

DR. HARRIS: Well, that's the one that I was going to refer to, if you would like.

JUDGE BRENNER: As I understand the question, it won't help us.

MR. ELLIS: Could we --

DR. HARRIS: The rosettes in the stud boss region, B, C, D, E, F, G, H and I, were all in the same horizontal plane.

JUDGE BRENNER: All right. There's been a failure of communication I thought there in Mr. Dynner's opening question as to whether the strain gages --

DR. HARRIS: I understood the question to be --

JUDGE BRENNER: To all the strain gages.

DR. HARRIS: All the strain gages, not

just the one in the stud boss.

JUDGE BRENNER: I thought he was asking about the stud boss because that's the question I had in my own mind. Anyway, we've got the answer to that one.

Q. Gentlemen, if I could ask you now to turn for a moment to Exhibit P-14.

JUDGE BRENNER: Could I ask one question Mr. Dynner. You've got four pair, I take it each pair is in just about as close a location as you can get to strain gages; is that the way it works?

DR. HARRIS: Yes, Judge Brenner, that's correct.

JUDGE BRENNER: Am I also correct that you get three readings from each strain gage?

DR. HARRIS: Each rosette has three strain gages in it. And you get three -- so you get three readings, one from each gage and each rosette, and those three readings allow you you to then characterize the principal strains at that location.

JUDGE BRENNER: So if sometimes the dialogue here has talked about each strain gage at the stud boss region, then it's actually eight strain gage rosettes and actually 24 strain gages

DR. HARRIS: Yes, sir. That is correct.

DR. MC CARTHY: It should be clear that on each rosette the strain gages are perpendicular, and one at 45 degrees, that's what a rosette does, gives you its two principal strains and the sheer axis, 45 degree to it. It's not 24 all reading in parallel.

JUDGE BRENNER: Yes, thank you. Mr. Dynner. We can break for lunch now or you can ask one or two more questions.

(Whereupon, at 12:00 p.m., the hearing was recessed, to reconvene at 1:30 p.m. this same day.)

AFTERNOON SESSION

JUDGE BRENNER: Good afternoon. We're back on the record. Mr. Dynner, you may proceed.

MR. ELLIS: May I raise one preliminary matter very briefly. When we discussed early on the order of proceeding and the Board asked us to reach an accommodation. The accommodation that we ultimately reached was to proceed further with pistons and then to go to crankshafts. The importance being the availability of Dr. Pischinger, central role in the crankshafts. It was my understanding, I might be mistaken, that the focus would be on Dr. Pischinger in the cross-examination initially and it looked like it was going on for some period of time that we might have to switch to crankshafts.

We are a bit concerned that at the rate of progress -- I'm not suggesting that the rate of progress should be any different. I'm just saying it's different from what I expected, and I don't mean that as a criticism of Mr. Dynner or of anybody. He cross-examined as he sees fit. But we would certainly like to suggest that we be prepared to go to crankshafts on which I think the parties have desired to cross-examine rather than more extensively than on pistons. We would prefer to go to that tomorrow and if we did not finish -- if we did not finish crankshafts by the end of the following week or if we did and we weren't able to get back to pistons, then we would lose Dr. Pischinger -- we would think that it's acceptable for us that Dr. Pischinger not be available for the remainder of the pistons. But it is not acceptable to us that he not be available for complete examination and, therefore, we think that starting tomorrow gives us the margin of safety and we do think we need to be conservative throughout this proceeding, given the margin of safety we need in order to finish crankshaft, given all the parties that want to cross-examine, and more questions as well.

JUDGE BRENNER: In general what you stated is correct, but on some of the specifics it is not quite correct only to the sense that it was not addressed. We did not say that the County would have to ask Dr. Pischinger the questions that would be asked of him first. We asked them to try to focus on him earlier, both on this subject and also on crankshafts, but you can recognize -- in advance you might recognize why that might not be possible and now that we see it here at the hearing it just reinforces my view it's not possible.

His testimony interweaves the whole area, number one, or a large part of the area number one. Number two, you've got a situation where he's been asked questions and now if you want to suggest that we change subject and he might not be back on the subject, you've got a problem because we may have a follow-up question on items that Dr. Pischinger has supplied testimony on. Although I've interrupted from time to time with some questions, by no means has that been the Board's questions on the subjects as they've come up. We've got questions that, I believe we have questions, I believe, already, I suspect, although I'll check more thoroughly that Board members other than myself may very well have questions of Dr. Pischinger. Also, and we're not going to allow his testimony to stand part way if we don't get the opportunity to ask him our questions.

The Staff also may have questions of Dr. Pischinger, for all I know. That's the problem, we need to try to ask witnesses and I told you what that problem might be. We're certainly going to get to crankshafts by the beginning of next week even if we haven't finished pistons first and I believe that

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we will finish pistons this week. But I'll have to think about your suggestion of changing subjects and going to crankshafts tomorrow because I certainly didn't have that intention.

MR. ELLIS:: All right, Judge. Let me -- I would suggest that if we're thinking about crankshafts for the four day period, Monday through Thursday of next week, I think based on my experience, I'm beginning to sound like a witness here, based on my extensive experience in these hearings --

JUDGE BRENNER: You have experience in the manufacturing of hearings.

MR. ELLIS: Design and manufacture and repair, maintenance and all the rest, and it's my opinion with a reasonable degree of legal certainty that you won't finish in those four days. And because that subject is --

JUDGE BRENNER: Fine. What's your solution given the problem?.

MR. ELLIS: My solution is to go to crankshafts tomorrow and pick up with pistons at the end.

JUDGE BRENNER: What do we do with Dr. Pischinger's testimony here on the pistons? I'm not going to allow his testimony to stand if we've got areas that were not questioned.

MR. ELLIS: : Then I would suggest we finish with Dr. Pischinger on pistons today.

JUDGE BRENNER: And what particular area would be Dr. Pischinger's area on pistons in your view?

MR. ELLIS: Other than the material that he's testified to, he has specific questions in the testimony and it's a relatively small number on which he is listed as a person, and I think this is -- I mean --

JUDGE BRENNER: Let me stop you there. I don't have a cross reference. Maybe I should have developed that, but I did not. In other words I don't have a reference by name to which questions there are; presumably you have such a reference.

MR. ELLIS: : Yes, I do. Side thrust load and tin plating. Roman V and Roman VI of our testimony.

JUDGE BRENNER: He's supplied a lot of testimony already on the oral testimony on the other subject, that is, the FaAA report conclusion that cracks may occur but will not propagate.

MR. ELLIS: : Yes, sir. That's because

he's been deeply involved and he agrees and he's an expert in pistons and diesels. In fact that's why we retained him because he's the best we could find in the world.

JUDGE BRENNER: You'd better find some inducement to keep him here then because -- I'm serious, because you told me that he would answer questions in the area you want to focus him on would be B and C, of the sub part of the text on piston, 4 B and C and he's answered a lot of questions on 4 A, some of it voluntarily.

MR. ELLIS: : And some in response to cross-examination.

JUDGE BRENNER: Part of it's been -- the door has been opened by the voluntary answer and the cross was followed up.

MR. ELLIS: Well, I still --

JUDGE BRENNER: That doesn't matter. Be that as it may, we've got testimony on the record from him which has not been followed up. I infer you're willing to waive your redirect.

MR. ELLIS: That's correct.

JUDGE BRENNER: I have to think what our Board questions might be and I don't know about Staff questions.

MR. ELLIS: I think --

MR. GODDARD: I can answer that, Judge Brenner, the Staff has no questions for Dr. Pischinger based on what he's testified to so far. We do have questions in the tin and possibly on the excess of side thrust area.

JUDGE BRENNER: I don't think we'd finish that this afternoon, anyway, in terms of all the parties asking questions on it.

MR. ELLIS: At the least, I would hope we could defer on our direct examination -- redirect examination.

JUDGE BRENNER: Then you get fouled up to the questions you may ask on redirect which overlapped into the area of a missing witness sometimes. I've seen this problem when we've tried to do it; in other words, I don't mean I don't mind trying to divide it up but if you try to divide it up too finely, that is, define that his sub area within an area is just A or B that's going to run into a problem.

For starters, Mr. Dynner, can you start on the area of B and C on part 4 of the contention and ask your questions on those, that is tin plating and side thrust load, and then we'll have the other

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parties ask their follow-up questions or their own questions on those subjects.

In the meantime, the Board on its own will be able to think of about -- these problems raised and what our own interests might be.

In that way, we can endeavor to see what happens and we'll try to let you know at the end of the day today, I guess, what the situation is.

I recognize you're in a difficult situation, Mr. Ellis, and I certainly don't mean to belittle the dilemma, but there are competing interests. We said that on the beginning of the conference call, that's why you cannot drop witnesses in and out of hearings. I understand it's not your desire to do that but you do that, circumstantial problems in that regard, and we have not yet gone into your justifying why it is he can't be available beyond those two weeks and I have to push that, but if we have to, that, too, may become pertinent.

MR. ELLIS: I agree, Judge.

MR. DYNNER: I'd like to -- this is the -- the first I heard of it is when we got back and I spent part of the lunch hour trying to refine my cross plan and eliminate some stuff. I would like,

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if we're going to jump to a totally different part, then I am preparing to have some time to at least review my cross plan and the questions I'm going to ask on the side thrust, the tin plating questions.

JUDGE BRENNER: How much more did you have on the A? We'll let you continue on that.

That's a valid point, Mr. Dynner.

MR. DYNNER: You know the difficulty we've had in predictions, I had sharpened down so that I was -- if you look at the cross plan for a second --

JUDGE BRENNER: Sometimes we spend more time talking about how much time it's going to take but --

MR. DYNNER: I'm just trying to give you the answer on the question. I've eliminated on part of page 4, all of page 5, almost all of page six, part of page 7 and was going to go into the area that begins in G quite quickly and explore that area which -- with some degree of who knows how deep I'm going to get into it. It depends on the answers that I get.

Old story. But then I was going into H on page 12

JUDGE BRENNER: G runs seven through 12.

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MR. DYNNER: Right.

JUDGE BRENNER: And then H.

MR. DYNNER: That's what I was planning to do.

If I'm going to switch around now and have to start an page 14, I would like to have 20 minutes or so at least to try to review what I'm going to do.

MR. ELLIS: Judge, we appreciate that consideration and we understand the difficulties that Mr. Dynner has, but we appreciate the Board's consideration and we sympathize with Mr. Dynner. I wish that the constraints did not put us in the position of making this request.

JUDGE BRENNER: We can't run late today. I'll tell you that right now, in case anybody was considering that.

I'm trying to guess how long it would take Mr. Dynner if we took the time to let him prepare and then start with page 14, and I don't think he'd be able to do it fast enough so that the other parties would have an opportunity to complete all the follow-up rounds, including follow-up questions by the County, the Board questions and staff questions and redirect this afternoon either.

so I don't think we'd finish that either. There's a chance, but hopefully optimistic.

I think it would take you about an hour and a half to go from I to the end, wouldn't it, Mr. Dynner? Well, I don't have an experience that -- the excess experience that my colleague, Mr. Ellis, has and, therefore, I don't really know the answer to that question. I don't know how long it's going to take. I mean we've had -- sometimes we get an answer from one witness that's short, sometimes we get an answer from seven witnesses that's long, so --

JUDGE BRENNER: And when you get short, even if you get short answers it's going to take about an hour and a half, and that's optimistic in terms of being on the lower end of the time scale. In my opinion so that won't solve the problem either, I don't believe. It would help because then you could always start crankshafts this week if we solved your other problem of what to do with Dr. Pischinger's testimony on the record heretofore on the other subject. I'm reluctant to take 20 minutes of the hearing now and find out it was for naught.

MR. ELLIS: I think that's right, Judge. I think the best thing to do is just go ahead and let's get as much done as we possibly can and

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reassess things at the end of the day.

JUDGE BRENNER: I'd be willing to consider skipping subjects a little if you find that Dr. Pischinger can't be here the week after next. If you want to talk about coming back after to that subject in the near future week, not a particular week, but from a time frame forward for that.

MR. ELLIS: Yes, sir. Well, I will discuss that with Dr. Pischinger.

JUDGE BRENNER: I think you'd better, okay. All right, Mr. Dynner. You may proceed as you had planned to.

BY MR. DYNNER:

Q. Page 7.

Gentlemen, I'm going to ask you to please refer to page 43 of your testimony and Exhibit P-23 of LILCO exhibits.

Gentlemen, as I understand, FaAA has concluded that cracks might initiate in the AE skirts under certain conditions such as under isothermal conditions with a 11 mil gap in the piston of relative low yield strength.

Now, looking for a moment at Exhibit P-23, would you identify which of the blocks nere, as I read it, at 11 in the right-hand part, where it says

11, and then next to an open square isothermal and then next to the block square, it's blacked out, it's an 11 steady state, does that refer to the .11 mil gap?

DR. HARRIS: Yes, Mr. Dynner, that's correct.

Q. And this crack initiation as shown by this document exists where you have the gap shown to the right of the solid diagonal on the left-hand side of the chart or to the left of that diagram? The diagonal I'm referring to says M I N sigma YS.

DR. HARRIS: In this particular exhibit, if the dot falls to the left of the diagonal line on the left hand portion of the figure, the cracks are predicted. Then cracks are predicted to initiate.

Q. So that would you explain why there are two open squares showing 11 mil gaps, one to the left of the sigma YS minimum line and one to the -- inside that line

DR. HARRIS: As shown at the top of page 4-3 of what I have been referring to as the thermal distortion report. And I'm not aware of whether this report has been entered as an exhibit. Let me give you the Failure Analysis Associates' report number, it's FaAA-84-5-18 dated June 1984, and I'm

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sure that the County has been supplied with a copy of this reference.

At the top of page 4-3, it states in the second sentence: "Two results are shown for each set of conditions corresponding to the minimum and the maximum values from table 4-1." I'd like to amplify that to say the two results shown correspond to the two results for each case that Mr. Dynner identified in his question. The two results are shown corresponding to the two sets maximum and minimum conditions from table 4-1.

Turn to table 4-1 of the same report which is on page 4-6, the minimum and maximum results referred to different sets of skirt stiffnesses that were estimated from the experimental results.

If you look at table 4-1, there's two sets of results, one for an AE, one for an AE piston skirt. Concentrating on the results for the AE piston skirt, there are four columns. One for stiffness is based on the finite element calculations. And three others, based on nominal. minimum and maximum stiffnesses estimated from experimental observations derived from the strain gage measurements.

I would like to point out that the two sets of -- two sets of results for each condition are very close to one another and serve to show the range of results that were obtained, both from the stiffnesses from the finite element results and the stiffnesses from the experimental observations.

In most instances the conclusions to be drawn from each of these sets are not altered by whichever set you use.

In the particular case that Mr. Dynner identified where we have the open squares, the conclusion regarding crack initiation could be changed if you were in a skirt with the minimum yield strength.

Dr. Swanger just pointed out to me in LILCO Exhibit P-17 much of the same type of information is presented, only for the AE.

In the particular instance of the two sets of results that you pointed out, you could come to a different conclusion regarding whether or not cracks would initiate; however, even the more favorable result is so close to the minimum yield strength line that any prudent engineer would check further to see whether or not cracks would propagate if they did happen to initiate, and they did go on to analyze the analysis of the possibility of propagation cracks in the AE skirt. And the conclusion from those results are that cracks will not propagate in the skirt even if they were to initiate.

Q. I'm just going to continue for a few questions just so I can try to understand this document at Exhibit 23.

As I understand your testimony, there were two factors. One is the size of the gap, and the other is the yield strength of the material which could influence whether or not the cracks might initiate; is that correct?

DR. HARRIS: A third factor is whether or not you are under isothermal conditions or steady state conditions.

Q. Fine. I'm going to get to that in minute.

Now, looking at this document again, where would one be able to identify the yield strength of the material?

DR. HARRIS: The yield strength of --

If you look down on the horizontal, if you look down on the horizontal axis in Exhibit P-23, the yield strength of the material is the intercept of the line with that horizontal axis.

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From there you could identify the yield
strength that was used in the drawing of this
exnibit.

Q. So this was a yield strength of what,
approximately 30 to 32 or something like that?

DR. HARRIS: Perhaps you misunderstood
my statement.

Q. All right.

DR. HARRIS: Because I read more like 62
to 65.

Q. I'm sorry. I see what you mean. The
base line in effect is the yield strength.

DR. HARRIS: On the horizontal axis, the
point at which the diagonal line intersects
corresponds to the yield strength.

Perhaps Exhibit P-21 would be a clearer
representation of the procedures that you go through
to draw this modified Goodman diagram.

You can see on Exhibit P-21 that where
you can see two sigma sub YS, that's the yield
strength of the material.

There's also on the vertical axis another
sigma YS so the yield strength figures prominently
in the drawing of this modified diagram.

Q. Are these two squares which are hollow which represent the 11 mil gap isothermal and one is shown as, I think you said, predicted to initiate a crack and the other is not, which of those represents the skirt stiffness ascertained from the finite element analysis and which represents the skirt stiffness ascertained from the experimental data?

DR. HARRIS: Neither of those represent the results drawn from the finite element analysis. Both of them use the stiffnesses determined by use of the strain gage observations, and the minimum and maximum bracket, the results obtained from the finite element evaluation of the stiffnesses.

This could be seen by turning to Exhibit P-17 and looking at the cyclic stresses under isothermal and steady state conditions on this figure. There are some intermediate -- very elementary intermediate calculations in going from the results on Exhibit P-17 to those on Exhibit P-23, but if you -- as an example, and I'll give you one example, not give you all of them, in order to expedite matters here, if you look at the -- in Exhibit P-17, there's a -- over on the column to the left, coming down towards the middle there's a row that's labeled sigma isothermal.

And you go over two more columns and look at the row that has an 11 by it, that's the G sub zero which is at the head of that column, that's the gap of 11 mils. The minimum stress under isothermal conditions, and you can see that going to the two columns furthest to the right which is the minimum, the maximum that we are dicussing, there is a number minus 63.8 for minimum and maximum of minus 68.1.

Going over the fourth column in from the right, under the column labeled FE at the top, which is finite element, you can see sigma equals minus 66.7 which falls between the minimum/maximum values that I discussed a moment ago.

DR. SWANGER: Just as a point of clarification, Dr. Harris has been using the term sigma minimum for minimum stress. He's referring to the algebraic smaller stress. These are all negative stresses but in truth they are the stresses which have the maximum absolute value, so these are indeed the highest absolute value stresses, the ones that contribute to fatigue cracking.

DR. HARRIS: A comparison of the finite element sigma and the corresponding values estimated by use of the stiffness from the experimental observations, you can see that the finite element result falls midway between the two extremes estimated from the experimental stiffnesses; therefore, if you were to plot the finite element result on Exhibit P-23, it would fall somewhere between the two open squares.

This serves to show that the mean and cyclic stresses that we estimate using these various sets of stiffnesses are very close to one another, and, therefore, the substance of the conclusions would not change if you were to use different sets of the stiffnesses. No matter which stiffness you use, you're going to conclude that cracks may initiate but will not propagate in the AE piston skirt under either steady state or isothermal conditions.

Q. If you had, reading this chart further, is it correct to say that generally that if the gap was in excess of .11 mils isothermal you could expect initiation of the crack and if -- in other words, the smaller the gap the less likely it is for a crack to initiate, the larger the gap, .11 mils and up, the more likely it is for cracks to initiate?

MR. ELLIS: Objection. The question is compound so when the answer comes we won't know whether he was answering specifically to the mils or whether it is not generally part of the question.

JUDGE BRENNER: Break it up a little bit, please.

Q. Yes. Is it correct that for a gap of greater than 11 mils in an isothermal condition that cracks would be more likely to initiate than for a smaller gap?

DR. HARRIS: I would first like to point out the gaps in the piston skirts at the Shoreham Unit have been measured and there are none that exceed 11 mils.

Q. Well, that's not -- you've answered my question. I'll get to that in a minute.

DR. HARRIS: If the gap, hypothetically if the gap was larger than 11 mils under isothermal conditions a crack would be more likely to initiate, however the engines are not operated under isothermal conditions.

I would also like to point out that we have also -- we have done the crack propagation analysis for a gap that never closes, so that would be a gap much bigger than 11 mils and you still come to the conclusion the cracks may initiate but will not propagate in an AE piston skirt, so the bottom line --

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Q. We'll get to propagation. Right now I'm talking about initiation.

Can you explain for me for a moment why it is that under steady state conditions, according to this chart, there is one situation in which a gap of 7 mils is shown to be more likely or at least it's closer to the left towards the line for the minimum stress than the steady state 11 mil gap? You see where you have the blacked out square in one case to the right of the blacked out triangle?

DR. HARRIS: Yes, I see what you are pointing out, Mr. Dynner. And what is occurring in this case is that the placement of the dot on this graph, that is, the mean and cyclic stresses are more dependent on the estimates of the spring constants that you use when you're analyzing a piston under steady state conditions. This is shown by the fact that the two blackout squares which correspond to steady state conditions are further apart than the two open squares which correspond to the isothermal conditions.

This tells me that the differences in the extreme values of the estimated mean and cyclic stresses are further apart under steady state conditions than they are under the isothermal conditions.

And in this particular case, the estimates for the 11 and the -- the upper and lower bound estimates for an 11 mil gap at steady state conditions overlap the range of estimates for the 7 mils gap under steady state conditions. Nonetheless, the conclusion remains the same no matter which of these sets you use for the spring constants, especially under steady state conditions where you're further down into the Goodman diagram and much further away from the points at at which cracks could initiate.

Q. Dr. Harris, you made the point that measurements have been taken of the gaps; were those measurements taken for all of the pistons at Shoreham?

DR. HARRIS: I would prefer to let some of the LILCO personnel answer that, since they were involved directly in those measurements.

MR. SEAMAN: Mr. Dynner, to answer that question, we have records that show that the gaps were measured both when the pistons were initially assembled and also after the assembly, after the DRQR inspections when the pistons were disassembled all indicating the gaps were between 7 and 11 mils

DR. HARRIS: I am familiar enough with those measurements to know that they were taken at four different locations around the circumference of the piston skirt.

I can also state that the -- in the experimental work, the gaps were measured at at least four locations by myself personally, so the experimental work that we have is definitely with pistons that fall within the range of 7 to 11 mils other than the modified crown that I discussed this morning.

JUDGE BRENNER: Mr. Seaman, maybe I'm getting tired, but in your answer I didn't hear the fact one way or the other whether all the pistons were measured.

MR. SEAMAN: I'm sorry; I didn't say that. I meant to say all the pistons were measured at both times.

JUDGE BRENNER: You told me what all the measurements disclosed, but it's not necessarily the same but I've got to know. Thank you.

Q. Just to clarify your testimony, Mr. Seaman, at the bottom of Page 8 for a moment, this may assist some of my confusion and perhaps the Board's confusion, there were ten pistons that those gaps were measured as part of the DRQR program and they're the ones shown in Exhibit P-4; isn't that correct?

MR. SEAMAN: The ten pistons that were measured by the DRQR program correspond to the ten pistons that were disassembled as part of the DRQR inspection program.

Q. And that's the material data that's given in Exhibit P-4; correct? It's on page -- that is correct, right? Page 8 to 9 of your testimony.

MR. SEAMAN: Yes.

Q. And you testified that gap sizes were measured in AE piston skirts when they were installed in November of 1983. That's on page 80 of your testimony. And that data is not presented as exhibits to this testimony; is that true?

MR. SEAMAN: I believe that's correct, yes.

Q. And do you know whether any of the gaps measured in November of 1983 exceeded 11 mils?.

MR. SEAMAN: Yes.

As I've testified already, the gaps were measured in November, and none of them exceeded the seven to 11 mils criteria.

Q. Now, going back to page 43 for a moment, in your testimony you mentioned, Dr. Harris, that the smaller initial gap is beneficial and reduces the cyclic stress under isothermal conditions, but contributes to the possibility of momentary crown lift-off. And then you go on to say that the lift-off is not detrimental because it does not have an adverse influence on the operation of the AE piston skirt in Shoreham and does not increase the cyclic stress.

Now, that testimony conflicts with the statements on the pages 6-8 and 6-9 of the piston report which indicates that the momentary lift-off could increase stresses; isn't that true? Do you see at the bottom of page 6-8, Dr. Harris, where it talks about this may result in opening the gap at the inner ring under inertia loading at center of the exhaust stroke. Such lift-off would alter the load path of the stud loads which could increase sigma maximum substantially above the values used in this report which assume no lift-off.

Could you explain this apparent inconsistency?

MR. ELLIS: I object. I think the original question is is it inconsistent. He said its apparent inconsistency and he goes ahead to explain then the record suggests its apparent inconsistency.

JUDGE BRENNER: The cross-examiner is allowed some leeway to ask the questions his way, Mr. Ellis, and it's my belief that you can get the very same answer phrased the way Mr. Dynner phrased it or the way you phrased it. He's not asserting there's an inconsistency and then going on to a second question based on that my assumption which is my quarrel.

Rather, he's asking the witness to explain the apparent inconsistency so we should get his answer. If he had done the other thing I just described, then you have a valid complaint, but I think it's going to be the same answer either way. And now with your objection I'm sure it will be, but I want to -- just consider whether you need to object.

MR. ELLIS: I withdraw the objection.

JUDGE BRENNER: That doesn't matter. We're beyond that in discussing future purposes. I'm a little concerned about putting ideas and thoughts to the witness by being educated through objections from counsel. I'm not —

MR. ELLIS: I object to the first

question.

JUDGE BRENNER: I'm not implying that was your motivation but nevertheless I'm concerned as to that effect and do think about the concern on my part before you phrase your objection.

DR. HARRIS: There is no inconsistency, Mr. Dynner, and let me explain why, but before I get to that, let me finish what's on the -- the sentence that comes after the quote that you just provided. "Such effects," meaning lift-off, "Such effects are beyond the scope of the current report, which is the piston report, which considers only isothermal effects and are the topic of a future report." The future report being the thermal distortion report that I mentioned a short while ago, that is, report FaAA-84-5-18.

The cyclic stress is determined by two different numbers, the maximum stress and the minimum stress. So you're looking for the largest differences in stress during the stress cycle, during a combustion cycle of the engine. So there are two numbers that go into the determination of the cyclic stress. One of these is the maximum stress. One is the minimum stress.

The closing of the gap actually reduces

the cyclic stress and, therefore, improves conditions as far as crack initiation is concerned.

The statement in the piston report that Mr. Dynner just quoted says that lift-off could increase sigma max substantially above the values used in this report and, indeed, it does increase sigma max above the value, but simultaneously with this, the steady state operating conditions also have a big influence on sigma minimum. The cyclic stress is changed a lot. The maximum stresses change a bit, and the net result is that you -- when you reduce the cyclic stress you're improving conditions from a fatigue crack initiation standpoint. In spite of the fact that the maximum stress can be increased due to the lift-off under steady state operating conditions.

I can certainly see the source of your confusion in this, Mr. Dynner. Hopefully, this explanation will help to clarify matters.

JUDGE BRENNER: That last part wasn't necessary, Dr. Harris. You stated the facts. I am sure you said it to be courteous, but it wasn't necessary.

BY MR. DYNNER:

Q. Gentlemen, I'm going to proceed now on to page 44 of your testimony.

If the crack that your finite element analysis under certain conditions exists were to initiate, how large is the crack that initiates?

DR. HARRIS: In order to draw the conclusion that we do from the fracture mechanics analysis it is not necessary precisely to define the size of the initiated crack because the fracture analysis shows that cracks — hypothesized cracks up to one half inch in depth are not going to propagate; therefore, the initiated size is really not a necessary input to our analysis as long as it's less than half of an inch.

Q. That's after the fact, isn't it, Dr. Harris, that's after you've done the fracture mechanics analysis for propagation?

I'm asking you, you've predicted from your finite element analysis that you may have a crack initiation. My question is how big would the crack be that initiates.

DR. HARRIS: As I said, it's not necessary to precisely define that in order to perform the fracture mechanics analysis to see whether or not the crack will grow.

A standard estimate of the size of initiated cracks is about ten mils, but I would like to emphasize that that's not a critical input not fracture mechanics nor the crack initiation analysis nor to any part of our analysis.

DR. MC CARTHY: And also it should be remembered that ten mils begins to correspond to the sort of size that people can find and, therefore, has acquired some currency as an initiated crack, but I would defer to Dr. Johnson on this, but my knowledge there is no stated definition at what size of crack it's initiated. As long as you find it's initiated below ten mils it gets more difficult to find even.

Q. In my problem in understanding this, when you state that a crack won't initiate and won't propagate, how do you know it didn't initiate at five mils and propagate to 15 mils and then you've discovered it?

DR. MC CARTHY: There are very few mechanisms that I'm aware of besides just plain rupture and overload which will bring a crack into existence at five mils. I mean most all fatigue theory depends at least some sort on the supposition and there's nothing -- there is not to my knowledge across the board agreement on exactly the -- the mechanisms of initiation but basically a crack will start growing and at some time it's below one mil and it grows to two mils and three mils and so on down the line. It always starts at something smaller than, you know, besides overload, something smaller than that. Fracture mechanics is the science that's concerned with a crack, by whatever reason it comes about is it going to go anywhere, and really what fracture mechanics is determined in bounding what kind of flaw, what kind of crack won't grow anywhere. Indeed on the AF pistons, those cracks did start, they grew and arrested, and that's the normal situation for a crack arrest. A crack will occur in driving mechanism such as a localized high stress, grow into a region of low stress and stop.

Q. What confuses me, Dr. McCarthy, is that I've heard a number of times, numerous times in the last two days in addition to your -- in your answers in addition to your testimony that a crack might initiate but won't propagate. Now it seems to m[illegible] you're saying it will propagate. It mi[illegible] one mil to five mils but then it will a[illegible] that what you meant by a crack will prop[illegible]

DR. MC CARTHY: No. Not precisely.

Assume any size crack, okay, or flaw, or crack-like flaw which is what everybody really

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6″

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

worries about. If it is below a half inch, it doesn't go anywhere. It does not grow.

Q. How does it get to a half inch?

DR. MC CARTHY: We don't -- like I told you yesterday my personal belief is you won't ever see cracks in these pistons.

Q. You predicted a crack might initiate; I'm just trying to take that as the assumption, and I know you testified many, many times that you really don't think that you're going to have any initiating in your own personal opinion although your report says that it might.

What I'm trying to get at is -- it's not to go somewhere to be seen, to be discovered. You yourself just said, it doesn't start suddenly at ten mil, 15 mil, you start at one and goes to two and goes to three.

I would like an explanation for how the crack gets from one to three mils without propagating.

DR. MC CARTHY: This is an interesting philosophical question for engineers and has been for quite some time. When does a crack come into existence. Basically what our conclusions are for the AE is that a crack or flaw-like imperfection will not propagate if it is below a half inch.

Now, this flaw could be a simultaneous gas coalescence of a few angstroms long, it could be a dislocation coalescence that would be barely measurable. Assume for a moment, contrary to what we find, that there was a small surface imperfection of a kind below the size that we were able to detect that is below a 32nd of an inch. Regardless of what type of hypothetical flaw you put in a stud boss area of the AE piston, it will not propagate.

We are not postulating that a small crack originates, grows to some finite size and stops. That is what happened in the AF piston. That is not what would postulate for the AE piston. Choose your postulated flaw. If it's below a half inch in size in the AE piston, it goes nowhere. It grows not.

Now, what kind of a small crack-like feature one wants to call an initiated crack, you can come up with a number of postulations. Suffice it to say, whatever you postulate, and regardless of how it springs into existence, if it's below a half inch, it's going nowhere.

Q. Dr. McCarthy, I don't want to talk about flaws in casting now. I want to talk about the crack that you predict could initiate given a particular gap size and a particular material. On that chart that we just looked at at Exhibit 32 -- or 23, I'm very sorry, P-23, in P-23 in your analysis of crack initiation doesn't presume the existence of any flaws, casting flaws or sand inclusions or anything like that; does it?

MR. ELLIS: I want to object to the first part of his characterization because I don't think it was correct. I don't have an objection to the final question. I just don't -- I do have an objection to the speech that he made on the first part.

JUDGE BRENNER: Sorry. I don't know which first part you're objecting to. The fact that he doesn't want to talk about flaws on the casting or the middle part after that?

MR. ELLIS: Yes. And the flaws that he characterized, what Dr. McCarthy predicted. I thought his previous answer was perfectly clear on the subject, but I'm not going to object to the final part of the question.

JUDGE BRENNER: All right. you're going to answer just the final part.

DR. MC CARTHY: What we mean by saying crack initiation, let's say that there is a field present that can drive a crack.

If there is, and it meets the criteria of the Goodman diagram, the crack will originate itself or has a possibility of initiating itself, if there's a field to drive it.

If you don't have a field to drive it, it may never grow. In fact it's postulated not to grow at all, so they will not be detected.

However, in the analysis of fatigue, there are two very different phases in a crack's life. There is initiation and propagation, initiation being usually the longer of the two but not always. The initiation criteria has to be viewed as something that will mean a crack will ultimately become detectable only if there's some cyclic stress field of enough intensity to drive the micro-initiated crack.

Q. By the field to drive the crack, are you suggesting the proper situation in which the crack can spring to life and grow to a size where it can be detected?

DR. HARRIS: Mr. Dynner, as Dr. McCarthy mentioned, the size of an inititated crack is an area under active discussion amongst engineers and borders in many ways upon philosophy. I think the important point which I've tried to make and I'll try again is that -- and this is also another example of the conservativism that we have built into our analysis. Let's say a crack initiates -- I'll be conservative and I'll say --

JUDGE BRENNER: Doctor, if I can interrupt, and forgive me if you're on this point, but if you are I'll say it, I think the question is what did Dr. McCarthy mean by the term field to drive crack, if we can get an answer to that, and if that's not what Mr. Dynner wants, we'll let him --

DR. HARRIS: I'm sorry, that was not the tack which I was upon.

JUDGE BRENNER: Let's try, and Mr. Dynner can correct me by asking the question.

DR. McCARTHY: There has to be the whole science of analyzing fracture and crack growth. As we know there are stress conditions which even though they're cyclic --

DR. MC CARTHY: We think from analysis of cracks and crack growth that there are variations in stress both in its mean level and cyclic variation that are sufficient to drive the fatigue cracks and other mean levels and cyclic variations which are insufficient to drive T cracks. You must have one of these variable drivers, if you will, sufficient mean stress and sufficient cyclic variations to drive an initiated crack, avoiding for a moment how small of a measure we want to use for initiation to some size where it would be visible or what we term measurable, I guess. You have to have that driving field for this to occur; and this field in this piston is not favorable for that driving.

Q. But you predicted it was favorable under certain conditions; right?

DR. MC CARTHY: No. No. Only that if you had a favorable driving field, the stresses are at a sufficient level to cause initiation or close to the borderline to cause initiation.

The whole reason that we have been saying again and again that the crack has to be at least a half inch in size is that unless it's that large the field is not favorable for crack growth.

DR. HARRIS: I think there might be some confusion as to the definition of favorable for crack growth. I believe Dr. McCarthy is saying that if it's favorable for crack growth, then the crack will grow. Such a field is certainly not favorable from the integrity standpoint of the piston, because it's not favorable to have a crack

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growing in your piston.

JUDGE BRENNER: That much I understood. We've got it on the record anyway.

DR. MC CARTHY: No one is suggesting, myself included, that we want a field to grow a crack, but you have to have a certain, what I'll use instead of favorable strength, loading field in the mean stress levels are of insufficient strength in the stud boss level to drive any crack unless it's bigger than a half an inch.

Q. Dr. Harris and Dr. McCarthy, on page 44 in the response to question 69, you refer to the use of engineering fracture mechanics in modern design and analysis in structures such as aircraft, space craft, pipelines and turbines, et cetera.

You mean to suggest that fracture mechanics are used in the design of these various structures in order to insure that, if there are defects or crack-like indications, that they won't propagate to dangerous levels.

DR. MC CARTHY: In a nutshell, yes. A lot of the work we do at Failure Analysis is just making those analyses for people of critical flaw size and what kind of a critical flaw can exist in your structure and I guess I should say to correct that, not just -- there are two things that you can do.

One is a critical flaw size to know your structure will not fail on overload.

And there's a second question. Does a critical flaw size determine how much you have to go back and look at your structure. Because not only do we deal with the analysis of when a crack will initiate, but indeed how fast it will propagate and at what size will it begin to affect the critical nature of your structure. And, in effect, the engine, the aircraft engine problem here referenced there, was that was not an a assumption of flaw size problem as much as a problem to anaylyze the rate at which cracks could grow in this field and how often such parts have to be inspected so that you can catch any growing crack at the appropriate time. You didn't have to postulate an initial flaw. These are expensive parts that are extensively inspected but come out with no real measurable flaws but, in fact, operate in the initiation range and, in fact, a crack would initiate and grow. And this was to establish their inspection interval.

DR. SWANGER: I might put this into the context of AE pistons at Shoreham and that is that our analysis says that no cracks are possible to propagate in these pistons; therefore, they do not need any reinspection. An initial inspection upon manufacture is sufficient to show that there are no cracks, and we have demonstrated through fracture mechanics that no further operational inspections are required.

Q. Was fracture mechanics used in the design of the AE piston skirt by DeLaval?

DR. MC CARTHY: It was used in our design analysis. We cannot speak for TDI's procedure.

Q. On the design analysis --

DR. MC CARTHY: It was used in our design analysis.

Q. My question is, was it used by DeLaval in designing the AE piston skirt?

MR. ELLIS objection. Asked and answered.

JUDGE BRENNER: The objection is sustained.

Q. Is your fracture mechanics analysis of the crack propagation in the AE piston one hundred percent accurate?

DR. HARRIS: Based on my 20 years of experience in the application of fracture mechanics engineering problems, I can confidently state that the fracture mechanics analysis that we have performed and the conclusions that we have drawn from it are as accurate as any engineering design tool that's being used.

Q. What I'm getting at, Dr. Harris, is there a margin for error that's assumed in these things? You say -- before, for example, you gave an answer that something was accurate plus or minus five percent.

Do you have some kind of sensitivity envelope where you say that this is 80 percent accurate or a hundred percent or 90 percent sure or there's a 10 percent margin for error?

Dr. Swanger, are you an expert in fracture mechanics also? The testimony is of Dr. Harris and Dr. McCarthy. I'd like to get their response to the question and then you can confer with them afterwards, if you don't mind.

DR. HARRIS: Could I please have the question repeated.

Q. I'll rephrase it.

In making your prediction in your fracture mechanics analysis, is there taken into consideration some margin for error? Do you assume that it's one hundred percent accurate or is it 90 percent accurate? Have you taken any sensitivity into consideration as to the accuracy of your analysis?

DR. HARRIS: We have certainly allowed for a margin of error in our analysis. It's very difficult to put the percentage number on it.

Invariably, we have selected conservative values of important input variables to the problem.

In cases where we did not have precise measurements other than strain gage measurements in most instances, we made conservative estimates of the important input parameters and used these conservative estimates of the input parameters in our analysis of the possibility of crack propagation in the AE pistons skirt. And even taking any of these conservative values, putting them into the analysis we still invariably conclude that cracks will not grow in the AE piston skirt. However, to quantify the degree, percentage of confidence that we have in our results, it's very difficult to actually quantify that, but I would say -- I am at least 95 percent confident that cracks will not grow in the stud boss region of the AE skirts as they will be operated in the engines at Shoreham.

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DR. MC CARTHY: If I could just add to the last answer, as a result of the operating experience that I alluded to previously when this problem came up before and the successful running of the ten pistons for a hundred hours, statistically the confidence and degree of comfort we have with conclusions that there will not be any crack growth in the AE pistons is extremely high. Once again, I don't know how to put a number on it, but certainly in excess of 95, certainly in excess of 99 percent confident. It's just a matter of such a small probability, it really is tough to put a number on it but we are extremely confident of our predictions in this regard.

DR. HARRIS: The predictions are not border line, as is brought out by a number of exhibits in the testimony. Perhaps to point out to the most compelling one, the exhibit, I believe, 34, where we have --

MR. DYNNER: I haven't asked a question, Judge Brenner. I'm getting all kind of -- the answer to the question, there was a five minute gap, not 11 mil gap and I think getting some he elaboration here that I think may be in the direct testimony and it certainly is not responsive to my question which was answered.

JUDGE BRENNER: Let's get the answers in off at this point and if there's something you want to get in, check with your counsel. Let's go off the record.

I want to go off the record. We'll take a break until 3:05 to go off the record.

(Afternoon recess)

BY MR. DYNNER:

Q. We're on page nine of the cross plan, Judge Brenner.

Dr. Harris, was the fracture mechanics analysis, if it was done on the AE piston made according to the same methodology as the fracture mechanics analysis that you performed on the AF piston skirt?

DR. HARRIS: Yes, Mr. Dynner. The underlying procedures involved were very similar, if not identical between the AE and the AF piston skirt.

Q. Well, for instance, on page 6-8 of the piston report, it's true, isn't it, that you've given an explanation of the fatigue crack growth analysis that you performed on the AF piston skirt, and then you have a sentence in the first full paragraph of page 6-8 that says corresponding fracture mechanics calculations for the AE piston skirt reveals that no crack depths provide Delta K and R values that exceed threshold conditions. By the use of the word corresponding calculations, does that indicate that whatever differences there were in the methodology were not significant?

DR. HARRIS: The methodologies employed on the two different types of skirts were the same.

Q. All right.

Now, do you have the same degree of confidence in the fracture mechanics analysis conclusions on the AF skirt that you just testified to with respect to your conclusions on the AE skirt, Dr. Harris?

DR. HARRIS: Yes, I do.

Q. All right. And it is true, isn't it, Dr. Harris, that when you look on Page 8-1 of the piston report, it concludes in the last, but under paragraph one that in no case are cracks predicted to propagate to a depth of more than 0.150 inch, and that's talking about the AF skirt; isn't it?

DR. HARRIS: That is, indeed, referring to the AF skirt, and it refers to the results of the analysis that was performed using the isothermal techniques that are reported in the report to which you just referred.

Q. Yes, but, in fact, notwithstanding that prediction, Dr. Harris, it's true, isn't it that, that the isothermal is — you've testified before -- you said before it was done according at the isothermal — well, what did you just say about isothermal?

DR. HARRIS: What did I just say about isothermals.

(The last answer is read back)

Q. In the isothermal techniques are conservative in your view, is that correct?

DR. HARRIS: The isothermal stresses are conservative from a fracture -- from a crack initiation standpoint.

Q. But they're not -- are they not conservative from a crack growth standpoint?

DR. HARRIS: They are not necessarily conservative from a crack growth standpoint. The reason for this is -- can be seen by comparing the crack growth analysis in the AF skirt that was performed under isothermal conditions or using the stresses developed for isothermal conditions in the piston report, comparing that to the results of the fracture mechanics calculations on the AF skirt under steady state operating conditions that are reported in the thermal distortion report, the FaAA 84-518.

The calculations on the AF skirt using the stresses determined under isothermal conditions predict that in no case will cracks deeper than .150 inches propagate in the AF skirt, whereas turning to the thermal distortion report, on table 4-2, page 4-7, there are additional calculations of crack propagation or the arrested depth of cracks that could propagate in the AF skirt, and it is seen that the arrested depth can be deeper than the .150 inches determined using the stresses under isothermal conditions.

Q. How deep would those be?

DR. HARRIS: The largest number that I see on table 4-2, page 4-7 of the thermal distortion report is .494 inches.

So indeed under the steady state operating conditions the sigma max is increased if lift-off occurs and it's the sigma -- and the sigma max has a noticeable influence on the crack propagation and the arrest depths.

Q. Dr. Harris, could you explain on page 46 of your testimony then where in answer 72 you testified that as temperature increases the fracture toughness increases. That's what that led me to believe, as I asked you in the question, that under higher temperatures if the fracture toughness increases then the likelihood of crack propagation would decrease.

Would you explain that for me?

Dr. Harris, maybe you could answer and then your colleagues would like to give their views.

DR. HARRIS: As stated on page 46, question 72 of our direct testimony, the fracture toughness is indeed a function of the temperature of the material. This is a characteristic of all ferrous alloys and really does not have any direct bearing on the difference in the arrested crack depths that I alluded to in the answer to the previous question.

Q. Well, is it your testimony that fracture toughness of the material does not have a bearing on the propagation of a crack in that same material or the crack growth rate?

DR. HARRIS: No, that is not my testimony, Mr. Dynner.

Q. Maybe you could explain it. I'm just not understanding you.

DR. HARRIS: The fracture toughness which is usually denoted as K sub IC is the value of the stress intensity factor which could be thought of as the crack driving force, is the value of driving force above which the crack can go unstable and result in a final failure.

At no time are any of the cracks in the AE skirt that are predicted to grow near instability. The K max, the maximum driving force to which the crack is subjected never is anywhere near the critical value of the crack driving force.

Therefore, the value of K IC of 40 ksi root inch really does not have direct influence on the depth of arrested cracks.

Q. Did you want to add something, Dr. Picschinger?

DR. PISCHINGER: In my understanding, it adds to the safety of this calculation.

DR. HARRIS: I believe what Dr. Pischinger is referring to is the fact that the maximum applied crack driving force is never anywhere near the critical value. It says that the crack never goes unstable and is just another example of the safety inherent in any possible crack propagation in the AE skirt.

JUDGE BRENNER: We're waiting for the next question, Mr. Dynner.

BY MR. DYNNER:

Q. Dr. Harris, turn for a moment to Exhibit P-25, which is referenced in your answer 76 on Page 49.

Dr. Harris, why did you assume in P-25 a seven mil gap rather than an 11 mil gap? You see in your testimony in question 76 you state that Exhibit P-25 shows the representative values of R and Delta K for various hypothesized crack depths for an AE piston skirt with a .007 inch gap operating under steady state temperature conditions.

DR. HARRIS: I would like to continue on with your quote. Next sentence reads: "This is the most severe condition from a crack propagation standpoint." By that I mean an 11 mil gap has a smaller maximum stress and is less severe. The cyclic stresses in an operating piston with an 11 mil gap are less severe from a crack propagation standpoint than those for a seven mil gap. So for illustration purposes, we took the worst result and included them in Exhibit P-25.

Q. Is the reverse true for crack initiation, that is, that an 11 mil gap is more likely to result in crack initiation than a 7 mil gap?

DR. HARRIS: yes, Mr. Dynner. That's correct. Once again, it's the difference between cyclic stresses and maxiumum stresses. All of these are important contributors to crack initiation and crack propagation.

Q. Is it correct that you conclude that the cyclic stress is the most important fact for crack propagation.

DR. HARRIS: No. It is not true that I conclude that. It's both -- it's the maximum stress-- the maximum stress, I believe, has the most important influence. The minimum stress is also important from the crack propagation standpoint.

Q. Which are cyclic?

DR. HARRIS: The maximum minus the minimum is the cyclic. To clarify matters, in some cases one half the maximum minus the minimum is the cyclic stress amplitude.

Q. Why is this seven mil gap the most severe condition for crack -- well, let me rephrase that question.

Does the fact that this is the most

severe condition for crack propagation have anything to do with the possibility of momentary lift off of the crown from the skirt?

DR. HARRIS: Yes, Mr. Dynner, it does.

Q. Is that the most important factor that makes the seven mil gap the most severe condition for crack propagation?

DR. HARRIS: Mr. Dynner, are we still talking about AF piston skirts or --

A. AE. We're talking about page 49, answer 76 of your testimony. That deals with the AE skirt; doesn't it?

DR. HARRIS: Yes, it does.

The P--25 also, of course, refers to the AE piston skirt.

JUDGE BRENNER: Why don't you repeat the question.

Q. Is the momentary lift-off of the crown in the operating AE piston with the seven mil gap the most important factor that makes this the most severe condition from a crack propagation standpoint?

DR. HARRIS: I would hesitate to say that it was the most important factor. I would say that it is an important factor.

Q. Could you briefly state what the other important factors are.

DR. HARRIS: The other important factors that influence lift-off of the crown from the skirt or --

Q. No. That makes your exhitit P-25 using a seven mil gap the most severe condition from a crack propagation standpoint.

DR. HARRIS: Under steady state operating conditions, the seven mil gap provides a greater propensity for lift-off than 11 mil gap. Once you do get lift-off you get increases in maximum stress and the more lift-off you get, the greater the crack propagation you will calculate. Therefore, the gap size itself is the most important factor in whether or not lift-off occurs. Everything else being equal, such as the thermal distortion of the crown.

DR. HARRIS: If I may proceed.

Q. Please do.

DR. HARRIS: The seven mil gap is very important factor controlling or contributing to lift-off. And the other factor is the thermal distortion and the amount of thermal distortion depends on whether you are at steady state conditions or isothermal conditions, but under steady state conditions, the gap is one of the most important factors influencing lift-off. Others are skirt stiffnesses, stud stiffnesses, spring stiffnesses of the stud washer span and so forth.

Q. Gentlemen, if you could turn for a moment to page 16 of your testimony.

Now, referring to a moment to your answer 20 -- I'm sorry, answer 19, and Exhibit P in Exhibit P-7, are the dimensions that were verified that you refer to in answer 19 the same as the sampling DROR dimensions which were made and referred to in Suffolk County's Exhibit 11.

MR. ELLIS: While they're looking may I have that question read back, please.

(The record is read)

MR. DYNNER: I'll refine the question a bit, make it perhaps more accurate or more easy to follow.

JUDGE BRENNER: Or shorter.

MR. DYNNER: Or shorter.

Q. It's true, isn't it, that the measurements which are shown in Exhibit P-7 for dimensions are, in fact, the measurements taken for the dimensional checks which are referred to on pages B-4 and B-5 of Suffolk County's Exhibit 11 which is the DRQR report on the pistons?

MR. ELLIS: Judge Brenner, there's an awful lot of data in P-7 and it seems to me that this is the kind of question that if we -- maybe we ought to give the witnesses an opportunity over the evening, if it's that important, maybe they can answer it without that, but it seems to me this is the kind of thing --

JUDGE BRENNER: I've got your point. Why don't you more precisely ask him what particular data you're interested in. There is a lot in P-7 indeed, especially since that's not going to be your ultimate point. You're just trying to make a foundation.

Q. The point is, were measurements taken of the dimensions of the AE piston skirts at Shoreham other than the dimensional checks on piston groove and ring height and the piston pin bore diameter in depths on the AE pistons reported in the DRQR report, pages B-4 and B-5 that I referenced you in the County's Exhibit 11.

DR. SWANGER: In addition to the dimensional checks that are shown in LILCO Exhibit P-7 and referenced in the County's Exhibit 11, additional dimensional verification checks were

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taken of the AE piston skirts which were installed in the Shoreham engines while they were still in the TDI plant in California.

These checks were taken by Stone and Webster under their procurement quality assurance program, and I believe Mr. Seaman can provide you with more details about the quality assurance aspects. Inspections of the key dimensions that Stone and Webster performed.

JUDGE BRENNER: Wait a minute. I'm confused. Wouldn't those be the AF pistons back then?

DR. SWANGER: No, these are the AE pistons.

JUDGE BRENNER: All right. You're talking about procurement involved in the AE piston.

DR. SWANGER: Yes, procurement of the AE pistons in October and November of 1983.

JUDGE BRENNER: I thought you said while the machines were still at DeLaval shop.

DR. SWANGER: If I might, while the AE pistons were still in DeLaval's shop.

JUDGE BRENNER: I misheard you. Go ahead.

MR. SEAMAN: As Dr. Swanger has mentioned, there were dimensional checks as well as liquid penetrant inspections of the stud boss area performed in the TDI shop. In addition to that there were normal inspections performed by LILCO, the startup organization in accordance with our repair/rework documents. For other dimensions that are important such as the piston crown gap, for example.

Q. Mr. Seaman, were measurements made of the dimensions of the boss area of the piston skirt to verify that they were in conformance with the drawings, if you know, Mr. Seaman, or anyone else that knows?

MR. YOUNGLING: Mr. Dynner, a whole series of measurements were taken of the piston skirts while they were still in Oakland, heights and diameters, as I remember. I don't remember whether that particular dimension was taken.

Q. Well, if it was taken, Mr. Youngling, would those measurements be documented in and maintained by LILCO?

MR. YOUNGLING: Yes. They would have been part of the documentation -- release documentation that Stone and Webster would have put in place prior to shipping the piston skirts.

Q. Do you know whether those measurements

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showed any deviations from the drawings?

JUDGE BRENNER: Wait a minute. He said he didn't know whether the measurements were taken. We're still talking about the measurements of the stud boss, correct?

MR. DYNNER: He said he didn't know whether those were taken. He said others were taken and I wanted to know whether the ones that were taken showed any deviation from the drawings. Sorry i' didn't make that clear.

MR. YOUNGLING: Since the pistons were shipped, the conclusion is that all dimensions were satisfactory.

Q. You say since they were shipped, would you define —

MR. YOUNGLING: Without, because the dimensions were satisfactory, the pistons were released for shipment and accepted.

DR. HARRIS: While we're on that subject of measurements of the piston skirt, I would like to point out that there were numerous measurements made on actual piston skirts that were supplied to Failure Analysis Associates in order to make measurements for construction of the finite element models and the piston that was supplied to Failure

Anaylsis Associates was from the same lot of pistons that was supplied by TDI to LILCO. Our finite element modelers including myself made extensive measurements off these pistons in order to have inputs for the computer finite element model. Such measurements, of course, are necessary in order to construct the models in an accurate fashion.

Q. In your experience, any of you, are there variations in the dimensions of the various AE piston skirts? When I say variations, I'm talking about from the piston skirt to piston skirt rather than the same area from piston skirt to piston skirt.

DR. SWANGER: Yes. As with any manufactured part, there are tolerances which are determined through engineering calculations, and the machining there is on the AE pistons will exhibit these machining tolerances in the order of a few thousandths of an inch but within the tolerances as specified by TDI and these will be the dimensions that were checked by Stone and Webster.

As for the highly stressed stud boss area that's an as cast surface of the AE skirt and as such is a metal replica of the pattern equipment that is used to produce the pistons. Since all of the AE pistons were made from the same pattern equipment in the highly stressed area they are all a replica of one pattern and thus are very close to the same.

The degree of uniformity between them is immaterial to the analysis that we made and immaterial to our conclusions.

Q. I'm going to now refer you to page 17, question 21. What vapors are present in the crank case?

DR. SWANGER: I'll begin by telling you my understanding, perhaps Professor Pischinger will be able to confirm it, but the major vapors that are present in the crank case of an operating diesel engine are from the blow by from the combustion process and that would be comprised primarily of nitrogen along with carbon dioxide and carbon monoxide, water vapor, some unburned hydrocarbons and some oxygen as well.

In addition, there would be vapors from the lighter fractions of the lubricating oil which would be in an assortment of short chain hydrocarbons, and some oxygen as well. In addition, there would be vapors from the lighter fractions of the lubricating oil which would be in an assortment of the short chain hydrocarbons, perhaps C3 through C7 or C8 hydrocarbons vapors present in the gas phase within the crank case, and perhaps Professor Pischinger will enlighten us more on this.

DR. PISCHINGER: I think the main components have been mentioned, but I should add that excess of these adhere to a metallic surface within the crank case is usually prevented by the oil which is sticking to the surface, also during the shutdown of the engine because of the adhesive properties of the oil particle, these surfaces stay oily and the diesel oil has to be basic, not acid, but basic and will protect the surface or parts of the surface of the crank case against any attack of -- if you think of this as opposed to asking in this direction, of any gases which, if they should be aggressive.

Q. Now, do any of those vapors that you refer to cause corrosion of nodular iron?

DR. SWANGER: The vapors did not cause corrosion of either AF or AE piston in the engines at Shoreham due to operation. Both the AFs and AEs have been inspected after operation with no signs of corrosion.

Q. That's not my question, Dr. Swanger. Please listen to my question. I said do any of the vapors that you mentioned cause corrosion of nodular iron.

MR. ELLIS: I object to the question because it's not relevant. The answer was right on point. We're not talking about any nodular iron. So it's immaterial to talk about it in the abstract.

JUDGE BRENNER: Give us an answer to the question and then we can have a follow-up or explanation on redirect. I'm not prepared to rule that it's immaterial just given the first question but usually given the answer to question 21 it may turn out to be the case but cross examiner is entitled to a little bit of leeway, but we certainly won't let something go for an hour or even ten minutes if it's not tied to something apparently relevant.

DR. SWANGER: It is possible that some of the gases, the water vapor, the oxygen and also one other that's present that I neglected to mention, sulfur dioxide could under certain conditions cause corrosion of nodular iron.

Q. Now, if the engine within a shutdown condition, Dr. Pischinger, would there be less oil in contact with the AE piston skirt than when the engine is running?

DR. PISCHINGER: Of course, there would be less oil than when the engine is running, but by experience, this less oil never will be non oil. You would need a process of — chemical process of oil removal to get a clean — really metallic clean surface which can be attacked.

Q. Dr. Pischinger, in your experience, have you ever seen corrosion in a piston skirt in an engine?

DR. PISCHINGER: Yes. In the case, if the lubrication oil is not changed according to the rules, so that it gets acid at the time of the accident, you can get corrosion in case of this together with very long stand still and water break in, but my experience is that with the usual oil treatment that means that you also — always have acid — a base number of the oil which is prescribed, which would be -- you can get no corrosion.

Q. If there's a crack on the inside of the piston skirt, would there be, in your experience, sufficient amount of oil that would adhere to the cracked surfaces to prevent any corrosion from any of these vapors that we talked about?

DR. PISCHINGER: Especially in cracks, oil accumulates and never goes out.

Q. And what did you mean when you said at very long stand still how long?

DR. PISCHINGER: I said this, I think, in connection with contaminated or -- what's the best word to indicate -- oil which has become acid -- acid.

Q. You've mentioned that sulfur dioxide might be one of the elements in the crank case, I think.

Mr. Youngling or whoever knows, do you know what the sulfur content is that's allowable in the EEGs, the fuel oil I'm speaking of --

MR. YOUNGLING: In fuel oil?

Q. Yes.

MR. YOUNGLING: Mr. Dynner, I'm referring to the TDI instruction manual in Section 8, Appendices -- of Appendix No. VIII, Fuel Oil Specifications, sulfur percent, maximum, 1.05.

I don't know the exact number that we're bringing in but I believe we're down probably around a quarter a percent. We're much better than the maximum specified.

Q. Can you please turn to Page 20. With respect to question 28, what is the basis for the testimony that FaAA did not consider peak firing pressure at overload because the engine operates a relatively small amount or time under overload conditions and, therefore, would have little effect on the initiation and growth of cracks.

DR. HARRIS: At the time the piston report was originally written, we had not considered pressures under overload conditions. We concentrated on conservatively estimated firing pressure for one hundred percent load. This is because the engine will spend the vast majority of its life at loads of a hundred percent or less, and in doing our fatigue analysis, we were interested in infinite life and, therefore, we concentrated on the firing pressure that's going to be there, conservative estimate of the firing pressure that's going to be present for the vast majority of the numbers of the cycles.

We have subsequently performed analyses at higher pressures. We've discussed these at least once previously in these hearings, and have considered pressures up to and including 2,200 psi and the conclusion regarding the crack -- the absence of crack propagation in the AF skirt is the same regardless of the pressure that was used up to pressures of 2,200.

Pardon, if I said AF. I meant to say AE.

All of my previous questions were in regard to AE skirts.

DR. SWANGER: Our consideration of peak firing pressures and its effect on the pistons also included the experience with the R5 test that you're running at 2,000 psi brake mean effective pressure for essentially ten to the seventh cycles and gives us additional confirmation that overloads, even though the magnitude which is unattainable at Shoreham of 2,000 psi brake mean effective -- or 2,000 psi peak firing pressure, if I said BMEP, I apologize, I mean to say peak firing pressure, have no effect on the initiation and propagation of cracks.

Q. When did you do the subsequent analysis that took you up to 2,200 psig that's referred to at the bottom of page 20 of your testimony?

DR. HARRIS: I believe those calculations were performed in early August.

In addition to those particular calculations we had over previous months dating back to almost the beginning of the piston analysis which was begun ten months ago, we had performed other fracture mechanics calculations using stresses -- using high stresses and were aware of the influence of high calculated stresses on crack propagation in both the AE and the AF, so we had performed analysis using higher stresses than we ended up reporting in the piston report, but the actual calculations that we are alluding to at the bottom of page 20 were performed, as I recall, in early August of 1984.

We were already aware of what the results of such calculations would be. We merely performed additional calculations in response to the contentions regarding the influence of higher peak firing pressures than the 1,670 used in the piston analysis report.

Q. Well, the overload conditions that you're talking about in the quoted section of your answer to question 28, we were talking about the more than -- 3900 KW and higher.

DR. HARRIS: Mr. Youngling might want to amplify to my response to your question.

To my way of thinking, overload conditions would be something like 110 percent of the named plate rating of the engine.

In the TDI factory log supplied with their engine including the engine at Shoreham they do report peak firing pressures up to 110 percent of the rate load. That's what my definition of

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overload is.

Q. So that's what you meant in your testimony, you meant 110 percent.

You and Dr. Swanger responded to this testimony.

DR. HARRIS: Yes. That's what I mean and I'd like to point out that at TDI factory load 110 percent load as I recall provides pressures on the order of 1800 psi which is well below the 2,200psig that was used for the peak firing pressure analysis of the influence of higher pressures so the 2,200 is way above the hundred and ten percent that I originally considered to be the overload.

Q. I understand that.

What did you mean by a small amount of time in your testimony?

MR. ELLIS: I believe it says relatively small amount of time, Judge. He ought to be given the benefit of the full --

Q. You see where you said this in your testimony. It's right in front of you so you can see exactly what I'm referring to, Dr. Harris.

DR. SWANGER: It was our understanding that on the 40 year functional life of the engines they would experience 3,000 hours of total testing and demonstration time. Of that approximately three thousand hours, about 60 hours over 40 years could be up to 110 percent of the -- or 11.4 percent. depends a little bit on exactly who you talk to, percent of the name plate load of the engines.

MR. YOUNGLING: I'd like to confirm Dr. Swanger's assessment that under the present technical specifications overload testing for the life of the engine would not exceed 60 hours.

MR. DYNNER: Judge Brenner, I'm going to move on to capital H of the cross plan now, and pick up one matter which is on page three of the cross plan, number four, so you can follow it.

JUDGE BRENNER: Thank you.

Q. Gentlemen, please turn to page 12 of your testimony.

What's the basis for your testimony that the AE inspection had not demonstrated design or operational problems?

DR. SWANGER: Which question number

Q. 13, bottom of the page.

DR. HARRIS: We at Failure Analysis Associates, I believe the people at LILCO, TDI owners group were not aware of any problems associated with AE piston skirts, either a design problem or an operational problem. This includes the -- I believe 622 hours on the R-5 engine that was tested by TDI in Oakland had a BMEP well in excess of the Shoreham rating and as well as the Kodiak experience and also the experience that's been related on the Shoreham engines.

Q. Did you conduct then a survey of all of the AE pistons that are in service?

MR. SEAMAN: The information that was provided to us from TDI regarding AE pistons that were -- that had seen service experience included the Kodiak engine and that is specifically why we contacted the people up in Kodiak Alaska to review those pistons that had been in service as well as the R5 pistons that had been run in the test engine, the R5 test engine at the Oakland facility.

Q. My question, Mr. Seaman, is did you conduct any survey in order to determine what AE pistons are in service?

MR. SEAMAN: Well, I guess Mr. Dynner, I don't really understand what you mean by a survey to determine where AE pistons are in service. We contacted the manufacturer of the engine, Transamerica DeLaval and asked them where these pistons were in service and contacted those facilities to find out what their experience had been.

Q. All right. So DeLaval told you what AE pistons were in service. Did they tell you how many were in service?

MR. SEAMAN: Yes. I believe they did tell us what the numbers were. They certainly told us that there were two in the R5 test engine. They also told us the number that was in Kodiak and I don't frankly recall what that number was except that we looked at two of them.

I believe it wasn't all 16 in that engine, but that's a recollection on my part.

Of course, the pistons that were supplied to Shoreham, the 24 that were run in the engine as well as two spares that we had were essentially the ones that were in service.

Q. Anybody else on the panel know whether there are any other AE pistons that are in service?

DR. SWANGER: There are AE pistons in service certainly at Shoreham as well as at the Grand Gulf Nuclear Station. I believe the AE piston skirts at Grand Gulf had accumulated between two and 300 hours of successful operation.

Other nuclear facilities have obtained

the AE piston skirts including the Catawba Power Plant at Duke Power, the Camanchee Peak --

JUDGE BRENNER: I think the question is, are any in service.

DR. SWANGER: I was going to say that I know that Catawba has reassambled their DG1A and I believe that it is operational now so it would be AE pistons in service at Duke Power Catawba Nuclear Station.

Q. Anybody on the panel aside from Mr. Seaman, he's already testified about Kodiak; he doesn't know how many for sure are in operation at Kodiak. Does anybody else know how many?

MR. YOUNGLING: Mr. Dynner, as I remember, there is one engine in Kodiak. It's a 16 cylinder engine and it has AE pistons in it.

Q. Are all 16.

MR. YOUNGLING: As I remember, yes.

Q. Who at DeLaval gave you this information about the AE pistons, Mr. Seaman?

MR. SEAMAN: I really don't recall, Mr. Dynner, where exactly that -- who exactly gave me that information.

JUDGE BRENNER: Is that going to be material, Mr. Dynner?

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MR. DYNNER: I guess it's not now since he doesn't recall

JUDGE BRENNER: Even if he had recalled, would that be material to anything you planned to go to?

MR. DYNNER: It might or might not. I can't say in the abstract.

JUDGE BRENNER: I can't say either unless you know something is going to be material or have a reasonable probability within the realms of certainty as there always is in litigation; don't ask questions that won't go anywhere. What if he said Joe Smith gave it to me. So what?

MR. DYNNER: That wouldn't matter

JUDGE BRENNER: Let's go on to something else.

Q. We could turn to page 12 of the cross plan.

JUDGE BRENNER: Mr. Dynner, do you want a few minutes to consider how you want to proceed? I realize you're going on to a new topic. We can give you ten minutes to think that through.

JUDGE BRENNER: Let's make it 4:35.

(Recess)

JUDGE BRENNER: We're back on the record.

We haven't been able to solve the same problem in our own minds that we were not able to solve for you earlier, Mr. Ellis, in terms of where to go and what to do. So you'll have to consider any other specific proposals that you can come up with and tell us about it tomorrow morning. If you can. I don't know if there's anything we can do.

MR. ELLIS: Thank You, Judge. I appreciate that. We will consider that. I think one thing would help is the postponement of the redirect.

JUDGE BRENNER: I'll think about that tomorrow, but I alluded to some difficulties I perceived in that -- maybe I didn't state it clearly, but we'll hold off and I'll restate them again, if I remain with that view tomorrow morning.

In a nutshell, the difficulty is although you may plan to have your redirect focused only on witnesses other than Dr. Pischinger, the redirect may be on areas to which he testified during the original cross-examination, and then in terms of follow-up to your redirect, it may be the desire of the County or the Board to find out what Dr. Pischinger thinks about something you asked another witness on redirect given his initial testimony already.

MR. ELLIS: Yes, I understand. I think I have a way around that but we can wait until tomorrow.

JUDGE BRENNER: To call him back for one more question, we may be able to work something out. Well, while we're on the subject let me say one other thing. I'm not going to let the convenience upset the proper compilation in terms of substance of a record on these important issues, and it's my paramount concern, I assume it's yours, also, but given that important concern, we'll do what we can, but we'll see how quickly that concern could be adversely affected.

We're going to be here a while, beyond next week, beyond the week after next week, that much is clear, and it's hard to believe that an individual who is going to be unavailable for the rest of all those weeks, although I recognize the geography involved. It's not as simple as flying in from Washington or even California perhaps but you let us know if you have any concrete proposals tomorrow.

I'm sure as sure as I can be which I'm perfectly sure but reasonably sure that we are going to finish pistons this week, even if we go through all the rounds, that is redirect and everything else, and we'd be ready to start crankshafts Monday morning. I recognize from your view that may not be enough time, but I think we'll be in a position to start on Monday morning.

Mr. Dynner isn't nodding yes. I don't know if he's agreeing or not.

MR. DYNNER: I'm being as helpful as everyone else to move quickly.

JUDGE BRENNER: Are you going to finish your cross by lunch break tomorrow?

MR. DYNNER: I would think so.

JUDGE BRENNER: Try very, very hard to do that.

If you're going to miss it, don't miss it by much.

MR. DYNNER: With the usual cooperation for the witnesses giving brief answers and being to the point, I think it can be accomplished.

JUDGE BRENNER: Maybe I'm trying to help by answering your expert questions also.

We'll go back to the cross-examination, pick a convenient time to stop around 5 o'clock?

Q. We'll start, Judge Brenner, on page 13.

item six of the cross plan.

Gentlemen, I'll ask you for your convenience to turn to page 56 of your testimony.

Dr. Johnson, you in fact went to Kodiak, Alaska along with Mr. Judge of LILCO in order to look at the AE pistons there, didn't you?

MR. JOHNSON: I did not go to Kodiak, Alaska to look at the pistons. Donald Johnson did.

Q. I'm sorry, I got the Johnsons mixed up.

MR. JOHNSON: Did you hear my answer to that?

JUDGE BRENNER: Yes.

Q. Anyone, if there were 16 AE piston skirts at Kodiak, why did you choose to inspect only two of the 16?

MR. YOUNGLING: Mr. Dynner, that was done as a courtesy with the utility up there. They were very cooperative with us to take their engine out of service and make two pistons available, and we felt quite pleased that they were willing to cooperate with us.

Q. Well, did they have to take the engine out of service to let you have the two pistons to inspect?

MR. YOUNGLING: Yes, sir. There is no

other way to remove the piston of the engine unless you take it out of service.

Q. Well, then why didn't you ask to see the other pistons?

MR. YOUNGLING: In order to take all 16 pistons out of the engine, you would probably require an outage of -- well, let me put it this way. At Shoreham it takes us about a week to strip the engine out and about two weeks to put it back together. So if we were to multiply that by two, and then, if course, take a good factor for economy to scale, we would be talking about a four or five week outage.

Q. How long was the outage with the two pistons going?

MR. YOUNGLING: I really don't know, but I imagine they did it in a day or two.

Q. They replaced those two pistons with two others?

MR. YOUNGLING: We gave them two replacement pistons.

Q. I see.

Were the two AE piston skirts that you got from Kodiak to look exactly the same as the AE piston skirts that are installed at Shoreham?

MR. YOUNGLING: I'll ask my colleagues on the panel if they can add, but I'll start by saying the pistons that are in the Kodiak engines are the same pistons that were delivered to Shoreham and put in service at Shoreham. That's certainly one of the reasons why we went up there to look at them.

In addition, one of the pistons out of the Kodiak engine was sent down to Failure Analysis, and they inspected the piston, perhaps someone else wants to comment.

Q. Does anybody else know whether they were exactly exactly the same, that's the question.

MR. JOHNSON: The Kodiak piston that was returned -- or, I mean, was delivered to Failure Analysis certainly appears to have the same appearance as the ones that were delivered to Shoreham.

MR. YOUNGLING: Mr. Dynner, we've looked at Exhibit No. 29 in our testimony at the photographs, and we are confident that the pistons from the Kodiak engine are the same as installed at Shoreham.

Q. Thank you.

JUDGE BRENNER: Let me clarify something in my own mind. Earlier, either Dr. Swanger or Dr.

Harris talked about the piston that was analyzed by FaAA, and it was the testimony that that piston was from the same lot as the Shoreham AE pistons. Am I correct so far?

DR. HARRIS: Yes.

JUDGE BRENNER: Now, the Kodiak piston that was delivered to FaAA is in addition to that piston.

DR. SWANGER: Yes.

JUDGE BRENNER: Thank you.

Q. You've referenced EXhibit P-29 which is also for ease of reference.

Suffolk County Diesel Exhibit 15, which contains a copy of a trip report to Kodiak Electric on January 22 to January 27 and signed by Donald O. Johnson.

Is Donald Johnson an employee of FaAA?

MR. JOHNSON: Yes, he is.

Q. Now, perhaps you could answer my question, one of the pistons as reported in this report was sent to DeLaval to inspect.

Do you know what the results of that inspection was?

Let me withdraw that question. Do you know what the inspection that DeLaval carried out, the type

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inspection carried out on the piston skirt?

Do you know what type of inspection that DeLaval carried out on that piston skirt?

MR. YOUNGLING: I've checked with the other members of the panel. We do not know what inspections were carried out on that piston skirt?

MR. YOUNGLING: I've checked with the other members of the panel. We do not know what inspections were carried out by TDI.

Q. Did FaAA or LILCO or the Owners make any inquiry to DeLaval about the inspection at that piston skirt?

MR. YOUNGLING: We're not aware of any inquiries.

Q. So it's true, isn't it, that you have no knowledge as to whether that particular piston skirt, any cracks or other defects in it, did you?

MR. JOHNSON: Both pistons at Kodiak were inspected, not destructively examined, both with penetrant and eddy current, and no defects were reported in -- defect indications were observed in the piston skirt that was supplied to TDI.

Q. What's the basis for that statement, Dr. Johnson?

MR. JOHNSON: That we observed no --

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would you repeat the question?

Q. Yes. I would just like to know what the basis is for your testimony that both of these piston skirts were inspected with the dye penetrant and eddy current at Kodiak. That's what you said. I want to know what the basis for your statement is.

MR. JOHNSON: The trip report of Donald Johnson and my conversations with Donald.

Q. Where does he talk about both of them being die penetrant and eddy current tested in the trip report that I have which is Exhibit P-29, if that's the same one you're looking at?

MR. YOUNGLING: Mr. Dynner, perhaps I can help.

Q. Well, maybe Dr. Johnson first can answer as to what the basis is for his testimony. Then you can give me your view.

MR. JOHNSON: My conversations with Donald Johnson after he returned from this trip?

Q. Well, the trip report says on the first page that Mr. Johnson did an informational inspection on the replacement pistons and found no crack like indications, and then on the following page, he says that the AE piston that was designated for LILCO was penetrant tested and eddy current

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tested.

Did he tell you that -- what he meant by an informational inspection on the first page of that report that was meant to include both the dye penetrant and eddy current inspection?

JUDGE BRENNER: Let's ask the foundation question first because maybe I misunderstood what was meant by that sentence.

Dr. Johnson, the replacement piston for Kodiak engine, were those the pistons going in or pulled out from the Kodiak engine if you know. If you don't know, that's the answer.

MR. JOHNSON: I don't know for a fact the answer.

JUDGE BRENNER: Does anybody have knowledge of that one way or the other?

MR. YOUNGLING: Judge Brenner, the game plan going up there was to pull those two pistons out and to inspect them and to send one down to FaAA and one down to TDI.

I think if we look at the report, we see in the first paragraph that he says, which included inspection of AE pistons and gathering of operating information.

Then if we go to the third paragraph --

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JUDGE BRENNER: Let me stop you. I can make some guess one way or the other of what the memorandum might mean and I'm telling you there's an ambiguity in that which I want to know if anybody on the panel knows rather than guessing what the memo says.

MR. SEAMAN: Judge Brenner, I may be able to provide some clarification regarding the language used.

The AE pistons in the Kodiak engine were replacement pistons.

If I recall correctly, engines were originally supplied to Kodiak with AN type pistons and those were replaced with AE, and that may be the source of confusion.

MR. YOUNGLING: Judge Brenner, I think in that third paragraph, where he says, I did an initial inspection on the replacement pistons, that was an inspection for the Kodiak people to insure them that we were giving them replacement AE pistons that had no defects.

JUDGE BRENNER: That's what I thought, and what Mr. Seaman just said is apparently inconsistent with that thought, unless maybe he thinks all the ones coming out were replacement pistons.

The only reason I got involved with this was Mr. Dynner was basing some of his questioning on that sentence, and I'm afraid Dr. Johnson based one of his answers on that sentence, too, and I don't want to sit around and guess.

I want to know if anybody knows, and apparently nobody knows.

DR. McCARTHY: Since it's five minutes before the end of the session, tomorrow morning we can have this whole thing resolved.

JUDGE BRENNER: Fine. I'll leave that up to you and the cross-examiner and your own counsel also. But we interrupted Dr. Johnson earlier, I believe I did. He was going to tell us -- you started to say you had some other knowledge other than a memo. Am I wrong, Dr. Johnson?

MR. JOHNSON: Yes. I also spoke directly with Dr. Johnson -- Donald Johnson concerning inspection immediately after the trip. He indicated to me that both penetrant and eddy current tests were conducted on both pistons at the site, and the piston which was eventually transmitted at TDI had no relevant indications either with penetrant or with eddy current.

JUDGE BRENNER: Presumably, you'll obtain further details just in case anybody wants to pursue it tomorrow. Mr. Dynner's other question went to the results and let me not take it too far today.

Do you have something else you wanted to ask, Mr. Dynner?

MR. DYNNER: Well, I'm -- I was going to follow up with some questions about whether there's documentation of that inspection and whether we could get additional information on what facilities he had at Kodiak to conduct the eddy current examination and the die penetrant examination, and -- unless you know that's information perhaps you could furnish tomorrow by talking to Donald Johnson?

MR. JOHNSON: With regard to the eddy current testing, he took our normal eddy current testing equipment with him specifically for the purpose of doing these eddy current testing. For the penetrant tests he also took penetrant supplies to do penetrant test.

Q. Can you tell us, Dr. Johnson, if you could, go to Page 2 of the trip report. It states in the last paragraph that one area -- I think it's referred to as the boss area was found to have a penetrant indication of three quarters inch long.

Upon inspection with eddy current, there were no crack-like indications noted.

Could you explain the difference between the -- an indication and a crack-like indication?

MR. JOHNSON: The penetrant indication and -- was three quarter inch long. And the crack-like eddy current indication, there was no such indication. The penetrant inspection is sensitive to -- is not -- the penetrant inspection from imperfections which have no significant depth. The eddy current test differs in that it is sensitive not only to the length of the indication but the depth of indication. Therefore, when we get no eddy current crack-like indication in this area, it's because the penetrant indication, the source of the penetrant indication was something of no significant depth.

Furthermore, when we brought it back to Palo Alto, of course, we re-examined it very carefully, both with penetrant and with eddy current, and the penetrant indication was not reproduceable. We also looked at it optically using a 15 power scope in this area. There was nothing that we could detect there. The environment in which they were doing the inspection up at Kodiak, of course, was not ideal such as one we would find in a laboratory, so we believe that penetrant indication was not a reproduceable indication and did not correspond to a material imperfection of any significance.

Q. In the inspection of this single piston from Kodiak, were any other crack-like indications on other areas of the piston noted?

MR. JOHNSON: There were no other crack-like indications noted.

Q. Were other areas besides the boss area inspected by dye penetrant and eddy current examination?

MR. JOHNSON: There's the boss area and-- the area down where the washers reside, which I guess is the washer landing area, which is part of the boss -- part of the boss configuration, but not the high stress area of the boss.

Q. But in addition to these examinations, was the AE piston skirt examined for any scuffing or fretting?

DR. SWANGER: When the piston was returned to FaAA in Palo Alto, we looked at the external surface of it to evaluate the patterns on it. We did not see anything out of the ordinary on that piston. We feel that it ran for approximately 6,000 hours at load with no indications of anything unusual on the outside of the piston.

Q. When you say at load, do you know what the load was for that particular skirt?

DR. SWANGER: One of the things that Don specifically did while he was at Kodiak was to obtain information on the operating logs, and I believe some of that information is shown in Exhibit 29. It's the page following Page 2 of the memo, and it shows two separate measurements of peak firing pressures on engine number four.

Q. My question is do you know which -- what the load was for that particular piston?

A. That particular piston was run for 6,000 hours at loads averaging about 5,600 kilowatts.

Q. Dr. Swanger, I didn't ask you an average. We got on the following page of that report, I can see it also, on the schedule that shows peak firing pressures on engine number four, and it shows different loads for different pistons.

And I'm asking you whether you know what the particular load was on the piston that you examined. You may not know.

DR. SWANGER: I may not know exactly what

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you mean by load, Mr. Dynner. What do you mean by load?

JUDGE BRENNER: I think he means the firing pressure; is that right, Mr. Dynner?

MR. DYNNER: Yes. Shows the peak firing pressures for various pistons which are related to the loads that they carry, right? Just looking at that chart, do you know which one of these pistons as shown on these charts was the one that you examined?

JUDGE BRENNER: That's a different question.

Q. I don't think so.

JUDGE BRENNER: I'll tell you what. I'm ready to break. You think about whether that's a different question or not.

He can know which piston that was but that doesn't necessarily tell him what the answer to your question, what the maximum firing pressure was seen by that piston.

MR. DYNNER: If he knows that's correct. one is related to the other and you're quite correct. Both questions then are pending. I'd like to know whether you know what load was run on the piston that was examined and also whether you can identify which of — which one of these pistons listed on this schedule was the piston you examined.

JUDGE BRENNER: I have a feeling the second question is a lot easier than the first. All right. Let's break for the day. And you can come with that question in the morning and I'm sure that somebody will remind you what the question was.

DR. SWANGER: The question is pending.

JUDGE BRENNER: Yes. You'll keep us in suspense on that. We'll come back at 9 o'clock in the morning.

(Whereupon, at 5:00 p.m. the hearing was adjourned, to reconvene at 9:00 a.m., Wednesday, September 12, 1984.)

CERTIFICATE OF OFFICIAL REPORTER

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

NAME OF PROCEEDING:

SHOREHAM NUCLEAR POWER STATION

Long Island Lighting Company

DOCKET NO.: 50-322-OL

PLACE: Hauppauge, New York

DATE: September 11, 1984

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(Sigt)

(TYPED) HELEN DOHOGNE

____

Official Reporter

Reporter's Affiliation

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STENOTYPE REPORTERS

October 30, 1984

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

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

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

ORiginAL + 3 COPIES
RJM.

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

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

Date	Page	Line(s)
9/17	22687	5-6
9/17	22725	14-16
9/18	22829	14
9/19	23030	16

Sincerely,

Alan I. Penn

Alan I. Penn
Vice President

Encl.
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