LILCO, September 20, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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

SUPPLEMENTAL TESTIMONY OF ROGER L. MCCARTHY, CHARLES A. RAU, CLIFFORD H. WELLS, HARRY F. WACHOB, DUANE P. JOHNSON, ROBERT K. TAYLOR, CRAIG K. SEAMAN, EDWARD J. YOUNGLING AND MILFORD H. SCHUSTER ON BEHALF OF LONG ISLAND LIGHTING COMPANY ON SUFFOLK COUNTY CONTENTION REGARDING CYLINDER BLOCKS

TABLE OF CONTENTS

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I. Introduction

1. What is the purpose of this Supplemental Testimony?

A. (McCarthy, Rau, Wells, Wachob, Johnson, Taylor, Seaman, Youngling, Schuster). This testimony supplements our original testimony with new information obtained since August 14, 1984. The testimony revises the depths and crack characteristics previously reported for cam gallery cracks; revises the depths previously reported for stud-to-stud cracks; and reports on circumferential crack indications recently identified in the original EDG 103 block.

2. What conclusions have you reached?

A. (McCarthy, Rau, Wells, Wachob, Johnson, Taylor, Seaman, Youngling, Schuster). Our conclusions are:

1. The cam gallery cracks in the original EDG 103 block vary in surface length up to a maximum of six inches with a maximum depth of 0.8 inch. Detailed fractography and metallography shows that the cracks are shrinkage cracks resulting from the casting process and have been present since the engine block was manufactured. The cracks have not propagated despite more than 1200 hours of operation, including more than 400 hours at or above 3500 kW. The cam gallery regions in the EDG 101 and EDG 102 blocks have been examined and the crack indications are less severe than in the original EDG 103 block. Therefore, it is our opinion that the cracks in the EDG 101 and EDG 102 blocks will not propagate.

2. FaAA has recently sectioned the block top of the original EDG 103 block in the area of the stud-to-stud crack. Measurements of the crack after sectioning revealed that the crack was actually a maximum of 3 inches deep rather than 5 1/2 inches. Accordingly, FaAA's conclusion that the EDG 101 and EDG 102 blocks can survive a LOOP/LOCA with substantial margins remains the same.

3. When FaAA sectioned portions of the original EDG 103 block, it identified shallow circumferential cracks that extended from the corner formed by the cylinder counterbore and cylinder liner landing 1/8 to 3/8 inch into the block top. Operating history on the original EDG 103 block demonstrates that circumferential cracks do not continue to propagate because they grow into a decreasing stress field. Since the cracks in the original EDG 103 block, with its inferior fatigue properties, did not impair engine operation, circumferential cracks, if any, in the EDG 101 and EDG 102 blocks will not impair the ability of the EDGs to perform their intended function.

II. Examination Of The Cam Gallery Cracks In Old EDG 103 Block

3. Please describe what work has been performed on the cam gallery cracks since August 14, 1984.

A. (Rau, Wells, Wachob, Johnson, Taylor). FaAA has conducted extensive non-destructive and destructive examinations on the original EDG 103 cam gallery cracks. The non-destructive examinations began with a visual inspection of the surface of the cam gallery cracks and of the backside of the cam galleries to verify that none of the cracks had penetrated through the 1-1/4 inch thickness of the block wall at the inner cam gallery lining. Next, a liquid penetrant examination was performed on the cam gallery cracks to identify the size and the shape of the indications.

Destructive examinations were also performed. First, 1-1/4 inch diameter holes were drilled into crack indications in the saddle areas of cam gallery nos. 5 and 7. Next, the holes were polished, etched, and replicated to determine the depths of the cracks. In addition, a large piece of cam gallery saddle area no. 6, which included the entire crack indication and one section from the no. 7 cam gallery saddle area, were cut out and evaluated.

4. What did the non-destructive examinations reveal?

A. (Rau, Wells, Wachob, Johnson). They revealed that there were surface cracks on all nine of the saddle areas in the cam gallery. In addition, it was determined that none of the cam gallery cracks had perforated the block wall to the water jacket side of the cam gallery.

The epoxy paint applied to the cam gallery area was removed to reveal the metal surface of each saddle area of the cam gallery. Once the paint was removed, it was discovered that all nine of the cam gallery locations had been welded, apparently as a repair of cam gallery shrinkage cracks.

Non-uniform (constrained) shrinkage associated with the welding process resulted in cracks between the base metal and the weld metal itself. These cracks, which run along the boundary of the base metal and the weld, produced the surface crack indications that were detected and measured by previous non-destructive examinations of the cam gallery saddle regions.

5. Did the repair welds in the original EDG 103 block degrade the strength of the cam gallery?

A. (Rau, Wells, Wachob). No. The welds apparently were performed for cosmetic purposes. The welding process itself neither enhanced significantly nor degraded the strength of the cam gallery region.

6. How were cracks selected by FaAA for destructive examination?

A. (Rau, Wachob, Taylor). FaAA identified cracks in cam gallery location nos. 5, 6 and 7 in the original EDG 103 block that appeared most severe for destructive examination to determine maximum crack depth and crack characteristics.

7. Please describe the destructive examination.

A. (Rau, Wachob, Taylor). FaAA drilled through the crack location in the region that had previously been ground in the saddle area of cam gallery no. 5. The inside of the drill hole where the indications were present was then polished for metallographic examination. Plastic replicas were made of the sides of the holes to reveal the crack depth. Two 1-1/4 inch diameter holes were drilled into the cam saddle area of cam gallery no. 7 and prepared in the same way. In FaAA's laboratory, cam gallery no. 7 was sectioned to enable metallography of the crack indications, and a section was broken open to perform fractography of the crack surfaces.

8. What did the fractography of the crack reveal?

A. (Rau, Wachob). It revealed that the entire surface of the crack was covered with a thick oxide. This oxide was dark in color rather than a rust color. The thick, dark oxide indicate that the crack was present and exposed to air at elevated temperatures before the cam gallery region was filled with lubricant. The dark oxide, the presence of high concentrations of calcium, and the absence of a rust colored oxide indicate that the entire surface of the crack was introduced during casting and exposed to elevated temperature at that time. Furthermore, no new crack surface has been formed since the time of the initial oxidation.

9. What caused the dark oxide to form on the crack surface?

A. (Rau, Wachob). In our opinion, the majority of the oxide formed during cooling at the time of the casting process. Because this oxide could only have formed in elevated temperatures and in the presence of an air environment, the crack had to be present and surface connected during cooling.

Since very little oxidation would occur once the cam gallery cracks were bathed in oil after initial engine startup, the presence of the dark oxide layer is consistent with the conclusion that the crack is fabrication-induced and not operationally-induced. Thick, dark oxide would not have developed on a crack surface exposed as the result of subsequent fatigue crack propagation.

This conclusion is confirmed by examination of the fracture surface. Any service-induced crack propagation of the shrinkage cracks in the cam gallery would not be covered by thick, dark oxide. Since the oxide was present over the entire surface of the cam gallery cracks examined in the original EDG 103 block, it is clear that no crack propagation has occurred.

10. Did FaAA perform a metallographic examination of the cam gallery cracks?

A. (Rau, Wachob). Yes. Metallographic examination of the cracks indicated that there were multiple, parallel

shrinkage cracks formed during casting. A family of cracks was observed in the metallurgical cross section rather than a single crack, and the heavy oxidation of the entire crack depth was apparent.

An examination of the surface of the crack after it had been broken open did not reveal any beach marks, or other surface variations on the fracture surface which might indicate progressive crack extension.

11. Have the cam gallery cracks propagated since the block was manufactured?

A. (Rau, Wachob). No. FaAA's fractographic and metallographic examination of the sectioned portions of the cam gallery cracks indicated that the cracks were fabrication induced and that the cracks have not propagated since the time of initial fabrication. The existence of cam gallery cracks in other new block castings, the thick, dark oxide and calcium contamination on the entire crack surface, and the morphology of the cracks demonstrate conclusively that the cracks are fabrication-induced. The cracks have not propagated during more than 1200 hours of engine operation despite the extremely poor fatigue properties of the original EDG 103 block material.

12. Is the conclusion in FaAA's June 1984 Report that cam gallery cracks propagate very slowly correct in light of recent examinations?

A. (Rau, Taylor). The June Report conservatively assumed uniform tensile stresses and therefore the fracture mechanics analysis predicted very slow crack propagation. Actual sectioning and examination of the cam gallery cracks demonstrates that FaAA's fracture mechanics analysis predicting crack propagation was indeed conservative. Even the very large cracks identified in the original EDG 103 block have not propagated.

13. Have you examined the EDG 101 and EDG 102 blocks for cam gallery cracks?

A. (McCarthy, Rau, Wells, Wachob, Johnson, Taylor, Seaman, Schuster). Yes. Cam gallery nos. 8 and 9 on the EDG 101 and EDG 102 blocks were opened and the paint was removed from the surface of the cam gallery areas. A visual examination of the region revealed the presence of repair welds and crack indications, but the welds and crack indications were smaller and had less porosity than those found in the original EDG 103.

FaAA did not examine the remaining seven cam gallery locations on the EDG 101 and EDG 102 blocks because access to those areas was blocked by the engine intercooler. However, an examination of LILCO's inspection records indicates that the length of the other cracks in the EDG 101 and EDG 102 blocks are smaller than the largest cracks in EDG 103 block. This

indicates that the cracks in the EDG 101 and EDG 102 blocks are less severe than those contained in the original EDG 103 block.

The somewhat smaller welds on the EDG 101 and EDG 102 blocks compared to the original EDG 103 block are entirely consistent with the known inferior fracture resistance of the original EDG 103 block.

14. Is it necessary to disassemble EDG 101 and EDG 102 to measure each of the cracks in those cam galleries?

A. (Rau, Wachob, Taylor). No. EDG 101 and EDG 102, like the original EDG 103, have operated for more than 1200 hours with the cam gallery cracks without suffering an engine failure. Extensive examination of the original EDG 103 block revealed shrinkage cracks with a maximum depth of 0.8 inch, which are believed to be deeper than any cracks contained in the EDG 101 and EDG 102 blocks. These cracks had not propagated since the time the original EDG 103 block was cast, despite the inferior fatigue properties of that block. Accordingly, smaller casting defects (cracks) in the much more fatigue resistant block material of EDG 101 and EDG 102 pose no threat to the ability of the EDGs to perform their intended function.

15. As a result of FaAA's recent examinations, do you have an opinion, based on a reasonable degree of engineering certainty, as to the adequacy of the EDG 101 and EDG 102 cylinder blocks with the known cam gallery cracks?

A. (McCarthy, Rau, Wells, Wachob, Taylor). Yes. The cam gallery cracks in the EDG 101 and EDG 102 blocks are shrinkage cracks induced during the casting process. Examination of similar but larger cracks in the original EDG 103 block demonstrated that the cracks have not propagated since the time the EDG blocks were cast. The extensive experience with the original EDG 103 block in conjunction with the differences in material properties of the EDG 101 and EDG 102 blocks has demonstrated that the cam gallery cracks in those blocks pose no hazard to the ability of the blocks to perform their intended function.

III. Laboratory Examination Of The Original EDG 103 Stud-To-Stud Cracks Establishes They Are Less Severe Than Previously Reported

16. Please describe what work has been performed on the block top cracks since August 14, 1984.

A. (Rau, Wachob, Taylor). FaAA has measured some of the crack depths on the original EDG 103 block top in its laboratory by destructive sectioning. The stud-to-stud crack on the original EDG 103 block between cylinder nos. 4 and 5 on the exhaust side was sectioned in two places to measure the depth of the crack. Measurements of the crack revealed that the maximum depth was 3 inches, as compared to the 5-1/2 inches previously reported from field inspection.

17. What effect, if any, does the new data have on FaAA's cumulative damage analysis?

A. (Rau, Wachob, Taylor). The fact that the actual depth of the cracks in the original EDG 103 block are shallower than previously thought does not in any way change FaAA's conclusions. In light of the more precise measurement, however, the cumulative damage index referenced in our original testimony changes slightly. Specifically, the number which needs to be revised occurs on page 53 of the testimony in response to question no. 72. That answer should now be revised to read "2%" rather than "1%."

IV. Circumferential Cracks Found In EDG 103 Will Not Impair The Ability Of The EDGs To Perform Their Intended Function

18. Have additional crack indications been identified since August 14, 1984?

A. (Rau, Wachob, Taylor). Yes. When the stud-to-stud crack on the original EDG 103 block was sectioned in FaAA's laboratory to verify its depth, FaAA identified some shallow circumferential cracks. These cracks are located at the corner formed by the cylinder liner counterbore and the cylinder liner landing. The cracks identified were very shallow, extending to a maximum of 3/8 inch into the block top.

19. Are circumferential cracks present in the EDG 101 and EDG 102 blocks?

A. (Rau, Wells, Wachob, Taylor, Johnson, Seaman, Schuster). The inspections performed to date have not identified any circumferential cracks in the EDG 101 and EDG 102 blocks. It is difficult to inspect for these cracks, however, because the cracks, if present, form in the corner between the cylinder liner counterbore and the cylinder liner landing. It is hard to clean this area entirely for testing, thus making interpretation of the results more difficult. Therefore, for purposes of its analysis, FAA has conservatively assumed the presence of circumferential cracks in the EDG 101 and EDG 102 blocks.

20. Do you have an opinion, based on a reasonable degree of engineering certainty, as to whether circumferential cracks, if any, present in the EDG 101 and EDG 102 blocks affect the ability of the EDGs to perform their intended function?

A. (McCarthy, Rau, Wells, Wachob, Taylor, Youngling). In our opinion, even if circumferential cracks are conservatively assumed to be present in the EDG 101 and EDG 102 blocks, they pose no threat to the ability of the EDGs to perform their intended function.

The operating history of the original EDG 103 block demonstrates that the circumferential cracks do not present a threat to the ability of the EDGs to perform their intended

function. Even in the original EDG 103 block, which is known to have markedly inferior fatigue and fracture properties compared to the EDG 101 and EDG 102 blocks, the circumferential cracks are shallow. Despite more than 1200 hours of operation, including more than 400 hours at or above 3500 kW, the circumferential cracks in the EDG 103 block did not propagate to the point where they impaired engine operation.

Because of the superior material properties of the EDG 101 and EDG 102 blocks, any circumferential cracks in these blocks are predicted to be smaller. Thus, even if circumferential cracks are conservatively assumed to be present in the EDG 101 and EDG 102 blocks, they will not grow to the depth reached in the original EDG 103 block, and they will not result in fracture of the liner landing or impair engine operation.

Finally, empirical evidence derived from the original EDG 103 block is consistent with analytical predictions that the cracks propagate into a decreasing stress field. As the cracks move into the block top material, the stresses decrease, and there is a reduction in the driving force for continued crack growth. Accordingly, it is our opinion that any circumferential cracks in the EDG 101 and EDG 102 blocks will grow slowly, arrest, and will not cause any operational

problems or impair the ability of the EDGs to perform their intended function of supplying emergency standby power for the Shoreham Nuclear Power Station.

CERTIFICATE OF SERVICE

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

I hereby certify that copies of LILCO's Motion to Admit Supplemental Testimony and LILCO's Supplemental Testimony on Cylinder Blocks were served this date upon the following by first-class mail, postage prepaid, or by hand as indicated by an asterisk:

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