ORIGINAL

UNITED STATES
NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF:

LONG ISLAND LIGHTING COMPANY

SHOREHAM NUCLEAR POWER STATION

DOCKET NO: 50-322-OL

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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In the matter of: :

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

(Long Island Light Company :

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State Office Building

Veterans Memorial Highway

Hauppage, New York

Monday, September 17, 1984

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

BEFORE:

JUDGE LAWRENCE BRENNER,

Chairman, Atomic Safety and Licensing Board

JUDGE PETER A. MORRIS,

Member, Atomic Safety and Licensing Board

JUDGE GEORGE A. FERGUSON,

Member, Atomic Safety and Licensing Board

APPEARANCES:

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(Errata to Testimony on behalf of Long Island Lighting Company regarding crankshafts)

LAY-INS FOLLOWS PAGE NO. 22,610
(Testimony of McCarthy, Johnston, Montgomery and Chen regarding replacement crankshafts; Testimony of Youngling and Pischinger regarding replacement crankshafts.)

E X H I B I T S

NUMBER	DESCRIPTION	IDENT.	REC'D	REJECTED
LILCO DIESEL EXHIBIT:				
C-1	Evaluation of Emergency Diesel Generator Crankshafts at Shoreham and Grand Gulf Nuclear Power Statins prepared for TDI Diesel Generator Owners Group dated May 22, 1984 (hereinafter "Owners Group Crankshaft Report"), Figure 3-4	22,610		
C-2	Specification for Diesel Generator Sets, Shoreham Nuclear Power Station - Unit 1, Spec. No. SH1-89, Revision 2, January 26, 1983, page 1-20	22,610		
C-3	U.S. Nuclear Regulatory Commission Regulatory Guide 1.9, Revision 2, December 1979	22,610		
C-4	IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations, Std 387-1977.	22,610		

E X H I B I T S

NUMBER	DESCRIPTION	IDENT.	REC'D	REJECTED
LILCO DIESEL EXHIBIT:				
C-5	Transcript of July 11, 1984 meeting of the TDI Diesel Generator Owners Group, pages 124-125.	22,610		
C-6	Available Logged Hours of Operation of DSR-48, Rated 3500 kw at 450 rpm.	22,610	22,673	
C-7	TDI Diesel Generator Run History - Shoreham Nuclear Power Station - Unit 1 August 6, 1984.	22,610		
C-8	Results of non-destructive examinatins of replacement crankshafts at Shoreham after 100 hours of operation at full load or greater.	22,610		
C-9	American Bureau of Shipping Rules, for Building and Classing Steel Vessels(1983) Sec. 37.17.1.	22,610		
C-10	American Bureau of Shipping, Rules for Building and Classing Steel Vessels (1983) Table 34.3	22,610		

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E X H I B I T S

NUMBER	DESCRIPTION	IDENT.	REC'D
LILCO DIESEL EXHIBIT:			
C-11	TDI Crankshaft Drawing Number 03-310-05-AC.		22,610
C-12	American Bureau of Shipping Reports on Castings or Forgings of Replacement Crankshafts		22,610
C-13	American Bureau of Shipping letter to TDI dated May 3, 1984		22,610
C-14	Diesel Engine Manufacturers Association Standard Practices for Low and Medium Speed Stationary Diesel and Gas Engines 19072 ed.,pages 53-56		22,610
C-15	TDI Proposed Torsional and Lateral Critical Speed Analysis, August 22, 1983.		22,610
C-16	Field Test of Emergency Diesel Generator 103 with 13 x 12 crankshaft, April 1984		22,610
C-17	Owners Group Crankshaft Report		22,610

E X H I B I T S

NUMBER	DESCRIPTION	IDENT.	REC'D
LILCO DIESEL EXHIBIT:			
C-18	Crankshaft Torsional Stress Calculations for 8L 17 x 21 Engine Generator Set, July 19, 1984		22,610
C-19	Table 2.2 from Owners Group Crankshaft Report showing natural frequencies from TDI analysis		22,610
C-20	Table 2.4 from Owners Group Crankshaft Report showing single order nominal stresses from TDI analysis.		22,610
C-21	Table 2.5 from Owners Group Crankshaft Report showing nominal stresses calculated from torsiograph		22,610
C-22	Crankshaft Torsional Stress Calculations for 8L17 x 21 Engine-Generator Set, July 19, 1984 page 11.		22,610
C-23	Figure 3-3 from Owners Group Report showing comparison of measured and calculated torque.		22,610
C-24	Tables 3.6 and 3.7 from Owners Group Crankshaft Report showing comparison between analytical and test results.		22,610

E X H I B I T S

NUMBER	DESCRIPTION	IDENT.	REC'D
LILCO DIESEL EXHIBIT:			
C-25	Failure 3-13 from Owners Group Crankshaft Report showing fatigue endurance limit of replacement crankshafts on Goodman diagram.		22,610
C-26	Oberg and Jones, Machinery's Handbook (18th Ed.) pages 352-53; Shigley, Mechanical Engineering Design (McGraw-Hill pages 212-13; Rothbart (Editor) Mechanical Design and Systems Handbook (McGraw-Hill) page 18-4.		22,610

P R O C E E D I N G S

JUDGE BRENNER: Good morning. We're back on the record.

We won't bother going through the appearances for each party every week.

If they're going to change or you have a new lawyer you would like to introduce, you can feel free to do that. I would note that there is no counsel for New York State present, so the only appearance noted would be for LILCO, NRC Staff and Suffolk County.

MR. STROUPE: I might just add that David Dreifus on my right was not introduced last week and he will be acting as counsel for LILCO.

JUDGE BRENNER: We met Mr. Dreifus at a previous conference hearing.

The Board has no preliminary matters. Does anyone else have preliminary matters?

MR. STROUPE: I have a couple of preliminaries. As you can observe we're missing Dr. Simon Chen from the panel. He missed his plane apparently at O'Hare because of some mechanical difficulty. He has indicated that he believes he can be here by lunch time or shortly after lunch time, so to that extent, we will be minus one panelist for the morning session.

With regard to the photograph, the original photographs that we talked about last week with regard to the piston testimony, I have been told that we will have those original photographs inserted in the copies to be bound to be given to the reporter by this afternoon, and we will be more than happy to insert those original photographs or copies thereof in the copies of the testimony that the judges have in their possession, if you wish that we do that.

JUDGE BRENNER: All right. We would appreciate that, and beyond that, the most important thing is to assure that the three copies of the exhibits with the official record be conformed. You'll have to work it out with careful instructions to the court reporting firm because I don't know where those exhibits are physically at this moment.

In addition, Suffolk County will have to do the same as they said they would with their exhibit, Diesel 71, and the Board will have to receive those original photographs for our own groups of D-71 also.

All right. Why don't you introduce the witnesses that are present and I'll swear them in.

MR. STROUPE: We may start with the first witness, Dr. McCarthy, each of you introduce yourselves, indicate your business address and your business affiliation.

DR. MC CARTHY: My name is Roger McCarthy. I'm president of Failure Analysis Associates, 2225 East Bay Shore Road in Palo Alto, California.

DR. JOHNSTON: My name is Paul Johnston. I am manager of the structural analysis group at Failure Analysis Associates, business address is 2225 East Bay Shore Road, Palo Alto, California.

MR. MONTGOMERY: My name is Eugene Montgomery. I'm a stress analyst in the Nuclear Engineering Department.

JUDGE BRENNER: You're going to have to speak a lot louder.

MR. MONTGOMERY: I'm a stress analyst --

JUDGE BRENNER: Louder. I don't mean to badger you on your first words but it's better done on something as simple as your name. I'm going to have trouble hearing the testimony unless you speak louder.

MR. MONTGOMERY: My name is Eugene Montgomery. I'm a stress analyst within the nuclear engineering department of Long Island Lighting

Company at the Shoreham Nuclear Power Station in Wading River, New York.

MR. YOUNGLING: My name is Edward J. Youngling. I work for the Long Island Lighting Company as the manager of the Nuclear Engineering Department at the Shoreham Nuclear Power Station, Wading River, New York.

DR. PISCHINGER: My name is Franz Pischinger. I am president and owner of FEV Company and at the same full-time professor at the Aachen Technical University. My address is, I will spell it. I-M-E-R-K-F-E- L-D, No. 4-D-5100, Aachen.

JUDGE BRENNER: Welcome back to the three of you and welcome to Dr. Johnston and Mr. Montgomery.

Why don't you all stand as a panel and raise your right hands, please.

Whereupon,

PAUL JOHNSTON,
EUGENE MONTGOMERY,
ROGER L. McCARTHY,
FRANZ F. PISCHINGER,
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:

JUDGE BRENNER: In the future, I think we can save time and skip the addresses at least and -- for those witnesses we know, you can even skip the business affiliations and just introduce the new ones.

MR. STROUPE: Judge Brenner, we have filed and served on the parties hereto an errata sheet dated September 11, 1984 making certain changes and corrections to the two volumes of testimony involved herewith and the three volumes of exhibits.

We have penned in the changes so they are, in fact, in the copies that were filed with the judges, so we would be more than happy to have the chairman of the panel, Mr. Youngling, read into the record those changes if the Board so desires.

JUDGE BRENNER: I don't believe it's necessary.

DIRECT EXAMINATION

BY MR. STROUPE:

Q. Dr. McCarthy, do you have in front of you a copy of the testimony on behalf of LILCO dated August 14, 1984 in this proceeding entitled the

Testimony of Roger L. McCarthy, Paul R. Johnston, Eugene M. Montgomery and Dr. Simon Chen on behalf of Long Island Lighting Company on Suffolk County's contention regarding replacement crankshafts on diesel generators at Shoreham along with three volumes of crankshaft exhibits containing Exhibits C-1 through C-26.

DR. MC CARTHY: I do.

Q. To the best of your knowledge, is that testimony and the exhibits with the corrections noted on the errata sheet true and correct?

DR. MC CARTHY: It is.

Q. Do you adopt it as your own?

DR. MC CARTHY: I do.

Q. Dr. Johnston, I would ask you the same question with regard to the same documents. Is it true and correct to the best of your knowledge?

DR. JOHNSTON: It is.

Q. And do you adopt it as your own?

DR. JOHNSTON: I do.

Q. Mr. Montgomery, I would again ask you the same question.

MR. MONTGOMERY: It is.

Q. And do you adopt it as your own?

MR. MONTGOMERY: I do.

Q. Mr. Youngling, do you have in front of you the volume of testimony dated August 14, 1984 entitled Testimony of Edward J. Youngling and Franz F. Pischinger on behalf of Long Island Lighting Company on Suffolk County's contention regarding replacement crankshafts on diesel generators at Shoreham along with three volumes of exhibits containing Crankshaft Exhibit C-1 through 26?

MR. YOUNGLING: Yes, I do.

Q. Is this testimony and the three volumes of exhibits true and correct to the best of your knowledge?

MR. YOUNGLING: Yes, it is.

Q. Do you adopt it as your own?

MR. YOUNGLING: Yes, I do.

Q. Dr. Pischinger, I would ask you the same question.

DR. PISCHINGER: Yes. I adopt it as my own. It's true to the best of my knowledge

MR. STROUPE: Judge Brenner, we hereby tender the witnesses for cross-examination. First of all, I would like to move that the testimony and the exhibits be introduced into evidence and admitted into evidence.

JUDGE BRENNER: All right. In the

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absence of any objection, we would — let's put in the errata sheet also since you had wanted to read it and that way the parties can see the source of the pen and ink changes. At this point we will bind in the following sequence the errata to the testimony and then the testimony of Roger L. McCarthy et al., followed by the testimony of Youngling and Pischinger. And we can admit them into evidence and bind them in here.

In addition, we will admit into evidence the exhibits identified as LILCO Diesel Exhibits C-1 through 39 and they, of course, will not be physically bound in. We will carry three copies of them with you.

MR. STROUPE: Judge Brenner, C-1 through C-39 also, that would include Volume 4 which is really related to the shot peening exhibits.

JUDGE BRENNER: You only want to admit through C-26 at this point?

MR. STROUPE: At this point.

JUDGE BRENNER: Changing that error on my part and we will admit into evidence LILCO Diesel Exhibits C-1 through C-26 and ask the reporter for the index page of the transcript to copy those titles through C-26 only from the index provided before C-1 and three copies of those exhibits will be with the official record.

I will assume that the version of C-17 which LILCO wanted to move into evidence has been substituted in the official record, that is, the May 22, 1984 version.

MR. STROUPE: That is correct.

(The Transcript of Testimony of McCarthy, Johnston, Montgomery, and Chen regarding replacement crankshafts; Transcript of Testimony of Youngling and Pischinger; regarding placement crankshafts; Errata to Testimony on Behalf of Long Island Lighting Company regarding crankshafts; Crankshaft Exhibits C-1 through C-26 are incorporated in the transcript at this point.)

JUDGE BRENNER: You have nothing further, Mr. Stroupe, correct?

MR. STROUPE: That's correct, Your Honor.

JUDGE BRENNER: Mr. Dynner?

MR. SCHEIDT: Judge Brenner, I'll be conducting the cross-examination.

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)	)	

ERRATA TO TESTIMONY ON BEHALF OF LONG ISLAND LIGHTING COMPANY REGARDING CRANKSHAFTS

The following are changes to LILCO's testimony regarding crankshafts:

Testimony of Pischinger and Youngling

1. Page 4, line 18 - change "600" to "1200".

2. Page 4, line 24 - change "13%" to "6%".

3. Page 5, line 22 - change "600" to "1200".

4. Page 6, line 2 - change "600" to "1200".

Testimony of McCarthy, Johnston, Montgomery and Chen

1. Page 4, line 13 - change "Industry" to "Industries".

2. Page 41, line 18 - change "would my opinion" to "would be my opinion."

Testimony of Wells, Johnson, Wachob, Seaman, Cimino and Burrell

1. Page 11, line 15 - change "insure" to "ensure".

2. Page 16, line 13 - change "Exhibit C-33" to "Exhibit C-31". After the reference to "Exhibit C-31", the following sentence should be inserted: "LILCO's ultrasonic testing as well as magnetic particle and liquid penetrant testing likewise revealed no relevant inclusions or voids. See Exhibit C-33 and Exhibit C-32, respectively."

3. Page 17, line 9 - change "journels" to "journals".

Exhibits

Exhibit C-17 - The Evaluation of Emergency Diesel Generator Crankshafts at Shoreham and Grand Gulf Nuclear Power Stations prepared for TDI Diesel Generator Owners Group dated April 19, 1984, should be replaced by a report of the same title dated May 22, 1984.

Exhibit C-25 - Figure 3-13 from the April 19, 1984 Crankshaft Report should be replaced by Figure 3-13 from the May 22, 1984 Crankshaft Report.

Respectfully submitted,

LONG ISLAND LIGHTING COMPANY

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DATED: September 11, 1984

LILCO, August 14, 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)	)	

TESTIMONY OF ROGER L. McCARTHY, PAUL R. JOHNSTON,
EUGENE F. MONTGOMERY AND SIMON K. CHEN ON BEHALF OF
LONG ISLAND LIGHTING COMPANY ON
SUFFOLK COUNTY'S CONTENTION REGARDING
REPLACEMENT CRANKSHAFTS ON DIESEL GENERATORS AT SHOREHAM

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I. INTRODUCTION OF WITNESSES

1. Please state your names, business affiliations and addresses.

A. (McCarthy) My name is Dr. Roger L. McCarthy and I am employed by Failure Analysis Associates as president and chief executive officer. My business address is 2225 East Bayshore Road, Palo Alto, California, 94303.

(Johnston) My name is Dr. Paul R. Johnston. I am employed by Failure Analysis Associates as manager of the structural analysis group. My business address is 2225 East Bayshore Road, Palo Alto, California, 94303.

(Montgomery) My name is Eugene F. Montgomery. I am employed by Long Island Lighting Company as a stress analyst. My business address is Shoreham Nuclear Power Station, Long Island Lighting Company, Wading River, New York.

(Chen) My name is Dr. Simon K. Chen. I am a professional engineer registered in the State of Wisconsin and the owner and president of Power and Energy International, Inc., a private consulting firm. My business address is 555 Lawton Ave., Beloit, Wisconsin, 53511.

2. Please summarize your professional qualifications and your role in evaluating the replacement crankshafts at Shoreham.

A. (McCarthy) I am principal design engineer for FaAA and hold five degrees, including a Ph.D. in mechanical engineering from M.I.T. My specialty is mechanical design. My resume is Attachment 1.

My role in evaluating the replacement crankshafts at Shoreham has been to personally inspect the broken crankshafts and the replacement crankshafts, to perform the final review of the FaAA reports and to oversee the corporate performance of FaAA's evaluation of the crankshafts.

(Johnston) I obtained my undergraduate degree in Civil Engineering (B.A.I.) in 1976 from Trinity College, Dublin, Ireland. Thereafter, I attended Stanford University where I received a M.S. in Structural Engineering in 1977 and a Ph.D. in Civil Engineering in 1981. I have worked for FaAA since 1978, principally in the analysis of failures in structures and machinery. From 1981 to 1983, I also served as a Consulting Assistant Professor at Stanford University, where I taught graduate courses in finite elements and structural dynamics. I am co-author of the book Finite Elements for Structural Analysis. My resume is Attachment 2.

My role in evaluating the replacement crankshafts at Shoreham has been to evaluate the adequacy of the crankshafts by analysis and by using the results of dynamic tests on the original and replacement crankshafts.

(Montgomery) I received my undergraduate degrees in Mechanical Engineering (B.A., B.S.) in 1973 under a combined 3/2-year program at Queens College in the City University of New York and Columbia University. Thereafter, I attended Columbia University where I received an M.S. in Mechanical Engineering in 1974 and an M.E. (Professional Degree) in Mechanical Engineering in 1981. I have worked for LILCO since 1981, principally in the area of engineering mechanics for safety-related piping, equipment and support structures. From 1980 to 1981, I was a senior engineer in the Piping Stress Analysis Department of Burns & Roe, Inc., Woodbury, N.Y. Prior to that time, I was employed as a senior engineer in the Stress Analysis Department of Ebasco Services, Inc., Jericho, N.Y. from 1978 to 1980. My resume is Attachment 3.

My role in evaluating the replacement crankshafts at Shoreham has been to serve as LILCO's engineering specialist providing technical review and direction to the work performed by LILCO's consultants: Failure Analysis Associates, Stone and Webster Engineering Corporation, and Power and Energy International.

(Chen) I received my undergraduate degree in mechanical engineering (B.S.M.E.) in 1947 from National Chiao Tung University. In 1949 I received a masters degree in mechanical engineering (M.S.M.E.) from the University of Michigan, and in 1952

I received a Ph.D. in mechanical engineering from the University of Wisconsin. I also received an M.B.A. from the University of Chicago in 1964. For the past four and one-half years I have been the owner and president of Power and Energy International, Inc. (PEI), a private consulting firm. Prior to forming PEI, I was president and chief technical officer of the Beloit Power System Division of Louis Allis Litton Industries from 1973 until 1979. From 1971 until 1973 I was vice-president of engineering and applications of the entire Fairbank Morse Power System Division. From 1969 until 1971, I was vice-president and general manager of the large engine division of the Fairbank Morse Power Systems Division of Colt Industries. From 1952 until 1969 I was employed by International Harvester. My first job was project engineer in charge of combustion development. My last job at International Harvester was divisional chief engineer in charge of all engine research and development. My resume is Attachment 4.

My role in evaluating the replacement crankshafts at Shoreham has been to perform a critical review of all analyses and testing of the crankshafts and to conduct an independent analysis of the adequacy of the crankshafts.

3. What issues have you been asked to address in your testimony?

A. (All) We have been asked to address Emergency Diesel

Generator Contention 1(a), admitted by the Board in its July 17, 1984 Memorandum and Order, which is whether:

> The replacement crankshafts at Shoreham are not adequately designed for operating at full load (3500 KW) or overload (3900 KW), as required by FSAR Section 8.3.1.1.5, because they do not meet the standards of the American Bureau of Shipping, Lloyd's Registry of Shipping, or the International Association of Classification Societies. In addition, the replacement crankshafts are not adequately designed for operating at overload, and their design is marginal for operating at full load, under the German criteria used by FEV.

In summary, this testimony demonstrates that the replacement crankshafts are suitable for unlimited operation in the emergency diesel generators at Shoreham. The structural integrity of the replacement crankshafts has been extensively evaluated by testing, analysis and inspections. There is no requirement that the crankshafts comply with the design standards of the American Bureau of Shipping, Lloyd's Registry of Shipping, the International Association of Classification Societies or FEV's criteria. Therefore, compliance with the design criteria of one or more of the above organizations is not necessary to demonstrate the crankshafts are adequate for their intended service at Shoreham. Furthermore, ABS has approved the torsional critical speed arrangement of the crankshaft.

The crankshafts are required to comply only with the recommendations of the Diesel Engine Manufacturers Association (DEMA). Conventional analytical techniques typically utilized by the diesel engine industry show that the 13-inch by 12-inch replacement crankshafts comply with DEMA recommendations. Angular displacements of the free end of the crankshaft, stress ranges in the most highly stressed crankpin fillets, and the range of output torque at the flywheel were measured at and above full-rated load. The torsiograph measurements of twist confirm the analyses and show that the crankshafts meet the DEMA recommendations.

In addition, strain gage measurements of maximum bending and torsional stress and calculations of maximum stress by a modal superposition analysis show that the crankshafts have a factor of safety in fatigue of 1.48, without taking into account any benefit of shot peening the crankpin fillets. This factor of safety is more than adequate to assure that the crankshafts will not fail in fatigue during operation. The factor of safety was determined from the measured endurance limit of the original 13-inch by 11-inch crankshafts that cracked in high cycle fatigue. The measured crankshaft response was in close agreement with that predicted by the modal superposition analysis. There is, therefore, more than adequate assurance that the crankshafts are suitable for their intended service.

II. BACKGROUND

4. Please briefly describe the function of the crankshaft in the diesel generators at Shoreham.

A. (All) The crankshaft converts the reciprocating (up and down) motion of the pistons and connecting rods into rotary motion. In this process, the crankshaft converts the inertial and gas pressure firing forces into torque, i.e., twisting force. The output torque from the crankshaft drives the electrical generator to provide emergency power.

5. Please briefly describe the failure of the original 13-inch by 11-inch crankshafts at Shoreham.

A. (Montgomery) On August 12, 1983, the original 13-inch by 11-inch crankshaft on EDG 102 fractured through the crankpin and rear (generator end) web under cylinder No. 7. Subsequent investigation revealed that the crankshaft on EDG 101 was significantly cracked at the No. 5 and No. 7 crankpins and the crankshaft on EDG 103 was cracked at the No. 6 crankpin.

6. What was the cause of the crankshaft failure?

A. (Johnston, McCarthy) Based upon extensive metallurgical examinations of the fracture surfaces, the cause of the crankshaft failure was determined to be high cycle vibratory fatigue.

7. What caused the crankshafts to fail in high cycle fatigue?

A. (Johnston, McCarthy) The crankshafts failed in high cycle fatigue due to the torsional (or twisting) stresses imposed upon them during operation. Testing and analysis revealed that the crankshafts experienced torsional excursions beyond their fatigue endurance limit, which ultimately led to their failure.

8. What action did LILCO take after the failure of the original crankshafts?

A. (Montgomery) LILCO did a number of things. First, Failure Analysis Associates (FaAA) was hired to determine the cause of the original crankshaft failure. FaAA's evaluation of the original crankshafts included: (1) a metallurgical failure analysis; (2) dynamic tests performed on the crankshaft from EDG 101; (3) a review of Transamerica DeLaval Inc.'s (TDI) torsional analysis of the Shoreham crankshafts; (4) a modal superposition analysis of the torsional system; and, (5) the development of a model employing finite element analysis to predict stresses imposed on the crankshafts during operation.

Second, after consulting with FaAA and TDI, LILCO ordered replacement crankshafts from TDI of a different design than the original crankshafts. The original crankshafts had a 13-inch main journal and an 11-inch crankpin. The replacement crankshafts have a 13-inch main journal and an 12-inch crankpin. The crankpin-to-web fillet radii of the replacement crankshafts have a larger radius of curvature than the fillet radii of the original crankshafts. Typical structural dimensions of one throw and fillet details are shown in Exhibit C-1. In addition, the fillet regions of the replacement crankshafts have been shot peened. The average ultimate tensile strength of the original crankshafts was approximately 93,500 psi. The minimum ultimate tensile strength of the new crankshafts is over 100,000 psi. The replacement crankshafts have greater section properties, greater material strength and a more enhanced surface treatment (shot peening) than the original crankshafts.

Third, LILCO embarked on an unprecedented program to test and analyze the replacement crankshafts. This program was designed to ensure that the replacement crankshafts are adequately designed to withstand the stresses they will experience during operation in the Shoreham EDGs. This program included: (1) a detailed multi-modal, multi-frequency torsional dynamic analysis of the crankshaft; (2) finite element structural modeling and stress analysis of a single quarter crank throw geometry; (3) field tests on the EDG 103 replacement crankshaft at various power levels to measure the principal stresses in the fillet region of the crankshafts, torsional vibrations (torsiograph tests), cylinder pressure time diagrams, electrical generator output, and transient conditions due to engine start-up and generator load changes; (4) non-destructive examination (eddy current tests) of the crankpin fillets on all three crankshafts at cylinder Nos. 5 - 8 after 100 hours of operation at 100% load or greater; and (5) review of the TDI torsional analysis using conventional Holzer and equivalent static equilibrium amplitude techniques.

III. DESIGN REQUIREMENTS

A. The Crankshafts Must Comply with DEMA

9. What were the design requirements for the replacement crankshafts?

A. (Montgomery) The replacement crankshafts were required to meet the recommendations of the Diesel Engine Manufacturers Association (DEMA). Stone & Webster's Specification for Diesel Generator Sets, Spec. No. SH1-89, Revision 2, January 26, 1983 (Spec. SH1-89) required that:

> The diesel engines and auxiliaries shall be designed, engineered, manufactured, and tested in accordance with the latest published applicable sections of the Standards of the Diesel Engine Manufacturers Association (DEMA), at least, but not limited to DEMA "Standard Practices for Low and Medium Speed Stationary Diesel Engines."

The relevant portion of Spec. SH1-89 is attached as Exhibit C-2.

10. Do the replacement crankshafts meet the DEMA recommendations?

A. (All) Yes. As will be discussed in detail later, the crankshafts meet the recommendations of DEMA, both for operation at full load (3500 KW) and at overload (3900 KW).

11. The County contends the replacement crankshafts are inadequately designed for operation at full load (3500 Kw) or overload (3900 KW) because they do not meet the requirements of the American Bureau of Shipping (ABS), Lloyd's Registry of Shipping (Lloyd's), or the International Association of Classification Societies (IACS). In addition, under the German criteria used by FEV, the crankshafts are marginal at full load and inadequate at overload. Is there any basis for this contention?

A. (Montgomery) No. There is no licensing requirement, either in the Shoreham FSAR or in any applicable Nuclear Regulatory Commission regulation or guideline, that the replacement crankshafts meet any of these criteria. In fact, the only standby diesel generator design criteria currently referred to in an NRC Regulatory Guide is DEMA.

12. Please explain.

A. (Montgomery) NRC Regulatory Guide 1.9, Revision 2 (December 1979) (Exhibit C-3), addresses the design of standby diesel generator units at nuclear power plants. The Regulatory Guide provides:

> Conformance with the requirements of IEEE Std 387-1977, "IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations," dated June 17, 1977, is acceptable for meeting the requirements of the principal design criteria and qualification testing of diesel-generator units used as onsite electric power systems for nuclear power plants. . . .

IEEE Std 387-1977 (Exhibit C-4), provides:

> 4.1 Standards. The equipment and accessories of the diesel-generator unit shall conform to the applicable portion of the following standards and the latest revisions thereof, as of the date of approval of this document.

* * *

[5] DEMA, Standard Practices for Low and Medium Speed Stationary Diesel and Gas Engines.

Nowhere is there any requirement that the crankshafts meet the criteria established by ABS, Lloyd's, IACS or FEV. As Dr. Carl Berlinger, NRC Lead Engineer for the Assessment of Diesel Engine Reliability/Operability, stated at the July 11, 1984 meeting of the TDI Owners Group:

> NRC does not require the use of Lloyd's and specifically references DEMA, and we would not propose to require that this design be compared to Lloyd's. I don't know whether we really need any additional discussion relative to what standard to use as a basis for licensing or approval of these crankshafts.

The relevant portion of the transcript is attached as Exhibit C-5.

Furthermore, the determination of the fatigue endurance limit of the crankshafts, independent of any code or design requirements, establishes that the replacement crankshafts are adequate for their intended service.

B. <u>The Crankshafts Do Not Have to Comply with ABS, Lloyd's, IACS or the Criteria Used by F.E.V.</u>

13. Notwithstanding that there is no licensing requirement that the crankshafts meet any of these design criteria, is it necessary for the crankshafts to meet the standards of ABS, Lloyd's, IACS or the criteria used by FEV to be considered adequate and reliable for their intended use in the Shoreham EDGs?

A. (Montgomery, Chen) No. The replacement crankshafts have been demonstrated to be adequate and reliable by an extensive program of testing and analysis. This program clearly establishes, apart from any code, that the crankshafts will perform their intended function.

In addition, there is extensive experience with 13-inch by 12-inch crankshafts in DSR-48 engines that establishes the crankshafts are reliable. A table showing the operating history of DSR-48 engines with 13-inch by 12-inch crankshafts is attached as Exhibit C-6. An additional table showing the operating history of each of the Shoreham engines is attached as Exhibit C-7. The crankshafts were all inspected after 100 hours of operation at full load or greater by eddy current inspection. This inspection revealed no relevant indications or crack formations on the crankshafts after more than one million torsional peak stress reversals. The results of the eddy current inspection are attached as Exhibit C-8. Finally, the crankshafts comply with the DEMA recommendations for torsional vibratory stresses.

14. The County contends DEMA is not a design code and that it should not be used to determine the adequacy of the crankshafts. Do you agree?

A. (Chen) I agree that DEMA is not a design code. That is to say, DEMA does not tell an engine manufacturer how to design a crankshaft. However, I do not agree that DEMA does not provide standards to measure the adequacy of a crankshaft. DEMA provides specific stress limits for crankshafts: 5,000 psi for a single order of vibration and 7,000 psi for the summation of the major orders. Engine manufacturers have used DEMA for years on stationary diesel generator installations to determine whether a crankshaft is adequate for its intended service. In addition, in over thirty (30) years of experience with diesel engines, I have never seen a crankshaft that complied with DEMA fail primarily from torsional fatigue.

15. The County states at page 114 of its testimony that "at a minimum, the crankshafts should be compatible with the rules of all the major classification societies." Do you agree with this statement?

A. (Chen) No. In fact, this statement is absurd. No reasonable person would say that a crankshaft had to comply with the rules of all major societies to be considered adequate. The rules, standards and design methodologies of design societies vary widely and, in fact, provide differing acceptance criteria for the same crankshaft design parameters (e.g., journal/pin sizing, allowable horsepower, allowable torsional stress levels, etc.). A crankshaft may not meet the criteria of certain codes and be perfectly adequate under other codes. Furthermore, certain of the codes explicitly recognize that special consideration should be given to detailed stress analyses and test data if a crankshaft does not comply with literal code requirements. For example, Section 37.17.1 of the 1983 ABS rules on the diameter of pins and journals (Exhibit C-9) provides:

> Where critical dimensions are proposed which are less than those determined by the above equation, complete supporting data, including detailed stress analysis, are to be submitted for special consideration.

In addition, note 3 to Table 34.3 of the 1983 ABS rules concerning Allowable Stress Values for Crankshafts and Tail Shafts Due to a Single Harmonic (Grade 2 Steel) (Exhibit C-10) provides:

> If torsional critical speed arrangements are similar to previous installations proven by service experience, consideration will be given to higher stresses upon submittal of full details.

In sum, the best way to evaluate a crankshaft is through engineering analysis. The County's suggestion that the crankshafts should comply with selected aspects of various codes (i.e., the most conservative part of each code) has no foundation.

16. Is a crankshaft inadequate if it does not comply with ABS, Lloyd's, IACS or the criteria used by FEV?

A. (Chen) No. A crankshaft may be structurally adequate for its intended service and not comply with ABS, Lloyd's, IACS or the FEV criteria. While compliance with one of the codes generally provides assurance that a crankshaft is adequate, noncompliance does not necessarily mean a crankshaft is inadequate. Rather, noncompliance merely means a crankshaft does not meet the design requirements of a particular code. If a crankshaft is not required to meet that code by specification or other requirement (e.g., insurance purposes, licensing requirements, etc.), and there is assurance from other sources (such as testing or detailed engineering analysis) that the crankshaft is adequate, noncompliance is not significant.

Furthermore, the critical surface temperature and various stress levels of an operating marine engine vary considerably depending upon ship hull design, swells, wind and other sea-ship interactions, as well as the type of fuel used. That is why the marine engine classification rules are more stringent than the rules for stationary land-based engines. A stationary engine, which is perfectly adequate, might or might not pass one or more of the marine codes.

17. What is the most accurate way to assess the adequacy of a crankshaft?

(A) (All) The most accurate way to assess crankshaft adequacy is not to rely upon the design criteria of any code. Rather, the most accurate way to assess crankshaft reliabilty is to perform the type of tests and analyses that were performed on the Shoreham crankshafts. This information permits the calculation of actual operating stress states, separate and apart from compliance with the standards of any code.

18. You have just described the most accurate way to

assess the adequacy of a crankshaft. Why are not all crankshafts assessed in this manner?

A. (All) Most crankshafts are not assessed in this manner because the design review normally occurs before the crankshaft is manufactured. This is where design codes are used. It is normally impossible to measure the actual stresses from tests on the crankshaft because the crankshaft does not exist when it is being designed. Because of the uncertainty in predicted loads and response, these design codes are very conservative.

Unfortunately, LILCO had the luxury of having data available from a smaller crankshaft that failed in the same engines. This allowed calculation of the fatigue endurance limit for the replacement crankshafts. This type of data is extremely useful, but it is normally unavailable. In the absence of this detailed information, design codes are relied upon to provide assurance of crankshaft adequacy.

19. Notwithstanding that the crankshaft is not required to meet any of these codes, has the crankshaft been approved by any of these ship classification societies?

A. (Montgomery) Yes. ABS has approved the crankshaft dimensional sizing for diameter of pins and journals and proportions of the crankshaft webs. A copy of the crankshaft drawing certified by ABS is Exhibit C-11. ABS has certified that the material properties of the replacment crankshafts conform to the requirements of ABS grade 4 specifications. A copy of the material properties certification is Exhibit C-12. Finally, ABS has stated that it would approve the torsional critical speed arrangement of the crankshaft, flywheel and generator at Shoreham for use on an ocean going vessel. A copy of ABS's letter of approval is Exhibit C-13.

20. The County contends ABS's approval is suspect because the information submitted to ABS was deficient in four specific areas: (1) shot peening; (2) maximum firing pressures; (3) strain gage measurement; and (4) operating experience. Please respond to each of these areas.

A. (Montgomery) The County claims the information on shot peening was inaccurate because TDI took credit for a 20% increase in the fatigue limit and there was no discussion of the first shot peening by TDI. As the separate testimony of Messrs. Wells, D. Johnson, Wachob, Seaman, Cimino and Burrell clearly demonstrates, the shot peening does increase the fatigue limit by up to 20%.

21. The County contends that maximum firing pressures as high as 1750 psi have been measured at full load. ABS was informed that the maximum firing pressure at full load was 1700 psi. Please discuss.

A. (Montgomery) The County is simply wrong. The documents relied upon by the County to show that peak firing pressures of 1750 psi have been measured at full load (TDI test logs attached to Suffolk County Exhibit 46) clearly show that the pressures above 1700 psi were measured at 110% of full load. The maximum firing pressure of 1700 psi relied upon by

ABS is correct. A fuller discussion of the inaccuracy of the County's contention concerning maximum firing pressure is contained in the testimony of Messrs. Harris, et al., on pistons.

22. The County contends TDI did not inform ABS that the strain gage test results were only accurate to within ± 5%. Is this significant?

A. (All) There is no significance to the fact that ABS was not informed that the strain gage test results were only accurate to within ± 5%. This is the expected degree of accuracy for field test results of this type.

23. Finally, the County contends TDI did not submit accurate information on the operating experience of the DSR-48 engines. Please discuss.

A. (Montgomery) The operating history submitted for the Shoreham engines was complete and accurate. The information submitted is attached as Exhibit C-6. This clearly shows the number of hours the Shoreham engines have operated at and above 3500 KW. In addition, there was no reason to submit information concerning block cracking since block data is not used in ABS's design rules for crankshafts. ABS was only asked to review the torsional critical speed arrangement. ABS was provided complete and accurate information for the Shoreham engines and approved the crankshafts on that basis.

IV. THE CRANKSHAFTS COMPLY WITH DEMA

24. Do the replacement crankshafts meet the recommendations of DEMA?

A. (Johnston, Chen) Yes, conventional analytical techniques typically utilized by the diesel engine industry show that the replacement crankshafts comply with the recommendations of DEMA.

25. What are the DEMA recommendations for crankshafts?

A. (Johnston, Chen) The DEMA recommendations for allowable crankshaft vibratory stress (Exhibit C-14) state:

> In the case of constant speed units, such as generator sets, the objective is to insure that no harmful torsional vibratory stresses occur within five percent above and below rated speed.
>
> For crankshafts, connecting shafts, flange or coupling components, etc., made of conventional materials, torsional vibratory conditions shall generally be considered safe when they induce a superimposed stress of less than 5000 psi, created by a single order of vibration, or a superimposed stress of less than 7000 psi, created by the summation of the major orders of vibration which might come into phase periodically.

26. How did you determine that the crankshafts complied with DEMA?

A. (Johnston) In August, 1983, TDI performed a torsional critical speed analysis of the replacement crankshafts. (Exhibit C-15). FaAA reviewed this analysis for compliance with the DEMA allowable stresses. In addition, in January, 1984, Stone & Webster Engineering Corporation, conducted torsiograph tests on a replacement crankshaft at Shoreham. (Exhibit C-16). FaAA compared the test results with the DEMA allowable stresses. Based upon the review of TDI's torsional analysis and Stone & Webster's torsiograph tests, FaAA concluded the crankshafts complied with DEMA at full load (3500 KW) and overload (3900 KW). FaAA's conclusions are contained in the TDI Owners Group Crankshaft Report. (Exhibit C-17).

(Chen) In addition, I performed independent calculations (Exhibit C-18) to determine whether the crankshafts met the recommendations of DEMA. These calculations employed an internationally known computer program (TORVAP), which is widely used by the diesel engine manufacturers industry to measure nominal crankshaft torsional stresses. On the basis of these independent calculations, I determined that the replacement crankshafts complied with DEMA at full load (3500 KW) and overload (3900 KW).

27. What is a torsional critical speed analysis?

A. (Johnston, Chen) A torsional critical speed analysis is a method of calculating the torque being transmitted through a crankshaft in a diesel engine at a particular speed and power level. When operating at a particular speed and power level, the torque being transmitted through a crankshaft in a diesel engine varies with time and location. For a four-stroke engine, the torsional stress relationship over time repeats itself every two revolutions of the crankshaft. The maximum torque on the crankshaft at any instant may be much larger than the mean torque required to run the engine at a given speed and power level. This additional torque is caused by a number of factors, including the cylinder firing order (excitation) and the presence of natural torsional modes of vibration of the crankshaft. To determine the maximum torque applied to the crankshaft, it is necessary to conduct a torsional critical speed analysis. Once the maximum torque has been calculated, it is simple to calculate the nominal torsional stresses for comparison to DEMA allowable stresses.

28. How was TDI's torsional critical speed analysis conducted?

A. (Johnston, Chen) TDI calculated the response of the crankshaft at 100% of rated load (3500 KW). The torsional analysis conducted by TDI was of two parts. First, TDI used an analytical technique, known as the Holzer method, to compute the natural frequencies and modes of vibration of the crankshaft system. If you strike a tuning fork, it will tend to vibrate at a particular frequency that is called its natural frequency. Similarly, a twisting force exerted on a crankshaft will induce the shaft to vibrate at certain discrete natural frequencies. The shape or angle of twist as a function of position along the shaft is unique for each natural frequency, and this is often referred to as a mode shape. The Holzer method permits the manufacturer to calculate the predicted natural frequencies of the various modes of vibration that will result from torsional forces exerted on the crankshaft during operation.

TDI used the Holzer method to calculate the system's first three natural frequencies, which are shown in Exhibit C-19. In a four stroke engine such as the Shoreham diesel generators, operation at the fourth order critical speed produces the maximum stresses. The fourth order critical speed calculated by TDI is 581 rpm. The Shoreham engines operate at 450 rpm, which is significantly below the fourth order critical speed.

29. What is the second step of the analysis?

A. (Johnston, Chen) The second step in a torsional critical speed analysis is to determine the dynamic torsional response of the crankshaft due to gas pressure and reciprocating inertia loading for each order. The first order is a harmonic which repeats once per revolution of the crankshaft. For a four-stroke engine, harmonics of the order 0.5, 1.0, 1.5, 2.0, 2.5. . . exist. TDI performs this calculation separately for each order of vibration up to 12. For each order, the applied torque and nominal torsional stress at a cylinder due to gas pressure and reciprocating inertia is calculated.

30. What was the result of TDI's analysis and how did the result compare to DEMA allowables?

A. (Johnston) TDI calculated the response for the first three modes and plotted the results for only the first mode, since higher modes produce much smaller stresses. The nominal shear stresses for the significant orders are shown in Exhibit C-20. The largest single order stress at rated load and speed is for the fourth order. This stress, 2980 psi, is well below the 5000 psi allowed by DEMA. Due to the analytical technique TDI employed, TDI did not calculate the torsional stresses created by the summation of the major orders of vibration for purposes of comparison with the DEMA allowable of 7000 psi.

31. Given that TDI only calculated single order stresses, what further action was taken to assure that the crankshafts complied with DEMA?

A. (Johnston) Stone & Webster performed torsiograph tests on the replacement crankshaft in EDG 103 in January, 1984 at various power levels. (Exhibit C-16). The torsiograph tests measured the total torsional vibrations resulting from all orders. These torsional vibrations were converted into stresses for comparison with DEMA.

32. How is a torsiograph test performed?

A. (Johnston, Chen) A torsiograph test is performed by placing a seismic instrument (a device for measuring angular displacement due to vibration) on the end of a crankshaft and recording the angular displacement due to vibration under different engine operating conditions.

The test is usually performed in two stages. The first stage is without load and is used to determine the location of critical speeds, or natural frequencies, of the crankshaft. This is done by varying the speed of the engine and recording the vibratory response. As the frequency of vibration for any orde approaches a natural frequency of the shaft, the amplitude of vibrations will increase and reach a peak at the natural frequency. If you know the engine speed where this peak vibration occurs, it is simple to calculate the natural frequency. Critical speeds may also be determined while operating at a fixed speed and observing the frequency content of the response.

33. How did the natural frequency measured by Stone & Webster compare to the natural frequency computed by TDI?

A. (Johnston) The frequency content of the torsional vibration signal at 450 rpm showed a resonance at 38.6 Hz. This value is in excellent agreement with TDI's computed value of 38.7 Hz. This comparison demonstrates that the mass elastic properties used in TDI's analysis for representation of the crankshaft are correct.

34. What is the second stage of the torsiograph test?

A. (Johnston, Chen) The second stage is to determine nominal stresses in the crankshaft under various load conditions. This test is performed at rated speed of 450 rpm with variable load. The purpose of this test is to confirm the forced vibration calculations.

The torsiograph provides the angular displacement response (the angle of twist) of the free end of the crankshaft as a function of time. This displacement may be decomposed into components corresponding to each order. The torsiograph also provides the peak-to-peak response. These responses are used to calculate the nominal stresses.

35. How were the nominal stresses determined from the torsional vibrations measured by Stone & Webster?

A. (Johnston) Stone & Webster tabulated the single order and peak-to-peak torsional vibration response for both 3500 KW (100% of rated load) and for 3800 KW (109% of rated load). FaAA factored these values to obtain nominal shear stresses, which are shown in Exhibit C-21. The results at 100% load show that the largest single order (the fourth order) has a stress of 3108 psi, which is well below the DEMA allowable of 5000 psi. The total stress of 6626 psi is also below the DEMA allowable of 7000 psi.

At 3800 KW the stresses of 3242 psi for a single order and 6875 psi for combined response are also lower than 5000 psi and 7000 psi respectively. At 3900 KW the corresponding stresses are 3287 psi and 6958 psi, by linear extrapolation. The measured response at 3500 KW is in close agreement with that calculated by TDI.

36. Did FaAA calculate the stresses at 95% and 105% of rated speed?

A. (Johnston) Yes, we calculated the fourth order and total stresses at 95% and 105% of rated speed. On the basis of our calculations, we conclude that the stresses at those speeds satisfy the DEMA allowables.

37. What conclusions did FaAA draw from the stresses calculated from the torsiograph test data and the stresses calculated analytically by TDI?

A. (McCarthy, Johnston) The design calculations on the 13-inch by 12-inch crankshafts performed by TDI are appropriate and show that the crankshaft stresses are below DEMA recommendations for a single order. Combined stress was not calculated by this method, but was determined by torsiograph testing. The Stone & Webster torsiograph test results show that the 13-inch by 12-inch crankshaft stresses are below the DEMA recommended levels for both single order and combined orders for both 3500 KW (100% rated load) and 3800 KW. A linear extrapolation to 3900 KW also shows compliance. In addition, no harmful torsional vibratory stresses occur within 5% above and 5% below rated speed.

38. Dr. Chen, do your calculations also show that the replacement crankshafts comply with DEMA?

A. (Chen) Yes.

39. Please describe your calculations.

A. (Chen) I calculated the natural frequencies, as well as the torsional stresses of the engine generator system using the TORVAP R and TORVAP C computer programs. I calculated the response for single orders and combined orders. I also calculated the torsional vibration at the free end of the crankshaft. The calculations I performed are typical of the calculations performed by the diesel engine industry to check the adequacy of a crankshaft to withstand torsional stress.

40. What were the results of your natural frequency calculations?

A. (Chen) The natural frequency calculations are essentially identical to the natural frequency calculations of TDI and FaAA. The results are shown in the following table:

Mode	TDI	FaAA	PEI
1st	2323.2	2323.8	2323.3
2nd	5575.5	5576.4	5575.2
3rd	7000.3	7002.0	7000.4

41. What were the results of your free end amplitude calculations?

A. (Chen) The results of the free end amplitude calculations are in close agreement to the values calculated by FaAA and measured by Stone & Webster. The results for the fourth order and the combined response are shown in Exhibit C-22.

42. What were the results of your single order nominal stress calculations?

A. (Chen) The maximum torsional stresses are caused by the fourth order. I calculated the fourth order stresses for all modes. This contrasts to TDI's calculation, which only allows the calculation of fourth order stresses for single modes. I calculated these stresses at full load, overload, 95% of rated load and 105% of rated load. The fourth order stresses are as follows:

Fourth Order Stresses

RPM	KW	PSI
450	3500	3455
450	3900	3740
427.5	3500	3071
472.5	3500	4010

43. What was the result of your sum of orders response and nominal stress calculation?

A. (Chen) The sum of orders stresses at full load, overload, 95% and 105% of rated load are as follows:

Sum of Orders Stresses

RPM	KW	PSI
450	3500	5101
450	3900	5401
427.5	3500	6232

472.5 3500 5673

44. Do the crankshafts comply with DEMA at overload conditions?

A. (Chen) Yes. At 3900 Kw the fourth order stress is 3740 psi and the sum of orders stress is 5401 psi. These figure are well within the DEMA allowables. It should be noted that DEMA does not require stress calculations at overload conditions. Nonetheless, the replacement crankshafts are within the DEMA stress limits at overload.

45. Dr. Chen, have you ever seen crankshafts that have failed from torsional stress?

A. (Chen) Yes. I have seen quite a few crankshafts that have failed from torsional stress.

46. Are you aware of any crankshafts that comply with DEMA that have failed primarily due to torsional stress.

A. (Chen) No. In more than thirty (30) years of experience in the diesel engine industry, I do not know of any situations in which a crankshaft that met DEMA recommendations has failed primarily from torsional fatigue. I was chairman of the DEMA Technical Committee from 1971 through 1973 and I can state with confidence that a crankshaft that complies with DEMA is reliable for its intended service.

V. THE FATIGUE ANALYSIS AND FIELD TESTING OF THE CRANKSHAFTS SHOW THAT THE CRANKSHAFTS WILL NOT FAIL DURING OPERATION

47. What is the purpose of a fatigue analysis?

A. (McCarthy, Johnston) The purpose of a fatigue analysis is to determine the useful life of a given component (in this case a crankshaft) for its specified service loads. FaAA performed a fatigue analysis which enabled us to conclude that the crankshafts have unlimited life for their intended service.

48. Why did FaAA perform a fatigue analysis of the crankshafts?

A. (McCarthy, Johnston) Although the crankshafts meet the nominal stress recommendations of DEMA for operation at 3500 KW and 3900 KW, the stresses for combined orders calculated from the torsiograph measurements are close to the recommended allowable of 7000 psi. (The stresses for single orders are considerably lower than the recommended allowable of 5000 psi.) While the DEMA limits are believed to contain an intrinsic safety margin, a fatigue analysis was performed to determine the true safety margin of the crankshafts and to provide an additional measure of assurance, independent of design criteria specified by <u>any</u> code, that the crankshafts are adequately designed to perform their intended function in the Shoreham EDGs.

49. How was the fatigue analysis conducted?

A. (Johnston, McCarthy) To conduct a fatigue analysis FaAA had to determine the maximum stresses the crankshafts would see in service, as well as the endurance limit for the crankshaft material. FaAA performed a two part analysis to determine the maximum stresses. First, a dynamic torsional analysis of the crankshaft was performed to determine the true range of torque at each crank throw. Second, using the results of the dynamic torsional analysis, a finite element model of a one quarter crank throw was used to compute the magnitude and location of peak stresses in the fillet region. Torsional and gas pressure loading cases were considered in the finite element model to evaluate the effects of twisting and bending loads. These analyses permitted FaAA to determine the maximum stresses. These stresses were also obtained from a dynamic strain gage test on the replacement crankshaft.

The fatigue endurance limit was established for the replacement crankshaft by first obtaining the endurance limit for the failed crankshafts, and then increasing that limit to reflect the difference in ultimate tensile strength between the failed and replacement crankshafts. The endurance limit was compared with values provided in the literature and found to be acceptable. The factor of safety against fatigue failure was computed from the test data gathered from the original and replacement crankshafts. The factor of safety is large enough to provide confidence in the reliability of the crankshafts.

50. Let us discuss separately each part of the fatique analysis. What is the purpose of a dynamic torsional analysis?

A. (Johnston) FaAA developed a dynamic torsional model of the crankshaft to determine the total torque at each crank throw. The total torque is calculated by a summation of the torque produced by each order and mode. The analytical method used by FaAA computes the phase relationship between the various orders and modes, which permits this summation. The dynamic torsional analysis represents a more accurate calculation of the stresses actually experienced by the crankshaft during operation than conventional analytical techniques. (Technical details of the dynamic torsional model are contained in Section 3.1 of Exhibit C-17).

51. What did you do with the total torque calculated from the dynamic torsional analysis?

A. (Johnston) The total torque was used as input data to the finite element model to determine the actual maximum state of stress in the crankshaft.

52. What was the purpose of constructing a finite element model of a one quarter crank throw?

A. (Johnston) The nominal crankshaft stress values calculated from the dynamic model (i.e. total torque) are considerably less than the actual maximum stresses in the crankshaft. Those nominal values would prevail if the crankshaft were a long circular cylinder. Stresses in the real crankshaft are greatly influenced by its complex geometry and by stress concentrations, especially at the fillet radii between the main journal and web and the crankpin and web. In addition, a crankshaft throw is subjected to loads of two basic types: (1) torque transmitted through the throw, which is influenced by the output power level and by the torsional vibration response of the crankshaft; and, (2) connecting rod forces applied to the crankpin and reacted at bearing supports. A finite element model of a one quarter crank throw, considering stresses due to torsional loading and stresses due to gas pressure loading, was used to compute the actual maximum value and location of stresses in the crankpin fillet area. The strain gages used during dynamic testing were placed at the location of maximum stress calculated by the finite element model. (Technical details concerning the finite element model are contained in Section 3.2 of Exhibit C-17).

53. Please describe the dynamic testing.

A. (Johnston) Stone & Webster conducted dynamic tests on the replacement crankshaft on EDG 103 in January, 1984. Instrumentation for the measurement and recording of significant dynamic data included the following:

1. Cylinder firing pressure of cylinder Nos. 5 and 7 was measured;

2. Dynamic torque in the crankshaft between the engine casing and the flywheel was measured by a strain gage torque bridge;

3. Crankpins Nos. 5 and 7 were instrumented with three element strain rosettes to measure crankpin fillet dynamic strains.

These tests were performed under a variety of loads and transient conditions to investigate the dynamic response of the crankshaft.

54. How were the results of these tests used in FaAA's analysis?

A. (Johnston) First, the cylinder firing pressure measured by Stone & Webster was utilized to obtain the gas pressure loading for input to the dynamic torsional analysis. The total torque produced by this loading was calculated and corresponds closely to the torque measured by Stone & Webster near the flywheel. (Exhibit C-23). Second, the dynamic strains measured by Stone & Webster in the crankpin fillets of crankpin Nos. 5 and 7 were used to compute the maximum stresses, which were used to calculate the factor of safety. These stresses are within the range predicted by FaAA's finite element analyses. (Exhibit C-24).

55. Are the results of Stone & Webster's dynamic torsional testing confirmed by the analytical models used by FaAA?

A. (Johnston, McCarthy) Yes. The results of FaAA's analytical models agree with the dynamic strain gage tests. Dynamic testing of the crankshaft, in this regard, is considered to be an essential element of the design review program because it is only through carefully conducted measurement that the actual engine dynamics and local component stresses are confirmed.

56. After measuring the maximum stresses in the fillet area, what was the next step in your analysis.

A. (Johnston) The next step in the analysis was to compare the measured stresses with the fatigue endurance limit of the replacement crankshafts. The results of the finite element analysis were used to determine the maximum principal stress range in the fillet area, which was then compared to the fatigue endurance limit of the replacement crankshaft.

57. How was the fatigue endurance limit of the replacement crankshaft established?

A. (Johnston) The fatigue endurance limit of the replacement crankshaft was established by first obtaining the endurance limit of the failed crankshaft. Since the endurance limit scales linearly with ultimate tensile strength, the endurance limit of the replacement crankshaft was increased to reflect the difference in ultimate tensile strength between the failed and replacement crankshaft.

58. How was the endurance limit established for the original crankshafts?

A. (Johnston) The original 13-inch by 11-inch crankshaft on EDG 101 was instrumented with strain gages in the fillet location of Crankpin No. 5. This fillet had previously experienced a fatigue crack during performance testing. After the test, the three-dimensional finite element model of a quarter section of a crank throw showed that the strain gages were placed close to the location of maximum stress. The measured stress range was used to establish the endurance limit in this analysis as a conservative assumption, although the actual maximum stress range was revealed by the finite element model to be about 15% higher at a nearby location. The original crankshaft on EDG 102 had experienced 273 hours at equal to or greater than 100% load, or about 4,000,000 cycles. By using linear cumulative damage techniques, it was determined that the endurance limit for the original crankshafts was 36.5 ksi.

59. What is the fatigue endurance limit for the replacement crankshafts?

A. (Johnston) The fatigue endurance limit for the replacement crankshafts is 39.2 ksi. This is higher than the fatigue endurance limit for the original crankshafts because the ultimate tensile strength of the replacement crankshafts exceeds the ultimate tensile strength of the original crankshafts.

60. Having obtained the fatigue endurance limit for the replacement crankshafts, were you able to calculate the factor of safety against fatigue failure?

A. (Johnston) Yes. The factor of safety against fatigue failure was calculated by plotting the maximum principal stress range measured in the crankpin fillet area on a Goodman diagram, constructed using the fatigue endurance limit and the ultimate tensile strength values for the replacement crankshafts. (Exhibit C-25). The factor of safety against fatigue failure is 1.48, without taking into account any beneficial effect of shot peening the fillet regions.

61. Does a factor of safety of 1.48 provide sufficient assurance that the replacement crankshafts are adequate for their intended service in the Shoreham EDGs?

A. (McCarthy) Yes.

62. What is the basis for your opinion that a factor of safety of 1.48 is sufficient for the replacement crankshafts?

A. (McCarthy) To explain that I must first explain what a factor of safety is. With that understanding, the acceptability of a factor of 1.48 will become apparent.

63. What is a factor of safety?

A. (McCarthy) A factor of safety is an additional margin of strength, in either the fatigue strength (endurance limit), yield strength, or ultimate strength, that is added to a mechanical design to compensate for uncertainties, i.e. effects or things we don't know. There is significant confusion often generated by a failure to identify whether a stated factor of safety is with regard to fatigue or endurance limit, yield, or ultimate strength. The factor of safety with regard to these three different failure modes will generally be different for the same design or part.

64. What is the difference between a factor of safety in endurance limit, yield strength, and in ultimate strength?

A. (McCarthy) A factor of safety in endurance limit is the factor of strength the part or design has over that required for the part to be expected to exhibit infinite life, or a life of some specified number of cycles in repeated or cyclic loading. A factor of safety in yield is the factor the yield strength of the part is greater than the expected service load. Similarly the factor of safety in ultimate strength or overload failure is the factor the breaking strength of the part is greater than the expected service load. In older design references it is not uncommon to see a very large factor of safety in overload recommended, and no mention of a factor of safety in endurance limit or fatigue strength, for parts that were cyclically loaded and could fail in fatigue. This was before fatigue and stress concentration effects were as well understood as they are now.

65. What types of uncertainties is the factor an allowance or compensation for?

A. (McCarthy) Uncertainties as to service load, material properties, stress concentration factors, lifetime, etc., which obviously are directly related to the amount of testing, analysis, and understanding a designer has of a particular part and its service environment.

66. What is an acceptable allowance for this uncertainity, or, in other words, what is an acceptable factor of safety?

A. (McCarthy) This is totally determined by the degree of uncertainity and the difficulty or penalties of adding additional strength to the design. Where the design envelope and the nature of the fabricated part are reasonably understood, a factor of safety in fatigue or cyclic loading of 1.3 to 2.0 is generally recommended. When the uncertainty of design factors is greater, higher values will be recommended. Some design texts will recommend that, if the designer is seriously considering a factor of safety of greater than two, he should devote additional time to analyzing the design, rather than accepting the ignorance which is causing him to select a higher factor of safety. Portions from several of the most widely used Mechanical Engineering design references are attached as Exhibit C-26. A factor of safety of 1.48 in fatigue or endurance limit will produce a much higher factor of safety with regard to yielding or overload failure.

67. How well is the design of the replacement crankshafts understood?

A. (McCarthy) To put it simply, extremely well. We have the benefit of the information gained from the failure of the original crankshafts, full scale instrumented tests of the actual service loading, material strength tests for the individual parts, torsiograph testing, and extensive three dimensional analytical modeling of the structure. The crankshaft is being run in a temperature controlled, oil filled environment. It is completely guarded from accidental and unanticipated impact by foreign objects by the engine block. Usually a designer has far, far less information to work with when assessing a design. This results in uncertainities in the design being reduced substantially.

68. What does this understanding of the crankshaft design mean in terms of an acceptable factor of safety.

A. (McCarthy) For well understood designs operating in environments that are not severe, a factor of safety in fatigue or endurance limit of 1.3 to 1.5 is generally accepted. For this particular part, it would be my opinion that our degree of understanding would certainly permit the use of a safety factor at the lower end of this range, when in fact the actual safety factor is at the high end. Therefore the factor of 1.48 is quite acceptable.

Attachment 1

Failure Analysis Associates

ROGER L. McCARTHY

Specialized Professional Competence

Mechanical, machine, and mechanism design. Dynamic mechanical system design, analysis modeling, control (including dedicated computer control), and failure analysis. Custom product design. Human factors engineering and testing; design analysis of man/machine interface. Design analysis research. Risk analysis; quantification of hazards posed by design and construction of mechanical components, products, or system failure in the industrial and transportation environments. Design analysis through large scale accident data analysis and evaluation, including vehicle design and collision performance. Evaluation of mechanical/electrical design-related explosion hazard; heat transfer design. Reinforced polymer composite design analysis, including tires. Patent analysis relating to mechanical design.

Background and Professional Honors

A.B. (Philosophy), University of Michigan, with High Distinction
B.S.E. (Mechanical Engineering), University of Michigan, summa cum laude
S.M. (Mechanical Engineering), Massachusetts Institute of Technology
Mech.E. (Mechanical Engineering), Massachusetts Institute of Technology
Ph.D. (Mechanical Engineering), Massachusetts Institute of Technology

President,
Failure Analysis Associates
Principal Design Engineer
Failure Analysis Associates
Program Manager, Special Machinery Group,
Foster-Miller Associates, Inc.
Project Engineer, Machine Design and Development Engineering, Engineering Development Division,
Proctor & Gamble Company, Inc.

Registered Professional Mechanical Engineer, California, #M20040
Registered Professional Mechanical Engineer, Arizona, #13684
Phi Beta Kappa, Sigma Xi, James B. Angell Scholar
National Science Foundation Fellow
Outstanding Undergraduate in Mechanical Engineering, University of Michigan

Member, American Society of Metals, American Society of Mechanical Engineers, Society of Automotive Engineers, American Welding Society, National Safety Council, American Society for Testing and Materials
Member, American Society of Safety Engineers
Member, Human Factors Society, System Safety Society, National Society of Professional Engineers
Member, American Society of Heating, Refrigeration, and Air-Conditioning Engineers
Member, National Fire Prevention Association

Selected Publications

"School Bus Wheel Rim Safety — Multipiece vs. Single Piece," National School Bus Report, Springfield, Virginia (December 1982) (with G. E. McCarthy).

"Warnings on Consumer Products: Objective Criteria For Their Use," 26th Annual Meeting of the Human Factors Society, Seattle, Washington (October 25-29, 1982) (with J. N. Robinson, J. P. Finnegan and R. K. Taylor).

"Average Operator Inaction Characteristics with Lever Controls — Study of the Column Mounted Gear Selector Lever," 26th Annual Meeting of the Human Factors Society, Seattle, Washington (October 25-29, 1982) (with J. P. Finnegan, G. F. Fowler and S. B. Brown).

"Catastrophic Events: Actual Risk versus Societal Impact," 1982 Proceedings, Annual Reliability and Maintainability Symposium, Los Angeles, California (January 26-28, 1982) (with J. P. Finnegan and R. K. Taylor).

"Product Recall Decision Making: Valid Product Safety Indicators," Proceedings of the Fourth International System Safety Conference, San Francisco, California (July 9-13, 1979). Published by Professional Engineer Magazine (March 1981).

"Large Vehicle Wheel Servicing: Reduction of Risk Through Implementation of An OSHA Standard Governing Multipiece and Single Piece Rims: Phase IV," Published by the National Wheel and Rim Association (March 1981) (with J. P. Finnegan).

"Program to Improve Down Hole Drilling Motors: Task 2, Lip Seal Design," Failure Analysis Associates Report FAA-81-7-6 to Sandia National Laboratories (October 1980) (with V. Pedotto).

"A Safety and Fracture Mechanics Analysis of the Pneumatic Tire: A Perspective on the Firestone 500 Radial Tire," Presented at the International Conference on Reliability, Stress Analysis and Failure Prevention, of the American Society of Mechanical Engineers, San Francisco, California (August 18-21, 1980) (with W. G. Knauss).

"Multipiece and Single Piece Rims: The Risk Associated with Their Unique Design Characteristics: Phase III," Published by the National Wheel and Rim Association (June 1980) (with J. P. Finnegan).

"An Engineering Safety Analysis of the Steel Belted Radial Tire," Society of Automotive Engineers Paper #800840 (June 9-13, 1980).

"A Simple Technique to Improve the Allocation of Safety Inspection Resources," Proceedings of the Fourth International System Safety Conference, San Francisco, California (July 9-13, 1979) (with P. M. Besuner).

"An Engineering Analysis of the Risk Associated with Multipiece Wheels," National Highway Traffic Safety Administration, ANPR Docket No. 71-19, Number 7 (June 1979) (with J. P. Finnegan).

"Planar Thermic Elements for Thermal Control Systems," Journal of Dynamic Systems, Measurement and Control, Vol. 99, Series G, No. 1 (March 1977) (with B. S. Buckley).

Attachment 2

EUGENE F. MONTGOMERY
18 Fourth Place
Syosset, New York 11791

Telephone - Home: 516/921-0866
- Office: 516/929-8300, Ext. 3637

EXPERIENCE SUMMARY:

Over eight years of progressively increasing responsibility in the performance and management of engineering mechanics activities on nuclear power plant piping systems and equipment for electric utility and consulting engineering firms.

EDUCATION:

Columbia University School of Engineering and Applied Sciences, New York, New York

Bachelor of Science, Mechanical Engineering - May 1973
Master of Science, Mechanical Engineering - October 1974
Mechanical Engineer (Professional Degree) - January 1981

Queens College, City University of New York, Queens, New York

Bachelor of Arts, Physics - May 1973

EXPERIENCE: (See Attachment for Details)

1981 to Present

Stress Analyst, Nuclear Engineering Department
Long Island Lighting Company
175 East Old Country Road
Hicksville, NY 11801

Shoreham Nuclear Power Station - Unit No. 1
Mark II BWR/4 Capacity 819 Mw Net

Responsible Owner's representative for the engineering, coordination, review and approval of stress related activities performed in support of Shoreham licensing, start-up and system turnover.

1980 to 1981

Senior Engineer, Stress Aniaysis Engineering Department
Burns and Roe, Incorporated
185 Crossways Park Drive
Woodbury, NY 11797

Washington Nuclear Project (Hanford) Unit No. 2
Mark II BWR/5 Capacity 1100 Mw Net

Lead Engineer for various engineering evaluations related to fatigue analysis and high frequency effects of Mark II Suppression Pool loads on containment piping, equipment and support structures.

EXPERIENCE (Cont'd.)

1978 to 1980	Senior Engineer, Stress Analysis Engineering Department Ebasco Services, Incorporated 2 World Trade Center New York, NY 10048 Laguna Verde Units No. 1 and 2 Mark II BWR/6 Capacity 600 Mw Net Stress Engineer responsible for the design, analysis and checking of major ASME III Code Class 2, 3 and USAS B31.1 nuclear power piping systems.
1977 to 1978	Engineer 'A', Stress Analysis Engineering Department Burns and Roe, Incorporated 185 Crossways Park Drive Woodbury, NY 11797 Washington Nuclear Project (Hanford) Unit No. 2 Mark II BWR/5 Capacity 1100 Mw Net Stress Engineer responsible for the combined application of finite element methods (ANSYS), piping flexibility analysis (ADLPIPE) and Fortran IV computer programming to achieve the optimum design of nuclear power piping systems and their supports (normal/pipe-rupture) according to project specifications.

PROFESSIONAL SOCIETY MEMBERSHIP:

Associate Member - American Society of Mechanical Engineers

Associate Member - New York State Society of Professional Engineers

Member - Tau Beta Pi (National Engineering Honor Society)

REFERENCES: Will be furnished on request.

ATTACHMENT

DETAILS OF EXPERIENCE LISTING

From 3/81 to Present

Stress Analyst, Nuclear Engineering Department
Long Island Lighting Company
175 East Old Country Road
Hicksville, NY 11801

Shoreham Nuclear Power Station Unit No. 1
Mark II BWR/4 Capacity 819 Mw Net

Responsible Owner's representative for the engineering, coordination, review and approval of stress-related activities performed in support of Shoreham licensing, start-up and system turnover. Major assignments included the following:

- o In responsible charge of engineering review and approval of calculations performed by project consultants (Stone & Webster, Inc., General Electric) for seismic qualification and hydrodynamic re-evaluation of all safety-related equipment subject to IEEE-344, 1975 and the latest NRC criteria. Represented client interests at NRC-Equipment Qualification Branch technical audits of detailed dynamics analyses and test reports. Interfaced and coordinated between NRC and consultants to obtain acceptable resolutions on outstanding technical concerns.

- o Member of Motor Operator Test Group addressing issues on vibration aging and mechanical fatigue of Limitorque motor operators. Participated in formulation of procedures and test specifications used to qualify the equipment to long-duration, high frequency loads.

- o Initiated and coordinated stress-engineering software development for the Nuclear Engineering Department. Conducted evaluations to assemble an applications package consisting of essential structural and piping codes.

- o Lead Engineer for the Independent Design Review of the safety-related portions of the ECCS Core Spray System piping, supports, equipment and structures. Developed program plan and description, reviewed technical proposals. Coordinated audit open items/findings resolutions between Independent Design Reviewer (Teledyne Engineering Services) and project consultants.

- o Project Engineer for the As-Built Piping Reconciliation Program responsible for monitoring and minimizing the impact of field modifications due to calculation close-out and reviews.

- o LILCO Engineering Specialist for the Transamerica Delaval (TDI) Recovery Program. Reviewed diagnostic calculations on failure of engine crankshaft and analyses of replacement crankshaft design. Developed "tracking System" for nuclear/non-nuclear diesel engine failure experience for use in the TDI Owner's Design Review/Quality Revalidation effort.

Special Training

LILCO sponsored departmental training lectures. Covered topics included:

- o 10 CFR 50 Appendix B Quality Assurance Requirements
- o BWR Systems Familiarization Course
- o General Employee Training (GET) (for access to vital plant areas)
- o Shoreham Emergency Preparedness Training
- o English Language Institute Study Course
- o Technical Specialist QA Auditor Training

From 4/80 to 3/81

Senior Engineer, Stress Analysis Engineering Department
Burns and Roe, Incorporated
185 Crossways Park Drive
Woodbury, N.Y. 11797

Washington Public Power Supply System

Washington Nuclear Project (Hanford) Unit No. 2
Mark II BWR/5 Capacity 1100 Mw Net

In responsible charge of engineering evaluations in the following areas:

- o Lead Engineer for the fatigue analysis of MSRV lines and downcomers subjected to extended duration LOCA-related hydrodynamic loads. Supervised engineering personnel in lower classifications.
- o Member of Mark II SRSS/LCAC (Square-Root-Sum-Square and Load Combination Acceptance Criteria) Subcommittee addressing issues on MSRV and downcomer fatigue analysis, essential piping functional capability, SRSS Newmark-Kennedy Criteria and high frequency content of Mark II loads.
- o Lead Engineer for analysis of drywell ECCS (Emergency Core Cooling Systems) for Annulus Pressurization faulted loading conditions. Assisted and trained other stress analysts in performing calculations on conformance with project design specifications and ASME code.

Conceptual Engineering

- o Developed an analytical approach for determining the optimum support configuration restraining large, eccentric motor-operator valves. Guidelines in the form of simplified computational procedures and tables were prepared. (Published paper titled, "Optimum Rigid Support Spacing for Eccentric Operator Valves," June 1981.)

From 5/78 to 4/80	Senior Engineer, Stress Analysis Engineering Department Ebasco Services Incorporated 2 World Trade Center New York, N.Y. 10048

Stress Engineer responsible for the design, analysis, and checking of major ASME Code Class 2, 3 and USAS B31.1 nuclear power piping systems.

Comision Federal de Electricidad

Laguna Verde Units No. 1 and 2
Mark II BWR/6 Capacity 600 Mw Net

- o Responsible for thermal, pressure, deadweight and seismic design, analysis and checking of safety-related systems according to ASME Boiler and Pressure Vessel Code, Section III and USAS B31.1 using the proprietary pipe flexibility code PIPESTRESS 2010.

- o Developed initial support location, selection and sizing (or modified line routing, when necessary) on the following BWR systems: reactor water cleanup (RWCU), reactor core isolation cooling (RCIC), high pressure core spray (HPCS), low pressure core spray (LPCS), residual heat removal (RHR), standby liquid control (SLC), and numerous other Reactor and Control Building systems.

- o Prepared, checked and reviewed system stress analysis reports. Interfaced equipment allowable nozzle loads, pipe support loads, and postulated pipe stress break locations with other disciplines.

Houston Lighting and Power Company

Allens Creek Nuclear Generating Station
Mark III BWR Capacity 1200 Mw Net

- o Performed investigative study to determine the structural response of proposed Main Steam and Reactor Feedwater seismic interface/pipe rupture restraint system outside primary containment. An in-house dynamic-plastic finite element code, PLAST 2267, used for analysis.

Conceptural Engineering

- o Responsible for deriving maximum seismic support spans based upon a frequency design criteria. Nondimensional charts and tables developed for supports around right angle elbows, large radius bends, and parallel offset configurations. Prepared summary report for inclusion in project Pipe Stress Analysis Guidelines.

Special Training

Ebasco Services, Inc. sponsored departmental training lecture series. Covered topics included:

- o Code Stress Basis
- o Quality Assurance
- o Stress Analysis of Fossil Plant Piping
- o Pipe Rupture Interface with Stress Analysis
- o Thermal Stress Analysis According to B31.1
- o Seismic Charts Analysis
- o Vibration Theory and Problems in Piping

From 2/77 to 4/78

Engineer 'A', Stress Analysis Engineering Department
Burns and Roe, Incorporated
185 Crossways Park Drive
Woodbury, N.Y. 11797

Stress Engineer responsible for the combined application of finite element methods (ANSYS), piping flexibility analysis (ADLPIPE) and Fortran computer programming to achieve the optimum design of nuclear power piping systems and their component supports according to the applicable portions of ASME Boiler and Pressure Vessel Code, Section III.

Washington Public Power Supply System

Washington Nuclear Project (hanford) Unit No. 2
Mark II BWR/5 Capacity 1100 Mw Net

- o Responsible for the pipe rupture analysis of Main Steam high energy line breaks outside primary containment. Non-linear, elasto-plastic, dynamic finite element analysis (ANSYS) used to determine whip restraint gap size, maximum support member forces/moments, plastic piping response, penetration nozzle reactions. MSIV end loads and deformations. Prepared and reviewed final stress analysis report.

- o Responsible for the engineering, design and analysis of major wetwell piping and components subjected to direct hydrodynamic Mark II submerged structure loads. Time history and response spectra techniques (ADLPIPE) used to locate supports and evaluate piping response on MSRV lines, downcomers and miscellaneous wetwell penetrations under normal/upset/emergency/faulted hydrodynamic loading conditions.

- Coordinated application of DFFR (GE Dynamic Forcing Function Report) and DAR (Design Assessment Report) for developing force vs. time curves due to SRV discharge, Chugging, Condensation Oscillation, Pool Swell and Fallback input to pipe stress analysis. Developed Fortran programs for data file manipulation.

- Performed detailed analysis of MSRV X-Quencher device and its associated support structure under direct and indirect structural loads. Verified member sizes and anchor bolt-down adequacy. Prepared final stress report.

Jersey Central Power and Light

Three Mile Island Unit No. 2
PWR Capacity 880 Mw Net

- Responsible for verifying the design adequacy of Reactor Pressure Vessel and Main Steam Generator base plate shear pin bolt design under longitudinal and circumferential hot/cold leg coolant line breaks. The dynamic finite element codes STARDYNE and ANSYS were used in conjunction with an empirically developed collapse moment equation. Prepared final stress report.

Conceptual Engineering

Prepared Fortran software necessary to interface company developed piping graphics package with ADLPIPE, a conventional pipe flexibility code. Linkage permitted free thermal execution of designers' proposed routing while simultaneously plotting the layout on orthographic or isometric view.

Special Training

- "Practical Seismic Design of Structures" administed by Structures Group, Metropolitan Section ASCE.

- "Advanced Topics and New Developments in Finite Element Methods" administered by MARC Analysis Research Corporation.

Attachment 4

PEI CONSULTANTS

Biographical Data On
Dr. Simon K. Chen, PE

March 16, 1983

Position President

Home 325 Racine Street, Delavan, WI 53115
Home Phone: 414-728-6994

Education

B.S., M.E.	1947	National Chiao-Tung University
M.S., M.E.	1959	University of Michigan
Ph.D., M.E.	1952	University of Wisconsin
M.B.A.	1964	University of Chicago, Executive Program

Work Experience

President, Power and Energy International, Inc. — 1979 - present
Technical consulting and product development

President, Beloit Power Systems, Inc. — 1973 - 1979
Manufacturers of engine and turbine driven alternators, up to 15,000KW, rotary positive screw gas compressor, power plant controls, and gen-sets.

V.P., Engineering and Application, Fairbanks-Morse Power Systems Colt Industries — 1969 - 1973
Developer of O.P. Blower series line with increased rating, O.P. sparked gas engine, manufacturer of SEMT-PC-2 for marines, stationary and nuclear standby applications, developer of 38A-20 engine, producer of large irrigation pump, rotary compressor, alternators and motors.

Divisional Chief Engineer, Diesel Engine R&D, International Harvester Company — 1965 - 1969
Developer and manufacturers of vehicular diesels and spark-gas engines for construction equipment, farm equipment, medium-duty truck, and industrial applications.

Chief Project Research Engineer, Engineering Research, IH — 1956 - 1965
Corporate research on alternate power plant, engine combustion, advanced power train concept, advanced vehicle analysis, and corporate product planning.

Project Engineer, IH, Melrose Park — 1952 - 1956
In charge of combustion research on diesel and stratified charge engine.

Technical Society Membership List and Honors

SAE, ASME, SNAME, EGSMA, CIE, Who's Who in the World, Who's Who in Finance and Industry, Engineers of Distinction by Engineers Joint Council in 1973, SAE Arch T. Colwell Merit Award in 1966, University of Wisconsin Alumni Distinguished Service Award, 1973, Chinese Institute of Engineer's Achievement Award in 1976, Director and Technical Chairman of Diesel Engine Manufacturing Association, 1971-73, Member Compressed Air and Gas Institute, 1973-79, SAE Fellow-1983, Registered Professional Engineer - State of Wisconsin.

PEI CONSULTANTS

Publications

Dr. Simon K. Chen

January 16, 1984

- "Compression and End Gas Temperatures from Iodine Absorption Spectra," Co-author, SAE, 1954.
- "Development of a Single Cylinder Compression Ignition Research Engine," Co-author, SAE 650733, 1965.
- "Development and Evaluation of the Simulation of the Compression-Ignition Engine," Co-author, SAE 650451, 1965.
- "Engine Development Criteria and Techniques," Modern Engineering and Technology Seminar, Taiwan, Republic of China, July 1974.
- "Engine Cycle Analysis and Combustion Problems," Modern Engineering and Technology Seminar, Taiwan, Republic of China, July 1974.
- "Diesel Application," Modern Engineering and Technology Seminar, Taiwan, Republic of China, July 1974.
- "Highlights of the Energy Session," Energy Quarterly, Republic of China, January 1975.
- "A Collection of Abridged Management Papers," Modern Engineering and Technology Seminar, Taiwan, Republic of China, July 1976.
- "Marketing in a Competitive Market," Modern Engineering and Technology Seminar, Taiwan, Republic of China, July 1976.
- "Management Philosophy and High Technology Development," Energy Quarterly, Taiwan, Republic of China, January 1978.
- "Vibration Analysis for a Sound Generator-Set Design," Electrical Generating Systems Marketing Association, Chicago, IL, September 26-27, 1978.
- "Waste Heat Recovery Cycle Analysis and Systems for Diesel and Gas Turbine Engines," 13th CIMAC Conference, Vienna, Austria, May 7-10, 1979.
- "Small Industrial Diesel Planning," September 16, 1980.
- "An International Perspective of Taiwan's Automotive Industry," Society of Automotive Engineers, SAE-ROC Technical Meeting, Tawian, Republic of China, November 23-25, 1981.
- "The Development of ROC Machine Tool Industry and the Impact of Automation," Industrial Technology Research Institute, Taiwan, Republic of China, September 1981.
- "Japan's Robot and Robotics Development," March 11, 1982.
- "Techno-Economic Recommendations to Fight Recession Accelerated by Energy Shock," May 5, 1982.
- "US Robots and Robotics," August 1983.
- "A Review of Engine Advanced Cycle and Rankine Bottoming Cycle and Their Loss Evaluations," Co-authored, SAE 830124, 1983.
- "Flexible Manufacturing Systems Applications," Modern Engineering and Technology Seminar, Singapore, November 1983.
- "The Impact of Automation on Newly Industrialized Countries," Modern Engineering and Technology Seminar, Singapore, November 1983.

LILCO, August 14, 1984

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Board

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

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TESTIMONY OF EDWARD J. YOUNGLING, AND FRANZ F. PISCHINGER ON BEHALF OF LONG ISLAND LIGHTING COMPANY ON SUFFOLK COUNTY'S CONTENTION REGARDING REPLACEMENT CRANKSHAFTS ON DIESEL GENERATORS AT SHOREHAM

1. Please state your names, business affiliations and addresses.

A. (Pischinger) My name is Dr. Franz F. Pischinger. I am president of FEV (Research Society for Energy, Technology and Internal Combustion Engines) and a professor at the University of Aachen, Institute of Applied Thermodynamics. My business address is Erkfeld 4, Aachen, West Germany.

(Youngling) My name is Edward J. Youngling. I am employed by Long Island Lighting Company, North Country Road, Wading River, New York 11792.

2. Please summarize your professional qualifications and your role in the investigation of the replacement crankshafts at Shoreham.

A. (Pischinger) I obtained my diploma (or master's) in 1952 and my doctorate in 1954 from the Technical University in Graz, Austria. I am currently and have been since 1971 a professor at the University of Aachen at the Institute of Applied Thermodynamics. I am also the owner and president of the Research Society for Energy, Technology and Internal Combustion Engines (FEV), a private consulting firm in Aachen, which I formed in 1979. From 1958 until 1962 I was employed as head of the research department by AVL Research and Development in Graz, Austria, and from 1962 until 1971, I worked as a department manager and later as the head of diesel engine development at KHD. My resume is Attachment 1.

My role in evaluating the replacement crankshafts at Shoreham has been to critically review the work performed by

Failure Analysis Associates (FaAA) and determine whether the crankshafts are adequate for their intended service.

(Youngling) I am Manager of the Nuclear Engineering Department for LILCO. Prior to May, 1984, I was Startup Manager for the Shoreham Nuclear Power Station and was responsible for all pre-operational test activities. In this capacity, I was directly involved in the testing of Shoreham's diesel generators and supervised the operation of Shoreham's diesels for over 3350 hours. I am familiar with the testing requirements for the diesels over the 40 year life of the plant. Prior to being Startup Manager, I held a number of positions at Shoreham including that of Chief Technical Engineer for four years. I have a Bachelor of Science Degree in Mechanical Engineering from Lehigh University. My resume is Attachment 2.

3. What is the purpose of this testimony?

A. (Youngling, Pischinger) The purpose of this testimony is to address Emergency Diesel Generator Contention 1(a), admitted by the Board in its July 17, 1984 Memorandum and Order, which is whether:

> The replacement crankshafts at Shoreham are not adequately designed for operating at full load (3500 KW) or overload (3900 KW), as required by FSAR Section 8.3.1.1.5, because they do not meet the standards of the American Bureau of Shipping, Lloyd's Registry of Shipping, or the International Association of Classification Societies. In addition, the replacement crankshafts are not adequately designed for operating at overload, and their design is marginal for operating at full load, under the German criteria used by FEV.

4. Dr. Pischinger, please describe the scope of your work on the replacement crankshafts at Shoreham.

A. (Pischinger) I have visited the Shoreham plant on several occasions and inspected the diesel engines. I have thoroughly reviewed the work performed by FaAA on the replacement crankshafts and I have compared the design of the crankshafts against a very conservative German design criteria.

5. Please describe the design criteria FEV used to review the replacement crankshafts.

A. (Pischinger) FEV reviewed the replacement crankshafts under the Kritzer-Stahl design criteria. These are conservative guidelines that are used in the German diesel engine industry as initial dimensional recommendations.

6. What conclusions did you draw from your comparison of the replacement crankshafts with the Kritzer-Stahl design criteria?

A. (Pischinger) Under the Kritzer-Stahl design criteria, the crankshafts should have unlimited life for operation at 3500 KW. In addition, FEV estimates that the crankshafts should be able to operate at 3900 KW for a minimum of 1200 hours. This is far in excess of the number of hours the crankshafts will ever operate at 3900 KW over the 40 year life of the plant.

7. Did your comparison with the Kritzer-Stahl criteria take into account any beneficial effects from shot peening the replacement crankshafts?

A. (Pischinger) No. However, if we assume a 6% increase in the fatigue endurance limit from the shot peening, the crankshafts should have unlimited life for operation at 3900 KW, as well as 3500 KW.

8. Is compliance with the Kritzer-Stahl design criteria, or any other code, necessary to assure that the replacement crankshafts are adequate?

A. (Pischinger) No. With most design codes, and particularly with the Kritzer-Stahl criteria, conservatism has been included in the criteria to estimate the crankshaft design requirements without the benefit of actual engine construction and development testing. However, it is common and normal practice in the diesel engine industry to rely upon field testing and failure analyses to develop a crankshaft that satisfactorily performs its intended service. Therefore, it is my opinion that the design analysis and field testing of the instrumented crankshaft conducted by FaAA is an appropriate and accurate method of assessing the adequacy of the replacement crankshafts.

9. Do you have an opinion about the adequacy of the replacement crankshafts to perform their intended functions in the Shoreham engines?

A. (Pischinger) Yes. In my opinion the replacement crankshafts are adequate for their intended service at Shoreham and have a sufficient safety margin. My opinion is based upon the evaluation of the crankshafts by FaAA, the results of the FaAA tests and the fact that the conservative Kritzer-Stahl design criteria predicts unlimited life at 3500 KW and a minimum of 1200 hours at 3900 KW, without taking into account shot peening.

10. Do you support and concur with FaAA's conclusions regarding the adequacy of the replacement crankshafts?

A. (Pischinger) I agree completely with FaAA's conclusion that the replacement crankshafts are totally adequate for their intended service.

11. Dr. Pischinger has indicated that the crankshafts can operate at 3900 KW for at least ~~600~~ 1200 hours. What is the maximum number of hours the EDG's would possibly operate at 3900 KW over the 40 year life of the plant?

A. (Youngling) The engines never attain a loading level of 3900 KW in support of an accident sequence at the plant. The maximum postulated load stated in the FSAR is 3881 KW for EDG 103. The maximum postulated loads for EDG's 101 and 102 are 3409 KW and 3383 KW. These peak loads occur during the first ten minutes of the accident sequence and significant load reductions occur thereafter. For example, after the first ten minutes the load on EDG 103 is reduced 2641 KW.

The engines operate at 3900 KW only during surveillance testing. This testing is performed on an 18-month interval in accordance with plant technical specifications. Each engine is expected to operate at 3900 KW for no more than 60 hours during testing over the 40-year life of the plant. Therefore, it is obvious that the crankshafts are completely adequate for their intended service at Shoreham.

12. Has LILCO performed any tests to measure actual peak loads on the diesel generators during a LOCA event?

A. (Youngling) Yes. During the preoperational test program LOCA conditions were simulated and plant response resulted in a peak diesel generator load that was even less than the FSAR peak loads.

CONCLUSION

13. Please summarize your conclusions.

A. (Pischinger) The crankshafts comply with the conservative Kritzer-Stahl design criteria for operation at full load. Compliance with the Kritzer-Stahl design criteria at overload is not required to determine that the crankshafts are adequate. The replacement crankshafts are completely adequate for their intended service at Shoreham. This has been demonstrated by analysis and testing of the crankshafts.

Attachment 1

CURRICULUM VITAE

Professor Dr.techn. Franz F. Pischinger
Date of Birth: 18.07.1930, Waidhofen/Thaya, Austria

1948 to 1952 studies and graduation in mechanical engineering at Graz Technical University. From 1953 to 1958 (1954 doctors degree) technical assistant at Graz Technical University. Then Head of Research Department of AVL (Institute for Internal Combustion Engines, Professor List, Graz). 1958 habilitation. 1962 to 1970 leading positions in research and development at Klöckner-Humboldt-Deutz AG, Köln (last position: Director of Research and Development Department). Since 1970 Director of the Institute for Applied Thermodynamics at Aachen Technical University. Supervising research and teaching in the field of internal combustion engines and thermodynamics of combustion. Also (since 1978) president of the FEV Forschungsgesellschaft für Energietechnik und Verbrennungsmotoren mbH, Aachen.

Attachment 2

Edward J. Youngling
Manager, Nuclear Engineering Department

Assigned as Manager, Nuclear Engineering Department in May 1984. Report to the Vice President, Nuclear. Responsible for the overall operation of the Nuclear Engineering Department. The Nuclear Engineering Department is charged with providing the technical direction for engineering, fuel management, and radiation protection for the purpose of maintaining the design basis of the Shoreham Nuclear Power Station.

Responsible for the organizational development of the Nuclear Engineering Department and the definition of functions and responsibilities of the Nuclear Systems Engineering, Nuclear Fuel, Nuclear Project Engineering, Engineering Assurance and Radiation Protection Divisions.

Provide timely technical support to Shoreham plant operating staff for routine and abnormal operations in areas of nuclear engineering, core analysis, radiation protection, health physics, chemistry and radiochemistry. Administer programs and approve procedures to provide engineering and engineering management for plant modifications and engineering studies. Establish reliability and risk assessment capability aimed at improving plant safety and availability. Provide engineering support to Shoreham in the disciplines of thermal-hydraulics, heat transfer, stress analysis, systems engineering, instrumentation and controls, materials engineering, nuclear fuel design, core physics, safety and reliability analysis, risk assessment, radiation protection, shielding, health physics, radiation chemistry, non-destructive examination, corrosion analysis, and nuclear waste technology. Direct engineering work to the Office of Engineering on matters encompassing the disciplines of electrical, civil, power and environmental engineering for projects related to Shoreham. Direct activities related to nuclear fuel cycle management and establish nuclear material accountability. Establish core analysis systems to provide core follow support and advice on control rod withdrawal patterns. Provide technical direction for the Company's Radiological Environmental Monitoring Program. Provide radiation protection engineering and health physics technology assessments for incorporation in the Company's ALARA radiation dose reduction program. Responsible for the Company's ALARA radiation dose reduction program. Participate with Nuclear Operations Support and Plant Operating Staff in the development and implementation of the Corporate Licensing Policy.

Prepare and approve all budgets related to departmental activities necessary to comply with Corporate requirements. Prepare testimony and participate in appearances before federal, state and local hearing boards as required (PSC Prudency, PSC Rate Case, NRC Hearings, etc.). Administer R&D efforts within the Department in support of the Corporate R&D program.

Edward J. Youngling

Responsible for the finalization of the Shoreham Delaval Diesel Generator Design Review/Quality Revalidation Program.

Graduated from Lehigh University in 1966 with a Bachelor of Science Degree in Mechanical Engineering. From June 1966 to March 1968 attended Union College and achieved credits towards a Masters of Science Degree in Nuclear Engineering. Successfully completed the following training courses:

"Introduction to Nuclear Power" by NUS Corp., July 1970
"Boiler Control Fundamentals" by General Electric Co., January 1972
"Fundamentals of BWR Operation" by General Electric Co. at the GE Dresden Simulator, August 1972
"Process Computer Concepts and Practices" by General Electric Co., February 1973
"Shoreham Research Reactor Training Program" at Brookhaven National Laboratory Medical Research Reactor (NRC SROC License candidate research reactor training requirement), May 1975
"Planning for Nuclear Emergencies" by Harvard School of Public Health, May 1976
"Interagency Course in Radiological Emergency Response Planning in Support of Fixed Nuclear Facilities" by Nuclear Regulatory Commission, September 1978
"Customer Engineer Training Program i the Methods Used to conduct Maximum Turbine Capacity Tests and Analyze Results to Detect and Correct Cycle Losses" by the General Electric Co., arge Steam Turbine Division, September 1979
"Shoreham Nuclear Power Station On-Sit Training Program" (NRC SROC license candidate plant systems training requ rement), January - April 1979
"LILCO Advanced Supervisory Workshop", pril 1979
"Assertiveness Training Works op", Nov ber 1980
"LILCO Management Workshop", December . 980
"Shoreham General Employee Training", 1983

Achieved a Senior Operator Certification from the General Electric Company on the Duane Arnold Energy Center Boiling Water Reactor.

March 1981 - May 1984

Assigned as Startup Manager in March 1981. Responsible for the Preoperational test activities for the Shoreham Nuclear Power Station. Report to the Vice President-Nuclear. Responsible for coordinating all Checkout and Initial Operations and Preoperational Testing. Set initial construction priorities by system/subsystem and monitor construction progress as it relates to the startup schedule. Had the authority to modify construction schedule as conditions demand. Chaired construction release meetings at which status of construction, as it relates to systems scheduled to be released, was discussed. Member of the Joint Test Group. Ensured that the established procedures of documentation control were followed. Responsible for the review, monitoring, supervision and approval of Checkout and Initial Operations Tests, Preoperational Tests, and Acceptance Tests, review of all test results summaries and recommend acceptance, rejection or modification by the JTG according to results. Responsible for the production of all the software required for testing of Shoreham. Certified Level III per ANSI N45.2.6 - 1978.

In August 1983 named as Manager for the Shoreham Delaval Emergency Diesel Generator Crankshaft Failure Recovery Program. Responsible for coordinating the failure analysis, rebuilding, retesting and requalification of the three diesel generator units.

Prepared testimony, was depositioned and testified before the Atomic Safety and Licensing Board regarding Shoreham contentions dealing with quality assurance, startup testing and emergency diesel generators. Prepared testimony and testified before the New York State Public Service Commission. Responsible for direct interface with NRC Resident, Regional and Staff personnel for matters related to the preoperational test program and emergency diesel generators recovery effort.

<u>May 1979 - March 1981</u>

Assigned as Nuclear Services Supervisor in May 1979, reporting to the Manager, Nuclear Operations Support Division. Responsible for the management and coordination of those support services required by LILCO Nuclear Power Stations. These support services included coordination of major station modifications, performance of operational design reviews, coordinating the resources of other LILCO Departments and outside consultants to achieve a desired result assigned to the Division, coordinating long-range planning activities associated with plant maintenance, fuel cycle strategy and budget and cost control, monitoring overall plant and individual equipment performance, maintaining a current knowledge of federal regulations, industry codes and standards, and changes thereto applicable to the facility.

Participated on the LILCO Corporate Task Forces assessing Shoreham design and operations, corporate communications, crisis management and overall company emergency preparedness following the Three Mile Island Unit 2 accident. Chairman of the Shoreham Review Task Group, responsible for developing action plans for implementing post TMI recommendations. Responsible for the Shoreham Control Room human factors design review.

Developed the corporate policy manual defining interdepartmental responsibilities for the LILCO Nuclear Program.

Edward J. Youngling

February 1975 - May 1979

Assigned as Chief Technical Engineer of the Shoreham Nuclear Power Station - Unit 1 in January 1975. Responsible for the activities of the Instrumentation and Control, Health Physics, Radiochemistry and Reactor Engineering Sections of the plant staff, including the development of administrative and technical programs and procedures to meet regulatory, company and industry requirements; and the training of professional personnel and technicians to satisfy qualification standards. Served on the plant Review of Operations Committee (ROC) and when designated acted as Chairman of the ROC in the Plant Manager's absence. Served as a member of the plant Licensed Source User's Committee as stipulated in NRC Nuclear Material License No. 31-17432-01, February 1977.

August 1974 - January 1975

Reassigned to the plant staff as the Instrumentation and Control Engineer, then Acting Chief Engineer-Technical. Responsible for manpower planning and the development of the technical training programs for subordinate personnel. Participated in generating portions of the Shoreham Safety Analysis Report, and in the review and approval of plant operating procedures, lesson plans and system descriptions.

July 1973 - July 1974

Named the Instrumentation and Control Engineer for Shoreham Nuclear Power Station and assigned to the General Electric Company Startup, Test and Operations (STO) organization at the Duane Arnold Energy Center in Cedar Rapids, Iowa. Participated in the preoperational test program in the areas of in-core nuclear process radiation and reactor vessel (pressure, level and temperature) instrumentation. Acted as G.E. shift engineer during fuel loading operations and as assistant to G.E. shift engineer during startup testing and power ascension program. Participated in the G.E. shift engineer training program and sat for the G.E. Certification Examination for DAEC.

August 1972 - June 1973

Reassigned to Shoreham Nuclear Power Station Project as the Assistant Project Engineer, then Project Engineer. Responsible for overall plant design control. Coordinated design effort between LILCO, Stone and Webster Engineering Corporation, General Electric Co. Nuclear Energy Division, various major equipment suppliers and regulatory agencies.

November 1971 - July 1972

Reassigned to the Northport Power Station to participate in the startup of Northport Unit No. 3. Directly responsible for the startup of the boiler for this 380MW unit including the fuel safety system, the combustion and feedwater control systems and associated mechanical equipment. Assumed overall plant shift operations responsibility during the latter stages of startup. Was an instructor in the Unit No. 3 systems training program given to plant supervisors, operators, technicians, and mechanics.

November 1969 - October 1971

Assigned to the Shoreham Nuclear Power Station Project in the Nuclear Engineering Department. Participated in the engineering review of the Shoreham plant design in the following areas: plant equipment layout, equipment specifications, equipment selection, main control board design, plant operations logic, plant instrumentation, plant computers. Review included contacts with the A-E, Stone and Webster, NSSS supplier, General Electric Company, various vendors and visits to several nuclear stations.

April 1968 - October 1969

Employed by the Long Island Lighting Company and assigned to the Northport Power Station. During the period, assisted in the startup of Northport Unit 2, assisted in the station maintenance section supervising route and shutdown maintenance activities and acted as the station Results Engineer responsible for the repair and calibration of the station instrument and control systems and for monitoring station performance.

June 1966 - March 1968

Employed by the General Electric Company at the Knolls Atomic Power Laboratory. Stationed at the West Milton Site as a Mechanical Test Engineer on the S3G Prototype "USS Triton" submarine. While at the S3G plant my responsibilities were to prepare procedures for tests and operations which were not in accordance with normal plant operations; supervise the actual tests, analyze the results and issue reports to the AEC. The following specific activities were engaged in: completed selected sessions of the Engineering Officer of the Watch Training Course, participated in numerous plant tests including routing low power physics testing including directing reactor control rod movements through Navy reactor operators, maneuvering transients, main coolant pump tests, power runs, various engine room tests and ultrasonic testing to trend pipeline degradation. Participated in the Advanced Reactor Control Program as Lead Shift Test Engineer, including completion of required training program, and performing preoperational tests and integrated plant acceptance testing.

Member - American Nuclear Society. Held a Guest Associate Engineer appointment in the Reactor Division at Brookhaven National Laboratory. Member - Pi Tau Sigma. Hold an Engineer in Training Certificate - State of Pennsylvania (State Registration Board for Professional Engineers).

Attachment 3

CROSS-EXAMINATION

BY MR. SCHEIDT:

Q. Dr. Johnston, you aren't a diesel engine expert, are you?

DR. JOHNSTON: My experience and expertise is in the area of structural analysis of structural mechanical components which would include crankshafts in large diesel generators. That is the area in which -- structural analysis is the area in which I have both practice and experience, also is the area of my education, also the area in which I have lectured at Stanford University.

Q. So, you are not a diesel engine expert, you are a structural analysis expert; is that your testimony?

DR. JOHNSTON: Yes, I am a structural analyst.

Q. And you are not a diesel engine expert?

DR. JOHNSTON: I am an expert in diesel generators to the extent that it relates to the analysis of diesel engine components by techniques such as dynamic analysis, modal analysis, finite element analysis.

Q. And prior to performing any of your work for the TDI Owners' Group, did you ever have any experience in the actual design of diesel generators?

DR. JOHNSTON: My experience prior to and subsequent to the Shorehsm project has not been in the design of diesel generators. It has been in the analysis of components, structural components such as crankshafts.

Q. And you had no experience in the manufacture of diesel generators or diesel engine components; isn't that true?

DR. JOHNSTON: I have no experience in manufacturing processes.

Q. And other than, perhaps, driving diesel engine vehicles, you never had any experience in operating diesel generators; isn't that true?

DR. JOHNSTON: I am not a diesel engine operator.

Q. And, in fact, your familiarity with diesel generators prior to your work with the TDI Owners' Group was limited to general knowledge that an engineer might have from reading papers and discussing matters with your colleagues, isn't that true?

DR. JOHNSTON: My experience with diesel generators would only be that which is related to my capabilities and experience in the analysis of structural components. It wouldn't be included in diesel generators or other machinery or other structures.

Q. Thank you, Dr. Johnston.

Prior to your performing any work for the TDI Owners' Group you had never before analyzed the crankshaft structure, isn't that true?

MR. STROUPE: I'm going to object to the form of that question. If he wants to ask him a yes or no question that's fine, but I think these continual leading questions, and the witnesses exhibit no hostility, are improper.

JUDGE BRENNER: It's cross-examination, he's allowed to ask leading questions.

MR. STROUPE: I understand that. But I still believe the way the questions are being asked that they are improper.

JUDGE BRENNER: The objection is overruled. I think they're proper.

DR. JOHNSTON: I think my experience and education is quite clear. It is in the area of structural analysis, both statically and dynamically. It is applicable to the analysis of many components including crankshafts, and I — that is the area that I specialize in. I am not an operator or manufacturer of generators and I have not in the past specifically been involved in the design of engine components but I have been involved in the analysis of such components.

Q. My question, Dr. Johnston, was isn't it true that you haven't structurally analyzed the crankshaft for diesel engines before?

DR. JOHNSTON: Specifically, I have not analyzed a crankshaft for a diesel engine prior to this project.

Q. Thank you.

DR. JOHNSTON: Although the same techniques are used to analyze many other similar components.

Q. When you say similar, what components or object do you believe is the most similar to the crankshaft that you performed the structural analysis on?

DR. JOHNSTON: The tools that I used to analyze a crankshaft such as the modal super position technique and finite element analyses, general techniques that I use to analyze many components that range from crankshafts to piping supports to off shore platforms to buildings, they are used for calculating stresses in components.

Those are the tools that I'm familiar with.

Q. Well, aren't pipes different from crankshafts in terms of structural analysis, aren't they subjected to different stresses?

DR. JOHNSTON: From the standpoint of structural analysis, they are not different. The techniques used to analyze them are the same. Yes, they are subjected to different stresses, but, however, the techniques used to analyze such components are the same. They take into account the different loading and use the same method to compute the stresses.

Q. And is the structure of a crankshaft such as that used in the EDG's at Shoreham significantly more complex than that of pipes used in nuclear power plants?

DR. JOHNSTON: Not necessarily.

Q. Well, can you explain --

DR. JOHNSTON: Well, for example, the intersection between a pipe and a vessel is an extremely complex stress analysis problem as indeed is a crankshaft a complex stress analysis problem. There are some problems that are easy, there are some problems that are more difficult. Crankshafts would not be representative, necessarily, of the most difficult component to analyze or necessarily the most difficult component that I have analyzed.

Q. I will ask my question again, because I do not believe that you answered it.

What component that you have analyzed before is most similar to that of a crankshaft in terms of structural analysis?

DR. JOHNSTON: I don't feel that there's any one particular component that I would regard as similar to a crankshaft that I have analyzed in the standpoint of what you see it doing or what it looks like. But as I outlined, the kind of components that I have analyzed are analyzed by the same techniques as those of a crankshaft. I'm not sure whether you would consider a shaft that didn't have cranks and webs as similar to a crankshaft. I'm not sure whether — what you would consider similar to a crankshaft.

What I have testified to and what I will state again is that the components that I have analyzed in the past are similar to those of a crankshaft because the methods used to analyze them are similar.

MR. SCHEIDT: Judge Brenner, I'd just

like the record to reflect that counsel from New York State has now arrived in the courtroom.

JUDGE BRENNER: Well, you have noted that and I'm sure you intend to be courteous. I have refrained from noting that last week and this week so it should not be taken as opposite of being courteous but ramifications may flow from the periodic attendance from New York State. You may proceed. You may proceed.

Q. Mr. Montgomery, do you consider yourself a diesel engine expert?

MR. MONTGOMERY: My experience has been in the area of stress analysis applying the disciplines of vibration mechanics and fatigue analysis that were employed in the design review for the replacement crankshaft at Shoreham.

The techniques that were employed for the design review on this component as Dr. Johnston has already stated is generic and applicable to a wide variety of components undergoing structural review and analysis.

Q. So you are not a diesel engine expert, is that what you're saying, but you are a stress analyst expert?

MR. MONTGOMERY: I am a stress analyst.

Q. Are you not a diesel engine expert?

MR. MONTGOMERY: Insofar as the question you're asking relates to diesels, no; however, the analytical techniques generically apply to a wide range of components including the crankshaft on the diesel generator.

Q. So that, Mr. Montgomery, have you ever either designed or manufactured diesel engine components?

MR. MONTGOMERY: I have not been involved in the manufacturing of diesel engine components.

Q. And have you been involved in the actual design of diesel engine components?

MR. MONTGOMERY: Your question, of course, relates to crankshafts.

Q. Have you been involved in the actual design of the crankshaft for a diesel engine?

MR. MONTGOMERY: I state that because diesel engine components would include a wide variety of engine elements which would include its various manifolds, piping supports, tubing. In these areas I've had direct relevant experience.

Q. Design experience.

MR. MONTGOMERY: In the general sense, yes.

Q. What do you mean by the general sense?

MR. MONTGOMERY: As my summary of experience will bear out, I have had direct design and analysis experience on nuclear safety related piping and pipe supports at various installations throughout the country.

Insofar as safety related piping in applications other than -- other than diesel generator applications, I have had direct experience.

Q. So you haven't had direct experience with respect to piping on diesel generators; is that true?

MR. MONTGOMERY: There's nothing significantly different about the piping configurations.

Q. That wasn't my question, Mr. Montgomery.

MR. STROUPE: I'm going to object to his interrupting the witness, Judge Brenner. I think the witness is entitled to give an answer. If he doesn't get his answer, then he's certainly entitled to request assistance or to ask it again.

JUDGE BRENNER: All right. Mr. Montgomery, you should try to answer the question asked first and then to the extent that you want to offer an explanation, you can do that. I infer that what you had started out with was the explanation.

and the problem is when a witness does that, sometimes he forgets to include the direct answer to the question by the end of that. Start out with the answer, and then we will assure that you'll have sufficient opportunity to provide an explanation as long as it's pertinent to the particular question and answer.

Do you recall the question at this time?

MR. MONTGOMERY: Yes.

JUDGE BRENNER: All right. Please answer it.

MR. MONTGOMERY: I have not had direct responsibility for design and analysis of piping in a diesel engine application; however, as I had started to explain, the application of the piping and pipe support design analysis tools for this type of configuration is generic, and can be utilized on a diesel engine as well as on any other piping application in the plant; so that for the case of the piping configurations supporting the diesel generator, there is nothing specifically or uniquely different about it.

Q. Mr. Montgomery, prior to working for LILCO, did you ever perform a stress analysis on a diesel engine crankshaft?

MR. MONTGOMERY: I have not performed a detail stress analysis on a crankshaft prior to joining LILCO; however, as was already stated in the testimony of Dr. Johnston, the analytical techniques that are utilized in the design and analysis of the replacement crankshaft such as forced vibration solutions to dynamic vibratory problems, fatigue analysis, modal superposition, all of these are standardized techniques that are well-known to people in my field.

Q. After the failure of the original crankshafts at Shoreham, did you perform any stress analyses of those crankshafts — I'm sorry, prior to the failure of the original crankshafts, have you performed any stress analyses of those crankshafts?

MR. MONTGOMERY: Your question is to me personally?

Q. That's a start.

MR. MONTGOMERY: Prior to the failure of the original crankshafts, we're speaking now of the 11 by 13 configuration, I was not directly involved in the review of the diesel generator sets or any of its design bases.

Q. You say that you were not directly involved.

What was the extent of your involvement in the stress analysis of the original crankshafts?

MR. STROUPE: I'm going to object to that question. I don't believe that accurately characterizes what he said in his answer.

JUDGE BRENNER: I guess it's a matter of interpretation. We can let the witness explain it or you can stay with just the second sentence of your question, Mr. Scheidt. Either way we'll get the answer and you can follow up.

MR. SCHEIDT: Okay. I'll try to ask the question again.

BY MR. SCHEIDT:

Q. Prior to the original failure, of the original crankshafts, you were not directly involved in the review of those crankshafts, and I assume when you say review, you mean stress analysis; is that correct, Mr. Montgomery?.

MR. MONTGOMERY: Yes.

Q. What was the extent of your involvement, if it was not direct?

MR. MONTGOMERY: My involvement was peripheral, in that in the standby diesel generator sets had been an activity monitored by other individuals within the project engineering division.

Q. And were those individuals Stone & Webster employees or were they LILCO employees?

MR. MONTGOMERY: My firsthand knowledge was of LILCO employees.

MR. SCHEIDT: I don't want to go into this area too deeply, but I'd just like to know which individuals at LILCO were responsible for the analysis of the original crankshaft prior to its failure.

MR. STROUPE: I'm going to object to that question on the basis there's no foundation or evidence that there was any such analysis.

JUDGE BRENNER: Well, we will find that out in a hurry. I thought you were going to object on some other basis, but that objection is overruled.

MR. STROUPE: I would also add to that objection that I believe this would appear to me to be outside the scope of the contentions as they are admitted in this proceeding.

JUDGE BRENNER: Can you explain the materiality of the question, Mr. Scheidt?

MR. SCHEIDT: One second, Judge Brenner.

Judge Brenner, the question is related to the expertise of the witness in the area of stress analysis.

I admit it's not directly related, but it would be relevant and material to know the extent of this witness's involvement in the analysis, if there was an analysis, Mr. Stroupe, and the extent of supervision, if he had any supervision, and the extent of the analysis as a comparative factor with what went on afterwards.

JUDGE BRENNER: I'm smiling only because I predicted the correct answer. If you wanted to ask the question, we'll allow it on that basis, but as you said, not too deeply.

MR. SCHEIDT: As I indicated --

JUDGE BRENNER: Because given that reason, it shouldn't be necessary.

Do you recall the question after all that, Mr. Montgomery? He wants to know the names of people at LILCO, if any, who performed the analyses, stress analyses of the original crankshafts prior to failure.

MR. MONTGOMERY: The stress analyses performed on the original 11 by 13-inch crankshaft configuration was done by Trans-America DeLaval. A review of that analysis was performed by our Stone & Webster engineering consultants.

LILCO did not directly perform a stress

analysis review on the original crankshafts.

Q. Mr. Montgomery, you testified that you were peripherally involved in this review.

What was the extent of your involvement, what did you do?

MR. MONTGOMERY: I believe that I stated that I was peripherally involved in matters related to the emergency diesel generators at Shoreham.

Q. And I would like to know what your peripheral involvement was.

MR. STROUPE: With regard to the stress analysis of crankshaft.

JUDGE BRENNER: Is that right, Mr. Scheidt?

MR. SCHEIDT: Yes.

MR. MONTGOMERY: In response to your direct question, no.

If I can -- to restate it, you asked for what my direct involvement was in the -- or peripheral involvement was in the stress analysis review that was being performed prior to the failure of the original 13 by 11 crankshaft; however, I may want to point out that subsequent to the failure of the 11 by 13, I was directly involved in the review of the TDI calculations as well as the developing

FaAA evaluations.

Q. Just so that I have an understanding of what you just testified to, did you state that you had no involvement in the review of the stress analysis prior to the failure?

MR. MONTGOMERY: Yes.

Q. And your involvement only came about after the failure of the original crank shafts; isn't that right?

MR. MONTGOMERY: Yes, that's correct.

Q. And you were involved in the review of the analysis of the replacement crankshafts; isn't that true?

MR. MONTGOMERY: I was involved in the capacity of engineering specialist within the DRQR program which developed out of or out of a consequence of the failure of the 13 by 11 crankshaft, and in that capacity, I provided technical review and direction to LILCO consultants which includes Failure Analysis Associates, Power and Energy International and Stone & Webster Corporation in their assessments of the original and replacement crankshaft.

Q. What technical review did you perform?

MR. MONTGOMERY: I performed reviews of

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the Phase 1 and Phase 2 replacement crankshaft reports as well as their supporting calculations as performed by FaAA.

I also performed a review of the failure report on the 13 by 11 crank shaft and its supporting calculations.

Q. Did you perform any independent review or independent analysis of the replacement crankshafts?

MR. MONTGOMERY: The review of the original crankshaft failure as well as the replacement crankshaft, as this panel would testify to, was directly performed by FaAA, and to some extent PEI.

In my review of their work, other than simple checks on the overall analysis, I performed no in-depth review or parallel review to their -- to replicate their work effort.

Q. And you've testified that you also provided direction to the work performed by LILCO consultants.

Could you elaborate what you mean by direction of that work?

MR. MONTGOMERY: I provided guidance in the area of the specific design requirements as specified in our purchase specification and our licensing requirements under LILCO interpretation of our commitments to our specialists for their implementation into the design review.

Q. What do you mean by LILCO interpretations of your FSAR requirements?

MR. MONTGOMERY: Let me state flatly then the FSAR requirements.

Q. When you say design requirements, do you mean the DEMA standards?

MR. MONTGOMERY: Yes, that is correct. Our purchase specification clearly states that the Diesel Engine Manufacture Association, DEMA standards are in effect for the replacement crankshaft.

Q. And what sort of guidance did you provide LILCO consultants concerning DEMA?

MR. MONTGOMERY: It is our testimony that the DEMA recommendations be implemented using conservative conventional analytical techniques, and in conjunction with our consultants, we interpreted the DEMA recommendations as specified by methodologies that are developed in the diesel engine industry over many years and these are reflected in our various reports.

JUDGE BRENNER: Mr. Scheidt, I wonder if

I might interrupt on what I hope is not a lengthy digression. I did not ask the parties whether anything had been worked out as to particular sequences within this sequence of the testimony and if any party raised anything so I assume everything has been worked out satisfactorily.

I had assumed in my own mind that after you finished the qualifications of the witnesses, and I sense that you're now overlapping into Part B on page 64 of the cross plan --

MR. SCHEIDT: Excuse me, Judge Brenner, by the witness's testimony, that wasn't my intent, but we're here --

JUDGE BRENNER: It's perfectly okay. I'm not criticizing it.

I had thought that maybe you would go to your primary questions to Mr. Youngling and Dr. Pischinger before focusing on this part of the panel, not that it was required, but just in case our time estimates turned out to be incorrect, but I don't know if that was discussed among the parties.

One reason I raised it is that I have something else in mind further down the line that we said we would try to the extent feasible to make some productive push forward for shot peening at least. I don't know if I'll be able to do any of that. But does Dr. Pischinger still have a scheduling problem?

MR. STROUPE: Judge Brenner, Dr. Pischinger is available for the remainder of this week.

My understanding is he will be going back to Germany at the end of this week. He has some obligations which are undeferable, so to speak. He will — we have asked him to make an attempt to accommodate his schedule to come back to this proceeding, perhaps the week following, a week to ten days, something like that.

JUDGE BRENNER: All right.

MR. STROUPE: We would obviously like to discuss later in the week, depending on how this goes.

JUDGE BRENNER: I didn't mean to get too far ahead, but if he will not be here next week, it may not make a difference, but would it affect your plan, Mr. Scheidt, to ask the questions you have on approximately page 69 of your cross plan before the questions starting at part B on page 64?

MR. SCHEIDT: It would affect my plans, Judge Brenner. I can accommodate Dr. Pischinger. I prefer to do it after I've established some points on cross-examination and preferably not today.

JUDGE BRENNER: All right. I recognize that the subjects overlap. All right. Well, I hope the cross won't go too far beyond today, but we'll see where it goes. Go ahead. I'm sorry for the interruption.

BY MR. SCHEIDT:

Q. Mr. Montgomery, you testified that you interpreted the DEMA recommendations as specifying methodologies that were specified in the diesel engine industry over a number of years; isn't that right?

MR. MONTGOMERY: I did not testify that I interpreted the diesel engine manufacturers associations recommendations.

The various consultants specifically are Dr. Simon Chen of Power and Energy International, who was a former chairman with the technical committee for DEMA, provided us with excellent insights into the application of DEMA for our situation.

Q. Was he the only source of your knowledge -- when I say your, I mean LILCO, FaAA, was he the only source for this interpretation?

MR. MONTGOMERY: We reached these conclusions or interpretations based upon a number of consultants' input, which includes Trans-America DeLaval, Failure Analysis Associates and PEI, all of which concur with the appropriate aspects of the DEMA calculations attributed to them.

Q. Mr. Montgomery, you spent a significant amount of time developing the tracking system for the TDI diesel engine failure experience for use in the DRQR, isn't that true?

MR. MONTGOMERY: One of my responsibilities within the DRQR program was to develop and assemble all relevant diesel engine experience including Shoreham, TDI experience, nuclear experience, which includes both TDI and non-TDI generators, and non-nuclear engines in the area of TDI's marine applications.

Q.. How did you determine which of this experience was relevant?

MR. STROUPE: At this point in time I am going to register an objection to this line of questions. I don't see how it's relevant to the admitted contentions.

JUDGE BRENNER: Well, I'll let Mr. Scheidt respond.

MR. SCHEIDT: The area is an area that he performed what, I believe, was a substantial amount of work and time on. I'm trying to develop what it is that he actually did and how much time he spent on it and so on.

MR. STROUPE: I'd like to know how that relates to —

JUDGE BRENNER: Wait a minute.

You're claiming just in the area of his qualifications.

MR. SCHEIDT: Background, what work he performed.

JUDGE BRENNER: Well, it's relevant to that. It's also, at least he's apparently not into it deeply yet, relevant to the LILCO testimony that extensive experience with the new crankshaft, the 13 by 12 crankshaft shows how good they are. So we'll allow it. Do you understand the question, do you know what the question is?

MR. MONTGOMERY: Please repeat it.

Q. How did you determine what experience was relevant and not in compiling this tracking system?

MR. MONTGOMERY: The relevancy or non-relevancy of the individual experience items was not determined by LILCO.

As the DRQR Phase 2 final report, nine volume set will show, within each diesel engine component, there is an appendix summary sheet which itemizes the Shoreham, nuclear and non-nuclear industry experience for that particular component, and determines whether or not that failure would have any consequences or bearing on the design review performed by the task leader of that component; so in the sense of relevancy, that was a determined -- a value determined by the group task leader for that particular component.

Q. What were the standards used with respect to crankshafts in determining whether a failure had a bearing on Shoreham?

MR. MONTGOMERY: As I just stated, the relevancy or bearing of a particular failure on a component's design review is the responsibility of the assigned task leader.

Q. It may be his responsibility, but do you know what the standards he used were?

MR. MONTGOMERY: I assume I would have to answer this question programmatically.

The assessment of the individual failure incidents by the responsible task leader would involve taking into consideration the impact that

that incident would have on the quality assurance, quality control, design adequacy, operation and maintenance, material selection, and any other factor as it relates to Shoreham, and what was, in fact, the steps taken at Shoreham to preclude the occurrence of that failure.

Q. Who was the task leader for crankshafts?

MR. MONTGOMERY: Dr. Paul Johnston.

Q. Perhaps this question ought to be directed to you, Dr. Johnston.

What were the standards used in determining what impact these incidents had on quality assurance, quality control, operation and maintenance, design adequacy and material selection?

MR. SCHEIDT: Doctor, I would like your answer and not Mr. Youngling's, if I may.

JUDGE BRENNER: Mr. Scheidt, you have eyes as well as I do. I assumed you had no objection to other members of the panel conferring on some of your questions. If you do have that problem, say so sooner rather than later.

MR. SCHEIDT: A certain amount of leeway can be given but it can be excessive, too.

JUDGE BRENNER: Mr. Youngling, if you have something to say on this, you can tell us directly. It's a matter of the witness's part, too. If it's just a check, I understand why you might want to confer and have the witness answer providing the question is not limited to one witness but we have a lot, but if there's a lot to say, its more efficient to get it directly.

DR. JOHNSTON: As task leader of the crankshaft design review, the standards used include the DEMA standards for the stress analysis of the crankshaft includes material specifications and material test reports for the materials, includes the inspection reports for the quality assurance work that covers inspections on the particular generators, and Mr. Youngling, I think, perhaps, would address the area of operations and maintenance.

MR. YOUNGLING: Mr. Scheidt, as far as the operation and maintenance was concerned, the initial base line documents that we used were the TDI operations manuals, which specified how to operate and maintain the manual — the engine generator sets.

From there, as we went into the operating experience, and the design reviews, we expanded into other recommendations that have been put forth by the Owners' Group.

As far as the testing is required, that mainly relates to the regulatory requirements by the NRC and our commitments to those requirements in the Shoreham FSAR.

MR. SCHEIDT: I think we're moving away from the original question that was asked and that was experience of other TDI generators in other installations and in determining the impact of that experience on Shoreham. The standards that were used in determining the impact of that experience on Shoreham.

MR. STROUPE: Judge Brenner, I will again make my objection. What has obviously started out as I think qualification questioning is now into the -- I believe the meat of the DRQR. It was my understanding that was not an issue in this litigation. The experience that, I believe, LILCO used was, perhaps, not experience gained as a result of the DRQR.

JUDGE BRENNER: Well, you know, I understood that is an objection by LILCO and we make certain rulings on the admission of the contentions that bear on that. I don't want to repeat the whole discussion, but in not ruling out -- in ruling out certain parts of the contentions, we emphasized that just because we were ruling it out did not mean that other experience was immaterial as applied to particular context, and apparently not only the County is taking us up on that, but I suggest to you that LILCO in its Exhibit C-6, among other places, has put that experience into issue, and you then relied on that Exhibit C-6 on your testimony, I believe, on page 13. And I don't know if Mr. Scheidt has planned on being there substantively, but there is no requirement for a bright line between qualifications and the substance, and he's going to get there sooner or later, I suspect. It might as well be now, and you can respond, Mr. Stroupe- but if you think I'm misunderstanding something about your testimony in Exhibit C-6 —

Let me the state my impression, Exhibit C-6 lists experience at other diesel generators, and the testimony — I shouldn't try to paraphrase from memory, but it says this experience shows that the other conclusions about the reliability of the crankshafts are correct. Let me find it precisely.

Page 13 of the LILCO testimony, McCarthy et al., on this particular — for which this particular panel — some members of this particular panel are present, states in the second paragraph of the answer in this edition there is extensive experience with 13 inch by 12 inch crankshafts in DSR-48 generators that establishes the crankshafts are reliable.

It goes on to cite the table on Exhibit C-6 that it refers to.

MR. STROUPE: I understand what you're saying, Judge Brenner.

JUDGE BRENNER: Questions are at least relevant to that, even if you disagree its relevance to other things. It may also be relevant to other things.

Q. The question is what are the standards that were used in determining whether incidents with other TDI generators other than the Shoreham EDG's had an impact on Shoreham?

DR. JOHNSTON: The standard is based on judgment.

Perhaps I could just give you an example.

One of the items that is entered as experience that should be accounted for in the design review of the replacement crankshafts is the failure of the original crankshafts, and the original crankshafts were analyzed so that we understood why it was that they failed, and why it is that we believe that the replacement crankshafts

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are adequate.

Having assessed the differences between those, we can then reach a judgment that that particular piece of experience does not present any problem to the adequacy of the replacement crankshafts.

Q. My question, though, goes to non-Shoreham EDGs and how that experience was determined to be relevant or not to Shoreham generators. I understand your point on the original crankshafts.

MR. MONTGOMERY: In a very similar matter the problems —

DR. JOHNSTON: The problems we experienced with V-16 engines, we had analyzed crankshafts on V-16 engines, we assessed where their criticals lie, we assessed what the stresses were in the crankshafts, both in V-16's now and in some V-16's that experienced difficulties because of different counter-weighting. We used those to assess what it is that's different about crankshafts that had problems from the crankshafts in the EDG's at Shoreham.

By doing that, and comparing the stresses that existed in crankshafts that had problems with those that exist in the replacement crankshafts at

Shoreham, we can assess the relevance of that experience.

Q. So it's your testimony that some of the standards that you used are the stresses that are present in other TDI generators; is that correct, and how they might differ from the EDG's at Shoreham?

DR. JOHNSTON: That is correct.

Q. What other standards do you use?

DR. JOHNSTON: Other standards include the material specs; for example, the EDG's at Shoreham have -- maybe have certified materials that is compared to the allowables.

JUDGE BRENNER: Dr. Johnston, in your last answer, were you restricting it to the crankshafts even though you did not expressly so state?

DR. JOHNSTON: Yes, sir, I was.

Q. Are there other standards that you used other than material specifications for the crankshafts?

DR. JOHNSTON: The standards for operation and maintenance typically related to the TDI manual for that, so that those also represent a body of standards by which operations and maintenance problems at other sites may be compared with that.

Q. Were the TDI operation manuals different from engine to engine, or were they the same? You can, for example -- for the DSR-48 generators, were those operating manuals the same?

MR. STROUPE: Do I assume correctly this is restricted to crankshafts?

MR. SCHEIDT: Yes.

DR. JOHNSTON: The operations manuals that I have seen for the Shoreham engine is certainly different than any other operations manual that I have seen.

Q. Does that include operating manuals for other nuclear power plants?

DR. JOHNSTON: Yes, it does.

Q. How does it differ? Well, certainly there's one area where it differs --

MR. SCHEIDT: Mr. Youngling, I'm following up with questions to Mr. Johnston.

JUDGE BRENNER: We'll let you add if you want, Mr. Youngling, but this is direct follow-up to the difference that Mr. Johnston at least has seen.

MR. YOUNGLING: I'm sorry, Judge.

DR. JOHNSTON: For example, the numbers of cylinders in an engine at Shoreham would be different than a number of cylinders at Catawba, that would be included in the operations manual for the two generators.

Q. My question was as between DSR-48 generators, do the operating manuals differ?

DR. JOHNSTON: I have not inspected the operations manuals for other nuclear service DSR-48 generators.

JUDGE BRENNER: Let's let Mr. Youngling add at this point if he wants to answer the question as to what differences there are in the operating manuals for, I guess the question ended up being focused on other DSR-48 engines, and if you then want to go beyond that, we'll accept that also.

MR. YOUNGLING: Depending upon the arrangement and the configuration, there could be differences in critical speed components in the engine which would require different precautions as to where the engine should or should not be operated.

That certainly could relate to the straight eights and certainly to the V engines which would make them different. That was the major point that I wanted to make.

Yes. There could be differences between the manuals.

Q. Dr. Johnston, did you ever examine the operating manuals for TDI DSR-48 engines in non-nuclear power plants -- in non-nuclear applications?

DR. JOHNSTON: No, I did not.

Q. Now, were there any other standards that you used in determining whether experience with TDI diesel engines at plants — installations other than Shoreham had an impact on Shoreham?

MR. MONTGOMERY: In addition to the standards already mentioned, there are a number of other general engineering standards for assessing both the adequacy of particular components and the reasons for problems in other components. These would include the endurance limits, for example, of parts that may have failed and other material parameters.

Q. Such as?

DR. JOHNSTON: Such as yield strength, elongation.

Q. Did the DRQR analyze any of the crankshafts on TDI engines that did not fail to determine whether they were relevant to the Shoreham crankshafts?

DR. JOHNSTON: Part of the design review

process, we have analyzed a number of crankshafts in DSR-48 engines, and including those at River Bend, Rancho Seco, also some engines in Saudi Arabia, so that we have, indeed, compared stress levels in engines that have operated satisfactorily with those at Shoreham, and we have included this experience in a number of reports, including the report on the failure investigation of the original 13 by 11 crankshaft at Shoreham.

Q. Which engines in Saudi Arabia did you compare stress levels for?

DR. JOHNSTON: We have compared the stress levels in the engines at Rahfa in Saudi Arabia.

Q. Where is this information reported?

DR. JOHNSTON: The stress levels for the engine at Rahfa, those calculations have not been specifically reported in the failure analysis reports, although the torsional systems for them have been reported in the TDI submittal to the American Bureau of Shipping.

Q. You mentioned that some of this information was contained in the FaAA reports.

Is it contained in the DRQR reports?

DR. JOHNSTON: Explicit stress analyses

or the results from the stress analyses are not included in the DRQR reports for the Rahfa engines; however, that experience base has been included.

Q. Has been included where?

DR. JOHNSTON: It is included in part of our assessment of the adequacy of the 13 by 12 crankshafts.

Q. And that's in the FaAA report on the original crankshaft; right?

DR. JOHNSTON: It is also in the FaAA report on the replacement crankshaft dated May 22, 1984.

Q. Is it included in the DRQR Phase 2 report on crankshafts?

DR. JOHNSTON: The DRQR report is a summary report that referenced the May 22nd, 1984 Failure Analysis report on the EDG's. The Failure Analysis report does include that experience.

Q. Mr. Montgomery, is it true that the component tracking system does not track experience with crankshafts and DSR-48's that haven't failed?

MR. MONTGOMERY: You're talking about the experience in the computer tracking system for the component crankshaft?

MR. SCHEIDT: Yes.

MR. MONTGOMERY: Only?

MR. SCHEIDT: Yes.

MR. MONTGOMERY: To the best of my knowledge, the computer tracking system generically contains information which encompasses known failures or problems that have been incurred on a particular component. It ordinarily does not reflect positive or service experience on a particular component.

Q. In fact, it doesn't indicate any analysis of non-failures; does it?

MR. MONTGOMERY: For the purposes of the DRQR review program, a listing of service experience serves no immediate function. A listing of known flaws or failures, maintenance oversights, material inferiority, these are the aspects that require further investigation and review.

MR. YOUNGLING: I'd like to add to that, if I could.

I think Mr. Johnston pointed out earlier that the DRQR and the FaAA people have looked and analyzed other engines that have operated satisfactorily and looked at their crankshaft designs, and, perhaps, Dr. Johnston can comment on that again.

MR. SCHEIDT: I don't think there's any need to go over the same testimony.

Q. Dr. Johnston, is it your testimony that the DRQR program only looked at the alleged satisfactory experience at three locations of DSR-48 engines in addition to Shoreham, Rancho Seco, River Bend and Saudi Arabia, Rahfa?

DR. JOHNSTON: No. That's not correct.

We have looked at engines at a number of locations which are listed in Table 4.1 of the May 22nd Failure Analysis report.

I indicated the other three engines as specific examples of engines which we have analyzed.

The stresses in DSR-48 engines vary a little bit from engine to engine due to minor differences in configurations such as a slightly different fly wheel, and so the stresses may vary a small amount from one to another.

We have looked at three other sites to compare the stress levels, but we have included the experience of eight sites in that Table 4.1.

MR. STROUPE: Mr. Scheidt, you might want to note that Table 4.1 is contained in LILCO exhibit C-17.

MR. SCHEIDT: I picked up on that, Mr.

Stroupe.

JUDGE BRENNER: Well, it helps the record when he does that, too, Mr. Scheidt.

MR. SCHEIDT: I understand.

DR. JOHNSTON: I'd just like to add that, it is our understanding that these eight sites represent all of the DSR-48's that are in service, and includes 26 engines.

JUDGE BRENNER: That's the same table as we have as C-6; isn't it? I guess I can compare it, too, but I thought you knew offhand.

MR. STROUPE: That's correct, Judge.

JUDGE BRENNER: When you interrupted to give us the Exhibit No., I thought you were going to give us C-6, and that's why I'm a little surprised.

BY MR. SCHEIDT:

Q. Did the DRQR program include an examination of the operating manuals for each of these 26 DSR-48 engines.

DR. JOHNSTON: Typically, the operations manual would be reviewed as part of the understanding of a failure event that would be reported in the computer component tracking system so that the operations manuals for all of these sites were not reviewed because of the fact that they did not experience failures.

Q. You stated that all of them were not examined.

Were any of them examined?

DR. JOHNSTON: Information from the operations manuals of these other -- of some of these other engines were examined in order to determine the torsional systems for other engines; for example, the Rahfa engine; however, the extracts of that information was performed by TDI.

Q. You said you relied on TDI for part of your analysis with respect to these engines.

MR. SCHEIDT: Does answering this question require a conference, Dr. Johnston?

DR. JOHNSTON: To answer your original question, the adequacy of the crankshafts was assessed without relying on information from Trans-America DeLaval; however, the particular exhibit that we are -- have been referring to, the history of other TDI engines in service was, indeed, compiled by Trans-America DeLaval.

MR. MONTGOMERY: I would just like to add to that, that the Shoreham experience, of course, was provided to TDI by LILCO.

JUDGE BRENNER: I guess they did hear

about it.

Mr. Scheidt, I'm looking for a convenient place to stop for lunch. Also I'm going to ask you whether you're ready to move on to Point 2 within your subpart C.

MR. SCHEIDT: I would prefer that Dr. Chen be present for that part of the testimony, so I will pick that up when he arrives.

JUDGE BRENNER: Let me phrase it carefully. Are you finished with Point 1 of C?

MR. SCHEIDT: Point 1 under which point, Judge Brenner?

JUDGE BRENNER: I think --

MR. SCHEIDT: Point C.

JUDGE BRENNER: I don't want to be confusing but I just wanted to know much I revealed would be solely past history which you would have no objection as to giving some insight as to something you might want to refer to so --

MR. SCHEIDT: I'm not through on C point 1.

JUDGE BRENNER: How much more do you have on it? We seem to be getting bogged down on it. I'm not criticizing any particular question and I understand cumulatively it's important because you want to give us the picture on it, but we've got the picture, so unless — now is the time to think about whether you have any particular factual points within the picture you've given us

MR. SCHEIDT: I do have greater detail fact points on this.

MR. STROUPE: Judge Brenner, I understand obviously Mr. Scheidt should be given and is given leeway in his cross-examination, but I note at this point in time, Dr. Pischinger, I do not believe, has been asked a single question, and I don't think if this pattern keeps developing we're not going to get very far with his testimony.

JUDGE BRENNER: Were you here on Friday or Thursday?

MR. STROUPE: I was here for the morning.

JUDGE BRENNER: He doesn't — well, I had a conversation with Mr. Scheidt this morning and he indicated he would not be ready to get to Dr. Pischinger today.

I indicated — well, I'm indicating now because I don't think I said it quite this way earlier, although it was what I was thinking earlier, that I would expect that the County could at least get up to page 69 of their cross plan by the end of the day today, and that would get them to Dr. Pischinger the first thing tomorrow.

Now, LILCO has all these witnesses up here as a combined panel. If you had elected to put Dr. Pischinger and Mr. Youngling up first, then we would have permitted that and the County would have had to ask those questions first. I don't mean to be overly critical because I recognize they overlap between subject matter and Mr. Scheidt has a little bit of that overlap problem, too. There are some things he'd rather establish first.

I did not infer that Mr. Scheidt meant he necessarily had to get up to page 69 in sequence as written in the cross plan. Page 69 is a reference to his cross plan, so we'll see how it goes.

But you've heard my comment on how far I think the County should be able to get.

What I meant essentially is that information. I didn't mean you had to follow it in sequence. If you had moved around and moved up to page 69 earlier, I recognized because you covered that, you would cover some of the earlier material and would want to come back to that tomorrow, but —

MR. SCHEIDT: Judge Brenner, I anticipate certain points between pages 64 and 69 in which I could jump to page 69, question Dr. Pischinger to the extent that I wish to question him, and then come back to that material between those two pages.

JUDGE BRENNER: All right. Fine. That may make sense from a subject matter content as well as a witness accommodation content.

Overall, I thought we were pretty patient last week and the length of time surprised me. I did not think it would take all last week to complete that panel. There were reasons on both sides of the aisle for that, and I would hope that through a combination of the cross-examiner as well as the speedy response by the witnesses, a direct question can be answered directly without taking two or three minutes to confer unnecessarily at times. Then we will make better progress this week. You can see just by the number of pages last week how many pauses there were before words were actually put on the transcript.

In addition, I voiced my opinion at least from time to time, as to when I thought it would be more efficient to get to the questions that the cross-examiner was leading to more directly, instead of background. That doesn't necessarily apply to anything that occurred today so far, I just want to be able to move a little further and faster.

MR. SCHEIDT: Judge Brenner, I have approximately two or three questions and we can take a lunch break after that.

JUDGE BRENNER: All right.

BY MR. SCHEIDT:

Q. How did Trans-America DeLaval compile this information contained in Exhibit C-6, I believe, concerning the other DSR-48 engines?

DR. JOHNSTON: I think that question should be asked to Trans-America DeLaval. I do not know how they compiled that particular table.

Q. Did FaAA attempt to verify the information contained in that table?

DR. JOHNSTON: The information on that table that relates to the Shoreham experience was verified independently through LILCO.

Information at other sites has not been verified by Failure Analysis.

Q. And with respect to the examination of the operating manuals to determine whether the torsional systems of the engines were comparable or not, other than looking at the Rahfa or•rating manual, were there other operating manuals that you looked at to determine comparability of torsional systems.

DR. JOHNSTON: Operating manuals are not the only way to determine the torsional system of another engine. It's done by looking at the drawings in conjunction with a torsiograph test which, of course, is independent of the operating manual.

In the TDI submittal to the American Bureau of Shipping, there is a list of a number of other torsional systems for other DSR-48 engines.

Q. But my question was: Did you look at any other operating manuals other than Rahfa, as I believe you indicated you had with respect to Rahfa?

DR. JOHNSTON: I did not mean to indicate — I don't believe I did indicate that I looked at the operating manual for Rahfa. I u... the torsional system for Rahfa. I have — the only operating manual that I have reviewed that contains information on DSR-48's is that of Shoreham.

Q. And where did you obtain the torsional information on Rahfa?

DR. JOHNSTON: It's included on page 17 of TDI's submittal to the American Bureau of Shipping.

Q. And that is the natural frequency

calculations for those engines?

DR. JOHNSTON: It's labeled Tabulation of Mass Elastic Data for DSR-48 Engines.

Q. And what does that tell you about the engine?

DR. JOHNSTON: It tells you the lumped parameters to the lump mass model that represents the crankshaft including eleven values of inertias and ten values of its stiffnesses.

Q. Is that the Holzer analysis?

DR. JOHNSTON: No, it's not. It's some of the data that is used for the Holzer analysis.

MR. SCHEIDT: Thank you. We can break now, Judge Brenner.

JUDGE BRENNER: All right. Let's take a break until 1:40.

(Whereupon, at 12:30 p.m., the hearing adjourned, to reconvene at 1:40 p.m., this same day.)

AFTERNOON SESSION

JUDGE BRENNER: Good afternoon. We're back on the record. We're prepared to have the County continue its cross-examination.

MR. SCHEIDT: Judge Brenner, at this time the County would move to strike portions of testimony on page 13 of LILCO testimony relating to the extensive experience with 13 by 12 inch crankshafts in DSR-48 engines that allegedly establishes that the crankshafts were reliable as well as the accompanying Exhibits C-6 on the grounds that this information is not reliable.

There is no TDI witness who is sponsoring this testimony. The witnesses have indicated that they do not know how this information was compiled and they, in fact, did not verify that information.

MR. STROUPE: Judge Brenner, my response --

JUDGE BRENNER: I'll hear from you in a moment. I didn't realize Dr. Chen was here and that should have been noted among other things. We have to swear him in

MR. STROUPE: I was going to do that at the outset.

JUDGE BRENNER: Let's take care of it after this ruling as long as we jumped into it. Welcome, Dr. Chen.

DR. CHEN: Sorry.

JUDGE BRENNER: It's not your fault if we understand the circumstances correctly. Mr. Stroupe, why don't you respond.

MR. STROUPE: Our position, Judge Brenner, put quite simply, is regardless of what Mr. Scheidt has indicated, to my knowledge there's been no showing that the information is not reliable. On cross-examination, they were free to make any points that they could, in fact, make about the reliability of this information.

To my knowledge, none of it was pointed out to be inaccurate by any cross-examination exhibit or information.

JUDGE BRENNER: Well, have your witnesses shown it is reliable, to state it the other way?

MR. STROUPE: I'm not sure that the witnesses have been accurately — all of them, questioned about what they know about this. It may be indeed that Mr. Youngling could have shed some light on this had he been asked the question.

JUDGE BRENNER: We've given this witness panel a lot of leeway to have any witness answer it, and I guess I'd better note that for the record given your comment, although the transcript will not necessarily reflect it, these witnesses feel free to confer among themselves this morning, even when a question was directed by name to a particular witness, there was at least one time when Mr. Scheidt indicated he wanted the answer from the particular witness, but even that was only after some moments of conferring had taken place, so it's not true that the witness panel did not have a chance for all of them to answer any questions, in my opinion, based on my observation of the dynamics of the panel this morning.

So I'm not going to accept that. Did you mean to -- I guess I understand your answer.

Can you represent to me, Mr. Stroupe, there is at least one witness on this panel who could have answered those questions with more information who you felt --

MR. STROUPE: No, I cannot represent that to you, Judge Brenner.

I would say in passing that this information has been contained in other documents, it's been contained in this testimony for some period of time, and we, of course, note that the County filed no motion to strike prior to this proceeding, and had we been noticed that this would be a bone of contention, the reliability of this information, I think we could have certainly done something to prepare ourselves for that eventuality rather than seeing it for the first time on cross-examination.

JUDGE BRENNER: Staff, do you have a

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question on it?

MR. GODDARD: The Staff is inclined to support the motion based upon what we've heard here this morning.

In the event that Mr. Stroupe is able to produce witnesses at a later point in time, having claimed surprise as to this motion, the staff would not oppose such a showing, realizing that it may somewhat delay the proceeding, but on the basis of the showing here, the staff would support the motion, does not feel that there's anyone here that is capable of supporting the material here.

I might further add that in response to Mr. Stroupe's comment, the publication does not improve the quality of the evidence before us.

JUDGE BRENNER: I'm sorry, I didn't hear.

MR. GODDARD: The publication, the fact that this has been set forth in the DROR publication, and other places does not lend support to the admissibility of the testimony here. I do not feel that a showing has been made.

MR. STROUPE: Mr. Goddard --

MR. GODDARD: That was my interpretation.

JUDGE BRENNER: Hold it. Talk to each other outside if you want to.

MR. JOHNSON: The state supports the County on its motion to strike the testimony for the same reasons that were given by Mr. Scheidt.

JUDGE BRENNER: If you feel it's important, I'll let you respond to Mr. Goddard's comments, Mr. Stroupe.

MR. STROUPE: I just wanted to make it clear for the record and to the court that my reference to this particular table and the information being in other documents was for the purpose of pointing out that a motion to strike could have been filed well in advance of this cross-examination.

MR. BRIGATI: If may I respond to that --

JUDGE BRENNER: No; not out of discourtesy. I understand both sides of the arguments and we try to keep it to a particular lawyer on one point. Does the immediate plan of attack rely on a ruling from us right now?

MR. SCHEIDT: I will proceed to question them on detail of the actual testimony and the exhibit, if you do not rule now.

JUDGE BRENNER: Why don't you give us a few minutes, I think I'd like to go next door.

The geography of the bench here makes it difficult.

(Discussion in Judge's Chambers)

JUDGE BRENNER: We're back on the record.

We're prepared to grant the motion subject to ascertaining the involvement or lack therefore of Dr. Chen in the pertinent portion of that answer.

I'm looking at page 13 of the testimony of McCarthy, et al., regarding replacement crankshafts, and Dr. Chen is listed as a co-author of the entire answer.

As we understand the motion to strike, Mr. Scheidt, you're asking to strike the first two sentences of the second paragraph of that answer along with Exhibit C-6; is that correct?

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

JUDGE BRENNER: All right. Since Dr. Chen was not here this morning, let's find out what his involvement might be and if he is not a sponsor of those two sentences, we'll grant the motion and I'll give the reasons, but let's swear Dr. Chen in, find out what the situation is, unless you can tell us as a representation that he had nothing to do with those two sentences and is not here to give us any insight into Exhibit C-6.

MR. STROUPE: I believe he may have some information that could be pertinent to those two sentences.

JUDGE BRENNER: All right. We'll find out.

Dr. Chen, could you please stand and raise your right hand.

Whereupon,

DR. SIMON CHEN

was called as a witness by and on behalf of the Applicant, and having been first duly sworn, was examined and testified as follows:

MR. STROUPE: Judge Brenner, would now be an appropriate time to have Dr. Chen adopt the testimony?

JUDGE BRENNER: All right.

MR. STROUPE: Dr. Chen, do you have in front of you testimony filed by LILCO of August 14, 1984 in this proceeding entitled "Testimony of Roger L. McCarthy, Paul R. Johnson, Eugene F. Montgomery and Simon K. Chen on behalf of Long Island Lighting Company on Suffolk County's Contention Regarding Replacement Crankshaft on diesel engines on the Shoreham" along with three volumes of exhibits relating to the crankshaft?

DR. CHEN: Yes, I see them here.

MR. STROUPE: To the best of your knowledge, is the testimony true and correct?

DR. CHEN: I don't think I can vouch for every piece of information that's in here but on those --

MR. STROUPE: Excuse me, go ahead.

DR. CHEN: On those things that I'm involved, I'm sure it will be truthful to the court.

MR. STROUPE: And do you adopt that testimony as your own?

DR. CHEN: Are those under my -- yes.

MR. STROUPE: Tender for cross.

JUDGE BRENNER: Dr. Chen, we've been discussing page 13 of the testimony, and the answer to question 13 begins on that page.

There has been some testimony, oral testimony this morning to which you were not present involving the information in that answer, and I'll give you a moment to look at it and you may also want to look at the related Exhibit C-6.

DR. CHEN: Yes. I see it.

JUDGE BRENNER: With regard to the second paragraph of that answer, the first two sentences, which begins: In addition, and ends with Exhibit C-6, did you participate or do you now believe you can participate as an author of those two sentences vouching for the statements made in those two sentences as supported by the exhibits or was that something that Mr. Montgomery prepared without you?

DR. CHEN: Yes. I have participated in investigating some of the information, certainly not all the information in Exhibit 6.

JUDGE BRENNER: I guess you'd better ask him some questions, Mr. Scheidt.

It's unfortunate for you, we recognize that had Dr. Chen not had his transportation problems, we would have been able to handle it all at once but we are reluctant to strike it if Dr. Chen can indeed provide some missing information.

BY MR. SCHEIDT:

Q. Dr. Chen, TDI compiled this information, did it not?

DR. CHEN: I think so.

Q. Did you verify any of this information

DR. CHEN: I have certainly verified the LILCO information.

Q. LILCO information?

DR. CHEN: LILCO information.

In other words, the hours run at LILCO and I have that information.

Q. Is there any information in Exhibit C-6 other than Shoreham LILCO information that you verified?

DR. CHEN: Yes. I have personally visited Kousheng plant late November, early December and made trips over there and went to see those engines, and also I have made telephone calls twice early this month to find out, what whether those engines are running reliably or not, and I have some latest hours on those engines, yes.

Q. I'm sorry, Dr. Chen. When did you visit Kousheng?

DR. CHEN: Late November or early December, yes. There are four engines there.

Q. And when did you have these telephone conversations that you referred to?

DR. CHEN: It's earlier this month, two weeks ago.

Q. And with whom did you speak?

DR. CHEN: I spoke through an intermediary, and he spoke to the — they call station manager at Kousheng.

Q. And what did he — what information did he transmit to you on the number of hours?

DR. CHEN: Yes. The first question I asked whether these engines have been operating satisfactorily up to that point. He said yes.

And then he -- I said how many hours they have been running, both total hours log and also hours above 3300 kw, and I received that information.

Kousheng is a plant which is in operation since 1980 running pretty much at the design load.

Q. What is the design load for those engines?

DR. CHEN: I say the plant is running at design load. The engines are standby generators and rated 3,500 kw, just like LILCO engines, they are eight cylinder, but as far as total hours, exercising hours every month to conform to their nuclear standards, so they have not been putting too many hours on as running satisfactory, but all four engines have been running from 110 hours and something less than 130 hours over 3300 kw ratings to satisfy their nuclear requirements for the last two to three years.

Q. Dr. Chen, perhaps I didn't understand you.

Are you testifying that they have run between 110 and 130 hours above -- at or about 3300 kw?

DR. CHEN: At or above, total hours.

Q. 110 to 130; is that right?

DR. CHEN: Yes.

Total hours run is more than that, but above 3300, at 3300 kw are only 110, to 130, because that's all that's required.

Q. Each engine has run 110, 130?

DR. CHEN: Four engines. I have numbers on four individual engines, yes, all above — they're all somewhat under 130, to the best of my knowledge, memory today.

Q. Dr. Chen, you testified that these engines were rated at 3,500 kw, is that correct? I'll refer you to the exhibit.

DR. CHEN: To the best of my knowledge, 35.

Q. So it's your understanding that this chart is incorrect, this exhibit, C-6, in that category?

DR. CHEN: Well, I cannot vouch for the 36.

Q. Dr. Chen, can you verify the number of total hours logged indicated in this exhibit for me?

DR. CHEN: Total hours logged is somewhere between 600 hours and I believe something over 700 hours on each of those engines.

I don't have the numbers here, but I can present it to you. I can present a telex to you of exactly how many hours logged and how many hours taken and how many hours above 3300 kw.

The main thing I was asking is — they have no big approximate, they are running satisfactorily and they say yes, they are running satisfactorily.

Q. What factors did you ask him to — strike that.

JUDGE BRENNER: Mr. Scheidt, maybe I can assist in efficiency.

I'll give it back to you if we don't get anywhere.

Other than the LILCO data and the Kousheng data in the table, Dr. Chen, do you have knowledge to support the truth of the facts in the rest of that Exhibit C-6?

DR. CHEN: I know as a fact that there are quite a few numbers of these eight cylinder engines shipped to Saudi Arabia since 1977, 1978 or even before that.

And I know the existence of those engines, but I don't have any details about how many hours they are run and at what load, no, sir.

JUDGE BRENNER: With respect to Kousheng, did I hear you correctly that as of your recent check, Kousheng, as of your recent check, about two weeks ago, each of the four engines had about 700 hours of total operation?

DR. CHEN: The way it's stated, total hours logged, started up for one reason or the other.

JUDGE BRENNER: Was my figure correct? Did I hear you right, 700 hours?

DR. CHEN: I would say that's about the average of those four engines. They are up and down a little bit, maybe some of them will have only 600 some hours and some of them have 700 some hours. As I say, I can produce these individual hours.

JUDGE BRENNER: On the chart for Kousheng, it gives the date log as 3-15-84, and in the total hours logged column, the highest number for one of the Kousheng engines is 368, and the lowest is 221.

DR. CHEN: Yes.

JUDGE BRENNER: Is that an unusual number of additional hours for the engines to have logged between March 15, 1984 and sometime early in September of 1984?

DR. CHEN: I would say for an operating

engine, you're correct, Judge, but I believe that this total hours logged here corresponds to another set of numbers I have that I got from telex, and the other column was the hours taking loads and generating upward.

That number is very, very close to what's in the Exhibit 6.

There's three sets of numbers that I have is total hours logged and total hours generating power, and then I asked specifically the hours generating power above 3300 kw.

I have three sets of data by telex.

JUDGE BRENNER: With respect to the latter category, you testified that the number of hours at over 3300 kw were somewhere at about 100 to 130 per engine for each of the four Kousheng engines; is that right?

DR. CHEN: Yes, sir.

JUDGE BRENNER: And in Exhibit C-6, it has a notation after the Kousheng date, quote, mostly one hundred percent, close quote, and I took that to apply to the total hours logged in the figures on that same chart.

Can you explain the discrepancy between my reading of the chart to mean that and the hours you've reported?

DR. CHEN: I cannot testify saying the average load is 200 hours since I'm not the author of that exhibit, sir.

JUDGE BRENNER: Give us a moment. We're going to grant the motion to strike LILCO Exhibit C-6, so, of course, it will stay in the record as an offer of proof, and what we'd like to do is back up on the index page and have a third column at least for that one to indicate that we struck at this transcript page. We're also striking the first two sentences of the second paragraph on page 13 of the testimony of McCarthy, et al., regarding crankshafts that would begin with in addition and end with Exhibit C-6.

(Thereupon, Lilco Diesel Exhibit C-6 is rejected.)

Dr. Chen certainly had information about the Kousheng diesels and the lawyers understand, but he might not understand that it wasn't for lack of trying by him that we are striking it.

Dr. Chen candidly told us what he knew and what he did not know, and that assisted us in our ruling.

There are, however, discrepancies even as to Kousheng about which Dr. Chen knew quite a bit between his knowledge and this chart here to the point where it's not precise enough to be reliable for the purposes by which — for which it was presented in the testimony.

And that is that the extensive experience on these other DSR-48 TDI diesels establishes that the Shoreham diesels are reliable.

In effect, our ruling is supportive of the same argument that LILCO has made from time to time about the crankshafts and, indeed, other components, that that the experience that other machines cannot be cited as being pertinent to Shoreham unless similarities and differences are well explained, and LILCO has failed to explain that even minimally with respect to this particular testimony to leave in evidence.

We did consider Mr. Stroupe's point that the County had not filed a timely motion to strike on this testimony and they could have.

If the County had done it, in our view, the following sequence would have occurred:

The motion to strike would have had to have been based on the point prior to testimony on the fact that there is an Exhibit C-6 and testimony sponsored by witnesses Montgomery and Chen, and there is no connection in the testimony showing that these witnesses have personal knowledge of the facts in the table.

The answer undoubtedly would have come in along these lines, although undoubtedly more eloquently stated, that under federal rules of evidence of several of them, particularly 703, the witnesses do not have to have personal knowledge of all the details so long as it's reasonable data of the type that an expert witness would -- as preparation for the hearing or preparation to obtain knowledge as an expert about the crankshafts would gather up, and we would have undoubtedly denied the motion to strike on that basis.

However, then we get to the hearing, and we are here to learn what weight we should attach to his testimony, and that depends more particularly on the witness's knowledge of the underlying data.

It all depends on the use to which the underlying data is being put. Certain uses require less precise knowledge of underlying data than other uses.

In this case, the knowledge required is quite precise, in our view, particularly given the arguments made in the past in other context by LILCO, and I've stated what that argument is.

In order to deem other experience material either to show success or failure, you need to know what the similarities and differences are.

The County had attempted to go into that on cross-examination, and the witnesses, in effect, cannot supply information, therefore, the County is deprived of its right to confront through cross-examination the truth and weight of this testimony, and for that reason we would strike it.

We could have stated since we are past the time for motions to strike, which could have been filed earlier, that given the fact that a motion to strike was not filed earlier, we would not strike it now, but we would give it the weight due this testimony based on the cross-examination.

However, I've explained why in our view that it would be unfair since the motion to strike, in this instance, would have been denied based on the way the written information, which is all we would have had at that time, would have stood.

We also were able to determine and support that the weight we would give this information is zero; so there's no sense in putting it off to a later date what we can decide today with respect to this particular testimony.

For that reason, it is struck. I will explain it at greater length if necessary. I was hoping that the witnesses would understand our thinking ability and know that it's not our reflection of their ability to testify as to matters they have as to expert knowledge, their attorneys can explain it better to them some day but that's our ruling.

JUDGE BRENNER: Go on, Mr. Scheidt.

One thing, we have not forgotten, we have a pending motion to strike the portion of the staff's testimony filed by the County and we have been considering that and continue to do that and we will have a timely ruling on it for you on that.

Certainly some of the same principles I've espoused here will apply to them, I'm sure, as well.

JUDGE BRENNER: Let me add one other footnote.

We considered leaving the data with respect to LILCO in Exhibit C-6 and decided it was necessary to the extent pertinent any of the operating data for the LILCO engines with the new crankshaft is contained in great abundance throughout testimony and exhibits, then we'll undoubtedly be hearing about it later in the hearing, too.

BY MR. SCHEIDT:

Q. Dr. Chen, are you familiar with the rules — are you familiar with the rules of Lloyd Register of Shipping?

DR. CHEN: I know how to apply them, yes.

Q. And are you familiar with the rules of the American Bureau of Shipping?

DR. CHEN: Yes. I know how to apply them and I have checked also ABS calculations.

Q. Those rules are based on years of wide practical experience with diesel engines: aren't they?

DR. CHEN: They are based on traditional calculations of crankshaft geometry, number one, and second, the torsionals are based on in most cases marine engine history, operating experience and history.

Q. And safety and reliability is of paramount concerns of these rules, aren't they, Dr. Chen?

DR. CHEN: I think seaworthy is the word

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the law uses. Certainly implies that if the crankshaft setisfies any of these marine rules which were basically designed for insurance, they will be seaworthy.

Q. And seaworthy encompasses reliability and safety, does it not, Dr. Chen?

DR. CHEN: I think that it really gives the owners and the people who insure some sense of surety.

Q. Of what, Dr. Chen?

DR. CHEN: Surety, that these crankshafts are conservative enough that they would be willing to insure.

Q. And they are willing to insure the crankshafts and the engines because they are safe and reliable based upon the rules; is that right?

DR. CHEN: I never thought of it that way.

I would think there's other factors from the owner's point of view that must be considered beyond the Lloyd and beyond the ABS to know that engine and the crankshaft is safe or not.

Q. Well, one measure that those shipowners use to determine whether the crankshafts and engines are reliable and safe is compliance with one or more of those classification society rules; isn't it?

DR. CHEN: I think I will try to answer that.

There's a difference o. judgment and opinion whether those rules are for insurance purposes, or is it for operation and shipowners purpose.

I think the shipowners and the insured sometimes took a little different point of view. This is my experience. Just to mention why, for example, shipowners would rely more on their own experience on the medium speed engines, even that they look — most of these crankshafts have maybe either Lloyd or ABS rules and they will go beyond that to talk about reliability.

I don't think shipowners will just take the ABS rules or the Lloyd rules and say, if they have Lloyd rules I would consider these crankshaft reliable, and/or on ABS, also, because a good example is the U.S. Navy does not require either U.S. — does not require ABS rules when they accept the engine, and they certainly want reliable engines.

Q. Most shipowners use compliance with one or more of these codes as an indicator, it may not be the only indicator, but as an indicator of safety and reliability; isn't that true?

DR. CHEN: I think I've said it several times. I think that this is one other factor they might consider so that they can get the insurance.

If I were an owner, I would certainly consider the Lloyd rules or ABS rules reliable -- not reliable, because as engineers especially, because some of those rules are not very explicit: and -- especially that as time goes on, the material strengths, the processing of the crankshaft and even the computation methods have advanced and affect some of those arbitrary -- I shouldn't say arbitrary, I'm sorry, empirical rules established, I would say, quite a few years ago.

Q. Based on years and years of experience, though, isn't it true, Dr. Chen?

DR. CHEN: Well, based on their experience.

I don't think that's true for -- from an engineer's point of view.

Engineers don't consider ABS rules and Lloyd rules used for design for reliability.

I think that's what I'm trying to say. I don't think owners would consider that either, because they are different rules, so which rules is more reliable.

There's all over the world, you have NKK rules which is different, Lloyd rules are different. You have different rules and Asia goes for — use quite a bit of ABS rules.

Russia has their own rules. Lloyd England, Lloyds of London has its own rules and Lloyd of Germany has a little different rules, so as an engineer, I think it's one of the parameters we have to consider if we want to sell to the marine owners, but it's certainly not a rule that we will consider whether we design the crankshaft safely or not safely. I repeat it again because many of the engines used in this country when they designed the one design they don't consider ABS rules.

They eventually will be used on auxiliary generators or on the ships or used by the Navy. They never received ABS rules.

Q. Dr. Chen, doesn't the Navy have standards of its own for its crankshafts and diesel engines

DR. CHEN: They use engineering evaluations, sir, and their own experience.

Q. Aren't those standards more stringent than the ABS standards?

DR. CHEN: They are different and they're based on engineering evaluation, not -- certainly not rules.

Q. Are you aware of any ships that are in the Navy that do not comply with the ABS standards?

DR. CHEN: Yes, sir.

Q. Which ships are those?

DR. CHEN: None of the military ships require ABS rules.

Q. That wasn't my question, Dr. Chen.

I'm asking do you know of any ships in the Navy that do not comply with the ABS rules?

DR. CHEN: Yes.

Q. Which of those ships --

DR. CHEN: Recently LDS-41 does not cite ABS rules.

Q. That's not my question, Dr. Chen. It's not a matter of citing ABS rules. It's a matter of complying with any ABS, do you know any ships?

DR. CHEN: What do you mean by -- I do not understand, sir, what you mean by comply.

Does it mean that they get the papers -- piece of letters from ABS certificate and say this ship arrangement conforms to ABS rules?

Q. Do you know of any ships --

DR. CHEN: I just mentioned LDS-41 that I'm also a consultant on.

JUDGE BRENNER: Dr. Chen, you have to let him finish the question. He's going to have to let you finish the answer. Otherwise, we will have to get a court reporter for each of you to take this down.

DR. CHEN: I'll slow down. I do --

JUDGE BRENNER: Why don't you you add the words "in fact" to one of your next questions and we'll get the distinction.

BY MR. SCHEIDT:

Q. In fact, Dr. Chen, don't the Navy ships meet the ABS standards whether or not they are required to comply with those standards or whether or not they have gone to ABS to determine whether ABS will give their approval?

DR. CHEN: Again, when you say -- maybe it's my English, when you say, in fact, whether I have performed some calculations or the Navy has performed some calculations to see whether that crankshaft satisfies ABS rules? That's my question.

Q. Dr. Chen, do you know of any ships for which calculations have been made under the ABS rules that show that those ships do not meet the ABS rules?

DR. CHEN: As I say, I don't know. I

don't know that the LDS-41 or the TAO diesel, these are the two major ship programs which are using medium speed engines. Whether they pass -- has anybody made calculation whether they pass ABS rules or not?

DR. CHEN: I think they certainly make a lot of calculations by the suppliers.

But I personally don't know whether those calculations and stress levels, torsional levels conform to ABS or not.

This is the truth.

Q. Dr. Chen, isn't it true that certain classification society rules are more conservative than others?

DR. CHEN: Well, some of the society rules are pretty old, and may be old fashioned, also, archaic.

There are rules that are handbook type of rules and the numbers are based on maybe lesser materials and based on less sophisticated calculations and their numbers appear to be lower, yes, sir.

Whether you consider lower limits as less safer or safer than the others, this is something I do not agree. I don't think that you can consider the lower numbers as safer.

Q. When you refer to lower numbers --

DR. CHEN: Limits.

Q. What are you referring to?

DR. CHEN: Lower allowable limits.

Q. Well, Dr. Chen, is it your testimony that some classification society rules are more conservative than others?

MR. STROUPE: I'm going to object at this point, Judge Brenner, unless Mr. Sheidt specifies one of the classification societies that I understand has been admitted as an issue or contention in this proceeding rather than just asking the general broad question about any classification societies.

JUDGE BRENNER: We'll sustain that objection.

You can get similar points to the extent material to the contention by being more precise, Mr. Scheidt, I think it would be more efficient, also. At the same time, I don't think it will deprive you of any substance to ask questions in context to the extent you still want to.

Q. Dr. Chen, isn't it true that with Lloyd's rules that an engine manufacturer can submit his design plans and seek approval of his engine?

DR. CHEN: I think in addition to design points, I think they also have to submit some other calculations, drawings, calculations and plans for his engines; isn't that right, what he submits to Lloyds?

DR. CHEN: Yes.

Q. And doesn't Lloyds have in-house staff of engineers and surveyors that review those plans and actually go out and look at the crankshaft in an engine; isn't that true?

DR. CHEN: In my deposition, I think before I have told Mr. Dynner that I don't know that much detail about Lloyds of London.

In this country, we use ABS and ABS is recognized all over the world as field surveyors all over the world, so I'm not familiar with what Lloyd does, and I have never had occasion to use Lloyd, sir.

Q. Then doesn't ABS have an in-house staff of engineers and surveyors who will review plans, drawings and send surveyors out to inspect the crankshafts in marine applications?

DR. CHEN: Yes. I believe what you describe is accurate.

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Q. And DEMA does not have an in-house staff of surveyors and engineers who will review plans and inspect crankshafts; isn't that true?

DR. CHEN: DEMA is not a standard as such.

I think it's referred to as a guideline. They certainly — certainly it's different from the ABS, and it does not have surveyors, it does not have inside technical staff to check calculations.

Q. And DEMA does not give its approval or disapproval to a particular crankshaft; does it?

DR. CHEN: All DEMA does is come up with, was a reference and a certain allowable limits to their member company and as more or less a self policing type of guidelines and it has no value to -- as far as — has no certificate about — or approval or not approval.

I think what you described is correct.

Q. And DEMA last revised its recommendations for stationary engines in 1972; isn't that true?

DR. CHEN: I believe it's 1972, yes.

I remember that, yes.

Q. And doesn't Lloyds rule -- Lloyds register and the ABS revise their rules almost every year?

DR. CHEN: ABS's last revision is 1984, so they have current rules.

Q. Do you know whether Lloyds revised its rules in 1984?

DR. CHEN: They actually sent out revision sheets every year, if it's revised.

They have a very thick volume, and they will send out revision sheets every year.

I have not -- I do not whether in 1984 rules on crankshaft is revised or not. I don't believe the 1984 revisions changed the torsional calculations.

Q. Dr. Chen, do you know whether the DEMA rules are currently considered to be up-to-date and current?

MR. STROUPE: Objection. Unless he specifies by whom.

JUDGE BRENNER: We'll allow the question as asked and an expert witness can take care of that, if there is such a possible distinction.

DR. CHEN: I am not on the DEMA technical committee today, so I cannot speak for DEMA. It would not be wise for me to speak for DEMA, but I did talk to the chairman, technical committee chairman, and co-chairman, and several other DEMA members, to question them about this, because it's my feeling that their quote unquote rules are not explicit enough to be used as a crankshaft criteria.

As time goes by, there's a lot of things which happens in the 1970's that are different than today, so I cannot consider them as up-to-date, in both the material area, especially the material areas, ABS, strength area, the calculation areas are different, and DEMA's rules are not that explicit.

But I do think that the members when they use it, they will use it because of some of these. Either way you can do, they will use it to design their crankshaft according to the -- to the spirit of DEMA, but, perhaps, maybe not the exact -- in exact formula, or -- what I'm tryin to say is the BEMA members, they do try to design the crankshaft, that will be satisfactory for the owners to use.

Believe me, no engine builders wants to build -- wants to produce a crankshaft that would not be reliable.

Q. Dr. Chen, are you through with your answer?

DR. CHEN: I'm just trying to tell you that -- you asked me the reliability of whether they are archaic or not, I'm trying to relate this obsolete formula, what engine manufacturers what they do in-house, how they use the DEMA standards.

Q. So, Dr. Chen, you don't know whether the DEMA rules are — the recommendations are still in effect; isn't that —

DR. CHEN: That's not true. That's not what I said.

I said that I talked to several DEMA members. They don't — they do not consider the DEMA rules are obsolete at this point, although there's some various discrepancies about the methods and interpretations of several — by their member firm.

The reason is like this. The way they explained it is the technical committee, because of the other more important standards they have to work out such as exhaust, emission, smoke, noise, particulates, that they do not — they have not found it necessary to revise some of the rules and some of the suggestions that have that I have submitted to them.

Q. Dr. Chen, you mentioned that -- you mentioned the words "archaic" and "obsolete" in discussing DEMA generally.

Do you believe that any portions of those recommendations are obsolete or archaic?

DR. CHEN: I don't — maybe I didn't use the words right.

What I'm saying is they are — they came out with the latest revision in 1971, 1972 like you informed me just a while ago, and actually there's very little changes between that version and the earlier versions, I believe, is maybe like 1950's, and so it is an older rules.

And, as I say, it is not the rules because they didn't specify how do you date -- they are based on old sets of criteria that they have accumulated throughout the years.

And that set of criteria goes back to the days of much weaker — much poorer was used.

And they find it satisfactory and the Navy found it satisfactory that some of those criteria are sufficient, adequate for the purpose of evaluating torsional vibration of the crankshaft.

Q. Do you know whether DEMA itself considers its rules to be outdated at the present time?

DR. CHEN: I think I just mentioned that I cannot speak for them.

I just — I talked to their members and that's what they told me, exactly. They said they have urgent things to do that they cannot respond to my questions.

Q. Dr. Chen, do you know -- Dr. Chen, isn't it true that the DEMA recommendations are no longer in print?

DR. CHEN: Well, I really believe that whatever reason that they say is adequate is the figures are conservative, so they don't think that the rules has misled their member firm, so that their different firm of suppliers will supply or furnish crankshaft which is not adequate.

I think that is one of also their thinking that when the member firm uses these formulas that the crankshaft will be satisfactory.

If the members uses these figures correctly, and if they do not use these guideline correctly and they will not be satisfactory, they don't have any other experience than that.

Q. Dr. Chen --

JUDGE BRENNER: Mr. Scheidt, I wonder if I might interject, obviously he was supplementing his answer to a prior question so you're undoubtedly warming up to restate your last question.

Let me suggest it for you differently because I don't know what you mean by no longer

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in print and I think there's a potential for miscommunication, unless you precisely state what you are asking.

Q. Dr. Chen, isn't it true that DEMA -- that the DEMA rules are no longer published and circulated by DEMA?

DR. CHEN: Well, I think -- what do you mean by that? Please, the menus are still used -- the standards are still used and from time to time they come out with revision sheets to update their standards or -- their so-called stationary standards and marine standards.

Q. Is it true, Dr. Chen, they haven't reissued any revisions to those rules since they were published in 1972?

DR. CHEN: You might know something I don't know.

I know that they have put supplementary sheets to their members about, I think I was personally involved, such as exhaust emission and acoustic measurement.

They sent the supplementary sheets to the manuals.

Q. Have they sent any supplementary organizations on the torsional aspects of the rules?

DR. CHEN: You'd better ask DEMA but I don't think so. I have not received any revisions on the crankshaft. I think the crankshaft standards have not changed since -- quote, unquote standards have not been changed since the last publication.

Q. Dr. Chen, do you know whether -- do you know that the DEMA rules are no longer available from DEMA?

DR. CHEN: I don't know that.

As I say, you'd better ask DEMA.

JUDGE BRENNER: Dr. Chen, when you talk about DEMA members, would those be limited to diesel engine manufacturers?

DR. CHEN: The DEMA members are only those builders, manufacturers of large reciprocating engines.

In this case, it would be -- maybe you can just refresh my memory, they are Cooper Bessemer, Waukesha Engine Company, Colt Fairbanks-Morse, and I believe White Superior, Dresser Industry. Dresser has two divisions and -- who are interested in DEMA, so Waukesha is one of the divisions. There's another division and Ingersoll-Rand I think adhered to DEMA. These are large diesel manufacturers. I might have missed some but these are the ones that --

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certainly my colleagues just reminded me that Enterprise Division, DeLaval Enterprise Division, TDI.

JUDGE BRENNER: Although you state you may have missed some, the sense that I'm getting from your answer is the number of members of DEMA are approximately five, perhaps some more, but not more than ten.

DR. CHEN: Not more than ten.

JUDGE BRENNER: Are they all American companies?

DR. CHEN: Well, these were organized only for -- interchange for technical information and set up some industry standards, practice, to upgrade the industry as a whole, so it's -- it's only for American companies.

MR. SCHEIDT: Judge Brenner, may I have a moment to confer with my colleagues.

(There is a discussion off the record.)

BY MR. SCHEIDT:

Q. Dr. Chen, you testified that you talked to some of the DEMA committee members.

What was the purpose of your conversations with those persons?

DR. CHEN: I have left the DEMA

organization since 1972, so I want to be sure that they don't have any concerning torsional calculations and crankshaft, and I did ask them whether they have — their methods that they are using are about the same as what I used before or any revisions in that area, so I asked for an interchange of information about torsional calculations, the methods, and certainly the limits.

Q. Are those the two — the only two general areas that you requested information from them on, and those areas being whether there were current revisions and to the methods used for torsional calculations and the limits?

DR. CHEN: Yes. Calculations, when you talk about calculations, there's a lot of details about calculations, yes, those are the areas that we're talking about.

Q. Who are the individuals that you spoke with?

DR. CHEN: I talked to Lee Evans who is the chairman of the technical committee.

Q. I'm sorry, what was the name?

DR. CHEN: LEE, L E E, E-V-A-N-S.

Q. Who else did you speak with?

DR. CHEN: Pardon?

Q. Who else did you speak with?

DR. CHEN: I talk talked to Richard Smally, S-m-a-l-l-y. I just remembered that I failed to mention Alco Engine Company is also a member. He's the chief engineer of Alco Engineering Company, and I talked to a staff member on the Colt Industries Fairbanks-Morse, he has been making crankshaft calculations since the 1940's, and I touched based with him and asked him about what is the latest DEMA practice, and -- industrial practice as well.

And I believe I also talked to someone at Cooper Bessemer about their calculations. They moved to Grove City, Mount Vernon.

Q. Approximately when did you speak with these individuals?

DR. CHEN: I talked to most of them earlier this year. When I was making some calculation for LILCO, I wanted to be sure that my calculations are still what's considered to be up-to-date calculations based on industrial experience.

And since I wanted to see whether those crankshafts were conforming to the DEMA guidelines, waoa

so I did check with the technical committee of the DEMA organization.

Q. And when you say earlier this year, can you give me an approximate month that you're referring to?

JUDGE BRENNER: Mr. Scheidt, I was trying to restrain myself for the last few questions, and I'm sure you're maybe seeing something that I'm not, but I fail to see how some of the detail you're inquiring into unless your questions will help us to determine the merits of the contention, particularly the names and precisely when he spoke to them, I can see why the general time frame might be relevant, depending on what the answer was, but I think we're getting more details than are necessary, yes.

MR. SCHEIDT: I think two more questions may establish or show to you the relevance and materiality of this line of questioning and I don't intend to pursue it in any more depth, much more depth.

JUDGE BRENNER: I don't recall anything in the cross plan that would have answered my question either, that's why I interjected, but go ahead.

He wants to know if you can tell him

approximately what month it was that you had these conversations, and then he's going to show me why the particular month has some materiality.

DR. CHEN: I think it's March or April that I have talked to several of them at that time, before I made the so-called DEMA calculations, and I also talked to them recently.

I talked to Lee Evans twice recently, and I talked to Bob Maddox which is a Fairbanks-Morse engineer, staff engineer, also recently. Recently means last three or four weeks, within the last three or four weeks.

Q. Did any of those individuals tell you at that time that DEMA is planning to revise its recommendations?

DR. CHEN: They say that it's not top priority, but they will consider to review it.

I don't think they say revise it, because I have asked some very direct and pointed questions.

Q. Isn't it true that DEMA -- DEMA committee is planning on meeting in November of this year, Dr. Chen?

DR. CHEN: They meet twice a year.

I don't know exactly when they meet, but regularly they meet twice a year.

I might want to add that the DEMA group is a very conservative group. They don't want to change anything if they find the calculations quite adequate; so I don't know whether they're going to revise or not.

I hope they will, because they are not that explicit.

Their first answer is, well, they have no problem with the rules, why would they want to — they more or less blame me to rocking the boat asking personal questions and pointed questions, and they think they are conservative — sufficiently conservative, but, yet, I have to say that it's my association with DEMA that they are very conservative, and also, I might add that large engines that I have designed that I have put in productions they all conform to the DEMA, and I have no problem at all with them, and also with my association with the DEMA members and other technical committee, I don't know of any case that they have problems with the crankshaft that they have passed the DEMA rules and have torsional problems.

I don't know of any, so the question is why do you want to change. I don't know whether

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they want to revise or not. That's the answer. I don't know whether they want to revise or not.

They are very defensive of their records.

Q. Dr. Chen, do you know that DEMA will not give out advisory opinions concerning their rules because DEMA considers those rules to be out of date?

DR. CHEN: They are very defensive about it. That's my impression. And they all seem to know what they are doing and they are a little bit resentful that I questioned what they are doing, frankly.

That's a true statement. And I don't know whether that they would consider it out of date or not. I think you have to ask them.

JUDGE BRENNER: Mr. Scheidt, I don't know what you mean by advisory opinions. That's a broad label. If you meant whether or not DEMA would refuse to state whether a crankshaft met its standards or not, then you'd better ask that question. You did not mean that --

MR. SCHEIDT: No. That was not the meaning of my question.

Go ahead.

BY MR. SCHEIDT: Isn't it true, Dr. Chen, that DEMA has a procedure where you can request an

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interpretation from DEMA of its rules regarding crankshafts and torsional vibrations?

MR. STROUPE: I'm going to lodge an objection at this point. I just fail to see the relevance of this line of questioning, Judge Brenner.

JUDGE BRENNER: Well, I see the relevance. I don't know if it will go anywhere, but it's certainly relevant as an opening question.

Objection is overruled.

JUDGE BRENNER: Do you need the question repeated?

DR. CHEN: Please.

Q. Isn't it true, Dr. Chen, that DEMA has a formal procedure where you can request a formal interpretation of DEMA rules concerning torsional vibrations and crankshafts?

DR. CHEN: When I was at DEMA on the technical committee or on the Board I didn't know such a rule. Maybe there's a rule, but it was never used when I was there.

Q. Well, I'm not talking about a rule. I'm talking about a procedure by which any manufacturer can request an interpretation of the DEMA recommendations.

DR. CHEN: I don't know whether there's

so-called set procedures. When the technical committee get together, they talk about different issues, and they can bring it up any time in the meetings.

As you know yourself, they meet twice a year.

Q. When you were a committee member for DEMA, did you ever receive a request for an interpretation of a DEMA rule?

DR. CHEN: I was associated with DEMA in 19 -- from 19 -- I resigned, I think, 1973, as a board member, and when I was at the head of the chairman of the technical committee, had not received any -- the way you described it, whatever that is, questions about how to interpret calculations, whatever you said.

I have not received it. I don't remember if I received it as a chairman of the technical committee.

Q. Dr. Chen, you testified that marine engine classification rules are more stringent than the rules for stationary land based engines.

Are you familiar with DEMA's rules concerning marine engines, and, Dr. Chen, I don't think you need Mr. Youngling to prep you on this.

If you know, you know, if you don't know, you can tell me. Mr. Youngling can chime in with whatever he wants to chime in after I get your answer.

DR. CHEN: I can answer the second part of it.

I don't think I can answer the first part of it.

Q. Well, try to answer the question, Dr. Chen, please.

DR. CHEN: Repeat the question again.

Q. I'll ask the question again.

Are you familiar with DEMA's recommendations concerning marine diesel engines

DR. CHEN: Yes.

Q. Isn't it true, Dr. Chen, that the marine diesel recommendations for DEMA had the exact same limits for torsional vibrations as the stationary land based engine rules do?

DR. CHEN: Yes, sir.

Q. So, Dr. Chen, isn't it true that DEMA then does not consider the — does not impose a more stringent rule concerning torsional vibrations for marine engines than it does for stationery engines; isn't that true, Dr. Chen?

DR. CHEN: First of all, when you talk about --

Q. Can I first have a yes or no answer and then the next question.

DR. CHEN: I can't answer it yes or no. May I explain this a little bit? This is not a yes or no answer. May I speak just two words?

JUDGE BRENNER: If you can't answer yes or no, then you can explain what your answer is.

DR. CHEN: The limits are the same but the rules are different, the calculations are different.

Q. Are those calculation formulas stated in the rules, Dr. Chen?

DR. CHEN: Yes, it says in the rules when you're marine you have to consider not constant speed, you have to consider variable speed operations, so the rules are -- the limits are not the same at design point, but you have to consider much more in the marine engine -- than you do in the stationary engines. In the stationary you only have to worry about synchronized speed.

Q. Isn't it true, Dr. Chen, even for stationary land-based engines DEMA have recommendations for underspeed and overspeed?

DR. CHEN: Yes.

Q. And does DEMA also have the same recommendations for marine engines?

DR. CHEN: If I read it, it would be different in this respect, that in the — in the stationary engines for the — especially modal engines, constant speed engines, you only have to worry about plus or minus of the design speed, but for the marine engines, you have to consider the whole speed range from idling to the design speed.

Q. Isn't that plus or minus ten percent rate of speed?

DR. CHEN: No. The marine engines you have to consider the whole speed range.

DR. PISCHINGER: May I —

Q. But the limits, Dr. Chen, are the same for torsional vibrations.

DR. CHEN: I think I mentioned that before. The limits and the design speeds are the same.

Q. Thank you, Dr. Chen

JUDGE BRENNER: Mr. Scheidt, I think Dr. Pischinger wanted to add something in answer to your last question. So I'll allow him to make his statement.

DR. PISCHINGER: I just wanted to add that most marine engines operate in a really wide range of speeds and even loads and it depends very much on their -- on the way of how they operate, what gearing, for instance, they have, if they use gears, and though the speed question is very, very complex and you have really to be concerned with the very wide range of these speeds, and this is one of the reasons why -- because -- or the reasons for the ship -- rules for ship engines, the range of rules for ship engines are usually very conservative because you cannot even define these ranges because you cannot define completely the operating range of a ship.

A ship can come into conditions which weren't even taken into account during design, therefore, you have to over design.

I want to state -- I know it's going a little beyond what I -- what your question was.

Q. Are you familiar with the DEMA rules, Dr. Pischinger?

DR. PISCHINGER: Yes.

Q. Isn't it true that the torsional vibration limits are exactly the same for the stationary marine based engines?

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DR. PISCHINGER: Yes, as far as nominal stresses are concerned.

Q. Thank you, Dr. Pischinger.

DR. CHEN: May I add one more thing, since — you asked whether — I think you're trying to say that the DEMA does not consider — there's a difference between the stationary and marine, and you do not consider the marine engines are more stringent applications.

I want to put it a little bit different way to try to convince you, yes, they do consider the severity of the marine engines, but since the stationary engines are sometime also used in marine, and also has to satisfy the marine, so if you — if the limits — same limits of thousand pounds and 7,000 pounds are adequate by experience for marines, I think you can almost say that this is a conservative type of limits for stationary.

JUDGE BRENNER: Mr. Scheidt, if you pick a convenient time, we can take a break. I don't know if this is it or if you want to go a little bit longer.

MR. SCHEIDT: This is a very convenient time.

JUDGE BRENNER: Let's break until 3:30.

(Recess)

JUDGE BRENNER: We're back on the record.

MR. STROUPE: Judge Brenner, I think Dr. Chen would like very much to correct a statement that he made on the record concerning DEMA, because I believe -- well, he has something he'd like to say, but I think you'll find that something he said was not what he thought he said.

JUDGE BRENNER: All right. If it's an error, we'll certainly allow a correction at this point.

MR. CHEN: I think -- half an hour ago, the County asked me a question about whether I have said whether DEMA's rules are obsolete or archaic. I need to clarify a little bit.

What I meant truthfully is DEMA rules and the limits in the 1972 edition say something about 5,000 pounds for single orders and 7,000 pounds for sum of orders -- of major orders, and those rules actually came from 1959, so it's some time ago.

And the material used at that time, I think, when we talk about rules, we talk about limits, we also have to talk about the background of those calculations and the limits.

The background at that time in 1959 and

1972 certainly are three things we have to consider, one is the material values used at that time, the limits is based on so-called conventional material to us engineers, conventional materials are SAE 1045, which is certainly not as good as the material used in these shafts we're talking about today.

Ultimate tensile strength is somewhere around 60, 70,000 pounds, not more than that, most probably a little bit less, if I check the details of that.

Number two is the calculation methods at that time frame, 1958 and given even as late as 1972 are what we call Holzer analysis force vibration which is based on the work -- previous work done by the engineering board by Kerr Wilson and by British organization called British Internal Combustion Institution.

The calculation methods at that time are the Holzer type of calculations, quite a conservative type of calculations.

It's an older calculations, and also --

JUDGE BRENNER: What kind of calculations? I just didn't hear the words.

MR. CHEN: It's older calculations, which they have attempted to correlate with the torsiograph data, and so we have to consider the methods to use and both the in the calculations and in the measurements, so at that time the limits of 5,000 pounds and 7,000 pounds has not changed since 1958 or 1971 — 1972, and not even today. They are based on those calculations.

As far as my experience and also some of the peoples that I talked to, these calculations are conservative in this respect.

If we use better material then we will have higher margin of reliabilities; however, if we use different calculations, if we use more modern calculations — then those numbers could even be exceeded, if we're still using the old material.

So there's a lot of these things involved here, but if we use the old material and if we use the Holzer forced vibrational calculations, and conventional crankshaft to those rules of 5,000 pounds or 7,000 pounds, maybe old figures are conservative limits and I do really believe that, because, as I mentioned earlier, that I've been working on engines and crankshaft since the 1950s and I don't know of any crankshaft which passed these rules and suffered torsional problems.

JUDGE BRENNER: I'd like to make two

points about that answer, one minor and one greater than minor one.

The minor one is I'd like the witnesses to watch the jargon. I take it when you said 5,000 and 7,000 pounds I take it you meant 5,000 pounds per square inch. I'd like to get --

MR. CHEN: Per square inch.

JUDGE BRENNER: When you said orders, you meant orders of vibration.

MR. CHEN: Yes.

JUDGE BRENNER: Major point, Mr. Stroupe, as counsel counsel to exercise better judgment to distinguish correction of an error for which we would give you leeway even there is no pending question.

The main reason for that, we certainly don't want questions and answers to go on for the rest of the day, perhaps even into another day based on an error. And then wait for redirect to turn something around, perhaps, as much as 180 degrees and then get a whole new round of cross-examination.

That's why we give leeway. What we just had now does not fall into that category of correction of errors. A large part of what we just heard is a lot of things that are repetitious.

To the extent it's not repetitious, it's an elaboration removed in time at least from the pending question and suitable for redirect and not interruption at this point.

I want the cross-examiner to be within reason to be able to set a pace.

I've worried about the time here and I've already alluded here to the fact that time is not solely the fault of the cross-examiner.

MR. STROUPE: I understand, Judge Brenner. I'd just state that I frankly thought the answer was going to be very short and somewhat briefer.

MR. SCHEIDT: One follow-up question to which was testified to, Dr. Chen.

Q. Your testimony if you used a more sophisticated analysis that you believe DEMA contemplates, and if you -- are you still using old crankshaft material, you can safely exceed the DEMA limits, is that what you testified to?

MR. CHEN: DEMA, when they designed the spec -- designed the limits, they used quote unquote conventional material. My interpretation of that is 1045 steel. I can find the reference to that. I think the question is also if we use a new calculation method, whether the results would be higher than what I described, the Holzer forced vibration calculation, it could be higher, so in that case, the limits, the stress level, nominal stress level calculated by newer methods could be higher than the methods were used in the 1950's, sixties, yes.

MR. SCHEIDT: Thank you, Dr. Chen.

BY MR. SCHEIDT:

Q. This is to anyone on the panel. Which are the conventional analytical techniques typically utilized by the diesel engine industry that LILCO is relying on to show compliance with DEMA?

MR. CHEN: In my testimony, I have explained what methods I used and it's also in the exhibit, the number is --

Q. I would just like the names or the analyses that were performed that you are using to show compliance with DEMA.

MR. CHEN: Yes. I used actually two methods. The first methods is to -- the traditional Holzer Wilson Bicera type of calculation which is widely used, even at that time, and certainly today, and that program -- the software I used is called TORVAP vibration program, TORVAP/R or C. That is available through Comshare, which is a computer software firm. I choose to use a common domain software to avoid any comments what I have used, whether it's right or wrong, and that TORVAP, it's developed by CAD, a program — computer program firm in England, and is sponsored by the British Internal Combustion Institute, and it's very close to — or basic — it's very close to what Lloyds described in their rules, and.

And I also used a more advanced computer program called TORVAP C, C as Charles. There is basically a — recourse harmonic synthesis method, basically simultaneous solution of many equations depending on the number of cylinders and number of mass we consider.

It's a complex number type of program and it will give you stress level, not only at the first mode — nodal point, but also give us stress level at all the mass or all the shaft section we consider.

So this is a more advanced, more precise method which is developed, which was introduced by TORVAP in the middle of the 1970's, and it's available in this country through first SDRC, SDRC then give it to Comshare, so SDRC is structural dynamics.

DR. MC CARTHY: Research corporation.

MR. CHEN: Research corporation which at that time was a division of U.S. Steel but today is -- it's hooked up with General Electric, affiliated with General Electric.

Q. You're relying on TORVAP/R and TORVAP/C calculations to show compliance with DEMA; is that correct?

MR. CHEN: For compliance, for calculation, yes.

DR. JOHNSTON: I'd like to add to that.

In addition, Failure Analysis Associates has reviewed the Holzer and forced vibration calculations of Trans-America DeLaval to agree with them that they show compliance with DEMA, and, in addition, the crankshaft at Shoreham has been torsiographed to actually experimentally measure the response of the crankshaft, and from those measurements, it is also shown that the crankshaft meets the requirements of DEMA.

Both these items are explained in more detail in Section 2 of the Failure Analysis report, which is Exhibit C-17.

Q. Thank you Dr. Johnston.

Dr. Chen, your TORVAP calculations are widely used in the diesel engine industry to measure crankshaft torsional stresses, isn't that true?

MR. CHEN: Please repeat your question. The last part I didn't hear very well. You said measured --

MR. SCHEIDT: I'll ask the question again, Dr. Chen.

Q. Isn't it true that your TORVAP calculations are widely used in a diesel engine industry to measure nominal crankshaft torsional stresses?

MR. CHEN: Quite commonly used in this country -- well, has been used in this country and certainly used in the United Kingdom, not to measure torsional vibration, but to calculate torsional vibration.

Q. I'm sorry, Dr. Chen, calculate.

MR. CHEN: Nominal.

Q. Is your method a modal superposition method?

MR. CHEN: I would say yes. Some other expert might talk about the difference between harmonic synthesis and modal superposition, but basically, this method is a simultaneous equation solution which was explained in my earlier paper.

Q. And although there may be certain

differences in the values that you use in your calculation, the method is basically the same or very similar to that employed by FaAA; isn't that true?

MR. CHEN: I think I did try to check these two methods, and I have to report the answers are very close, although I don't know the detail program that FaAA used.

Q. But, Dr. Chen —

MR. YOUNGLING: Excuse me.

JUDGE BRENNER: There's been a question answered.

Let him ask the next question then. Go ahead, Mr. Scheidt.

Q. Did you review the calculations that were performed by FaAA?

MR. CHEN: I reviewed the answers and the description of the methods they used.

Q. So in addition to looking at the description of the method that they used, you compared your results with those of FaAA, is that what you're saying?

MR. CHEN: Yes.

Q. And you don't know the detail of program that they used, you aren't familiar with the detailed program that they use; isn't that true?

MR. CHEN: Detailed program, I have talked to the author of that paper, which is Dr. Johnston. We believe it's comparable.

It's very close, although I have not seen all the equations, all the assumptions that they make.

I believe that if we use the same input, hour output, it will be within a few percent.

Q. Now, are you an expert in finite element analysis, Dr. Chen?

MR. CHEN: I am not an expert of finite element methods.

Q. Have you ever performed a finite element analysis on a crankshaft on a diesel engine?

MR. CHEN: I'm not an expert.

I have not performed an analysis on a crankshaft using finite element.

Q. Now, is modal superposition analysis a conventional analytical technique that is used in the diesel engine industry?

MR. CHEN: I would say that in the last few years, whether it's 1975, 1976, they are certainly more used.

I don't think that this method is used by

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all the engine manufacturers, or I don't think — I don't know how you describe popular, but in this country I don't think it has been used by too many companies.

Q. Well, you testified that TORVAP is widely used by the diesel engine industry — engine manufacturers industry, didn't you?

MR. CHEN: TORVAP/R or its equivalent are more or less the traditional methods and the traditional industrial practice, yes.

TORVAP/C, I would consider that a more advanced method. It does quite a bit more than TORVAP/R, and I don't know how many people are using it today, but certainly after I get on this job, I find out as several other consultants are using these methods.

Q. And FaAA is an organization which uses the modal superposition analysis in its analysis of crankshafts; isn't that true?

MR. CHEN: I think we talked about that before, and we — I say I have even tried to compare results with the two methods, and they are very close, within a few percent.

Q. And would you say that the most modern and up-to-date diesel engine manufacturers and consultants use a modal superposition analysis to determine the adequacy or not of crankshafts and diesel engines?

MR. CHEN: I didn't say that.

I say it's a method to calculate nominal torsional stress, and a crankshaft calculation takes much more than just to determine the nominal torsional stress.

It's just one other thing you have to do.

Q. But the more modern up-to-date manufacturers and consultants use modal super-position analysis as part of their analysis of the structural adequacy of crankshafts; isn't that true, Dr. Chen?

MR. CHEN: When you say more than some of the other people who don't use these methods, but they might still give very good answers, I — they were — they would object to what I say, but what I'm saying is if I use the TORVAP/C type of calculations or the modern modal superpositions or the harmonic synthesis methods or the Holzer complex methods that some of these consultants use, that they will be able to predict the dynamic behavior of the crankshaft better than the Holzer traditional methods.

Q. Now, did FaAA use the results of its modal superposition analysis to show compliance with DEMA, Dr. Chen?

I'd like Dr. Chen to answer this question. You can follow up —

MR. STROUPE: I'm going to object to this on the basis this question should be more appropriately put to FaAA rather than questioning one witness what another witness did.

JUDGE BRENNER: May I have the question read back.

(The reporter read the record.)

JUDGE BRENNER: Yes. The objection is sustained.

Why don't you direct it generally to the panel, and if Dr. Chen wants to add something or if you want to ask Dr. Chen, in particular, about it, you can, but you've got FaAA witnesses here and they would be the witnesses to ask.

Q. Dr. Johnston, you didn't use the results of your modal superposition analysis to show compliance with DEMA; did you?

DR. JOHNSTON: FaAA showed compliance with the DEMA standards based on its review of TDI's calculations for single order response, and for combined order response based on the measured torsiograph method; so that our modal superposition method, rather than being used to compare to the DEMA allowables, was used to calculate an actual stress in a concentrated fillet location by following up with the finite element method, and that, then, was correlated to the experimental strain gauge results in order to compute the factor of safety of the crankshaft.

Q. So FaAA did not use of the results of its modal superposition analysis to show compliance or not with DEMA; isn't that true?

DR. JOHNSTON: The compliance with DEMA for offspeed conditions was, in fact, performed by using a modal superposition analysis to predict the free end response of the engine that would have been measured by a torsiograph, had it been possible to run the engine at those off-speed conditions under load.

Then the standard torsiograph method was used to reduce that front end amplitude to a nominal stress.

So for that particular part of the compliance with DEMA the modal superposition method was used somewhat indirectly.

The direct application of the MODAL super position analysis was not used for the comparison with DEMA but was used for the calculation of a factor of safety.

Q. And, in fact, Dr. Johnston, don't the results of your modal superposition analysis show a stress -- show stresses higher than the DEMA allowable limits for some of the orders?

DR. JOHNSTON: The stresses computed by the modal superposition analysis we do not feel are appropriate to compare with the DEMA allowables.

Q. Dr. Johnston, please answer yes or no first.

JUDGE BRENNER: Let me interrupt.

JUDGE BRENNER: Answer his question first, Dr. Johnston. Then answer the question.

(The record is read by the reporter.)

DR. JOHNSTON: Judge Brenner, I think that's sort of an apples and oranges comparison which is why I could not answer that question as yes or no.

In fact, the true stress in the fillets of the crankshaft are of the order of 24,000 pounds per square inch as is shown in our report that included as Exhibit C-17.

Again, that number would not be a number to compare with a DEMA allowable. Simply because it is a different type of stress, so the point that I was trying to make was that since the modal superposition analysis technique including the 24 orders that were summed was not the type of calculation as Dr. Chen has testified, that would be performed to compare to the DEMA limits set in 1972.

Q. In fact, Dr. Johnston, Dr. Chen did perform those calculations and compared them against the DEMA limits.

MR. STROUPE: I'm going to object to that question.

I don't believe Dr. Chen testified he used the methodology utilized by FaAA.

JUDGE BRENNER: That wasn't the question. Objection is overruled.

Q. Didn't Dr. Chen, in fact, use the modal superposition analysis to show compliance with DEMA?

I'd like your answer, Dr. Johnston. Didn't he?

MR. STROUPE: Again, I would object, Judge Brenner, on asking one witness to describe what another witness did in an independent calculation —

JUDGE BRENNER: This is — we sustained your objection before.

This is one is a little different.

This time Dr. Johnston relied for support on something he said Dr. Chen did or did not do, and the cross-examiner is entitled to follow-up.

We'll certainly give Dr. Chen an opportunity to add if he wants to, and that should solve your problem.

DR. JOHNSTON: I believe Dr. Chen indicated he used the TORVAP program to show compliance with DEMA.

I have not been involved in a review of Dr. Chen's work, and have not, in fact, reviewed the TORVAP power program.

MR. CHEN: May I add, since my name is mentioned here.

We think consultants just between consultants, just like between experts, they will compare methods and there are two things I should mention here, there's Dr. Johnston's methods and my methods.

Dr. Johnston's methods is using — using what I call actual torsiograph data which is any time where there's any doubt in any of these codes, you will always refer to the test data.

Test data take precedant, so he used the torsiograph data, and using a conservative Holzer force vibration type of simulation and obtain the results that way.

Yes, I used both the TORVAP/R and TORVAP/C methods to see whether the DEMA allowable is exceeded or not.

I also looked at Dr. Johnston's calculations when he used the TORVAP/C methods on single order. It's okay.

The single order between consultants, there's very little disagreement. When he used the single order when compared with the 5,000 pounds DEMA specified between the consultants there is very little disagreement, because that calculation is more straightforward, doesn't mean it's easy. More straightforward.

It's when you talk about the sum of the orders that even between the consultants there might be some discussions on.

I want to refresh your memory that I testified before, I say that DEMA code for the sum of the orders they are talking about the sum of major orders, so then I would -- I would be going into how major orders are defined.

What TORVAP/C calculations which is quite recognized, consider do it this way, how do you define major orders.

We use altogether 20 orders of input, harmonic input.

Then from -- in the TORVAP/R calculations, the TORVAP/C allows you to pick the major orders out of that calculations.

If you see some of the industry calculations, use sometimes two major orders, sometimes four major orders.

The TORVAP/C software I used can go up to -- from those 20 orders we can add them together, summarize together six orders, so six orders rather than either two or four sometimes industry used.

So I based my DEMA -- the so-called DEMA calculations based on six major orders, and using the -- what I call modal superposition methods or harmonic synthesis methods which considers all the modes and all the orders -- well, 20 orders.

Then I pick six of them and later on I pick 12 of them and see whether it conforms to DEMA limits or not.

The industry will be happy with four or

six. I believe ABS only used two, so I think that we both have just different terms what is the DEMA rules. That's the difference.

Q. Dr. Chen, for purposes of Dr. Johnston's answer can you tell him whether your calculations were in compliance with DEMA?

MR. CHEN: I believe I mentioned before if we use the same input, same assumptions and same orders, our answer will be within a few percent.

Q. Dr. Chen, I am sorry.

I am not asking you how your calculations --

MR. CHEN: It will conform. If you use the same inputs, same assumptions and same major orders that I considered, I consider up to twelve. If he used those twelve orders and -- they will conform.

Q. Okay. I'm asking you your calculations by themselves supposedly show compliance with DEMA; isn't that true?

MR. CHEN: Yes.

Q. Okay.

Dr. Johnston, now, Dr. Chen has used his modal superposition analysis to show compliance with DEMA.

You had testified earlier that you didn't know what he had concluded.

Now, isn't it true -- is that not true, that you did not testify to that?

DR. JOHNSTON: I don't believe I did testify that I didn't know whether he had reached a conclusion that the crankshaft satisfied DEMA. I indicated that I had not reviewed his calculation and could not tell you what the TORVAP/R program specifically did.

Q. Okay. Then I misunderstood your testimony.

Isn't it true that he used modal superposition analysis to show compliance with DEMA?

DR. JOHNSTON: Dynamic analysis techniques, if you go back far enough will find the same root.

Whether you say, for example, the TORVAP/R uses modal superposition and so does the method used by Failure Analysis Associates, and they both are modal superposition are not the calculations the same is really not the point.

If you go back far enough in dynamics, all equations -- all methods used Newton's equation of F equals MA.

Basically, the distinction, as I think

Dr. Chen has explained, is that in his technique he specifically uses what DEMA states as major orders.

And in his capacity of being an ex-chairman of the technical committee of DEMA is able to interpret what those major orders should be and has used them in his analysis to show compliance with DEMA.

DR. PISCHINGER: May I?

JUDGE BRENNER: Wait. Dr. Johnston, I think you went beyond the question.

Perhaps, the questioner disagrees with me.

I think you were trying to guess where he might be going with his follow-up questions.

Why don't you ask your question again, Mr. Scheidt.

JUDGE BRENNER: Ask the question again.

Q. Didn't Dr. Chen use a modal super position analysis to show compliance with DEMA?

DR. JOHNSTON: As I indicated before, I don't know the method he used except to the extent that he used the TORVAP program.

I do know that his calculations show compliance with DEMA.

Q. Do you know whether the TORVAP program is a modal superposition analysis?

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DR. JOHNSTON: I don't.

Q. Did you hear Dr. Chen testify to that effect minutes ago?

DR. JOHNSTON: Yes, I did.

Q. Don't you believe him, Dr. Johnston?

MR. STROUPE: I'm going to object to that question.

JUDGE BRENNER: That's unnecessary, given the explanation by Dr. Johnston.

The last question was mostly answered although not totally completed, it was also an implied mischaracterization, in any event.

Why don't you get to where you want to go with Dr. Johnston by asking him to assume certain things and you can then tell us — in your findings you established an assumption through another witness; if you, in fact, feel you need to follow up with further question and answer.

Q. Isn't it true, Dr. Johnston, that your calculations under the modal superposition analysis that you performed results in stresses that exceed the limits of DEMA of 7,000 psi?

MR. STROUPE: I'm going to object to this question.

I think it has been asked and I believe

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he got a full explanation of the answer some time ago.

JUDGE BRENNER: It had been asked, but I disagree with your last point, so the objection is overruled.

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

(The record is read).

DR. JOHNSTON: No. That's not true, because the limits that are set in DEMA specifically refer to the summation of major orders, and that is not what was performed in my analysis.

That was what was performed in Dr. Chen's analysis; thus, the stresses calculated in Dr. Chen's analysis should be compared with the allowables in DEMA, and those calculated in my analysis since I summed many more orders than are included in the term major orders should not be compared with the DEMA limits.

JUDGE BRENNER: You summed 24 orders of vibration?

DR. JOHNSTON: That's correct.

JUDGE BRENNER: What was the result?

DR. JOHNSTON: Depending — at what location? It varies along the shaft.

I think we could refer you to the report.

JUDGE BRENNER: All right. Refer me to the report.

DR. JOHNSTON: Exhibit C-17, Table 3.4 on Page 3-15 shows the amplitude of nominal shear stresses at various locations along the crankshaft as summation of the 24 orders.

JUDGE BRENNER: All right. Thank you.

MR. SCHEIDT: One second, Judge Brenner.

BY MR. SCHEIDT:

Q. Dr. Johnston, when did you perform your — let m. start it over again.

Did you perform your modal superposition analysis after you knew the results of the Stone and Webster torsiograph test?

DR. JOHNSTON: I really don't recall.

It was approximately the same time.

These analyses were conducted after the test program of January 1984 because of the fact that these particular analyses use the pressure loading that was measured during that same test; so we were using the pressure from that test, the torsiograph measures were made up during that same test.

I can't be sure which data I got first

and which analyses I did first.

It all happened approximately the same time.

Q. Well, if I can refer you to Exhibit C-17, wherein on page 3-1, the third sentence at the top of the first paragraph —

JUDGE BRENNER: Mr. Scheidt, I'm sorry, I missed your page reference.

Q. Page 3-1 of Exhibit C-17. It is stated that, however, the stresses for combined orders were quite close to the 7,000 psi that is recommended as an allowable, and that refers to the calculation of nominal shear stress from the torsiograph test; isn't that true?

DR. JOHNSTON: That is correct.

Q. Now, did you have the results of those calculations prior to performing your modal superposition analysis?

DR. JOHNSTON: I think I just explained that it happened at about the same time.

I don't remember on which day I did which calculation.

Basically, obviously both calculations were performed prior to the writing of this report.

But within the month or so that the work was being done, I don't recall which happened first.

Q. Now, Dr. Johnston, how do you know which are the major orders under the DEMA rules?

DR. JOHNSTON: In my analysis, I have not chosen major orders.

The analysis that I have conducted includes the 24 orders and was specifically done because of the -- of this statement that you just referred to, because of the fact that the torsiograph showed numbers that complied with DEMA but were still slightly below.

We felt it prudent to follow up that with a more complete analysis, both of testing and of modal superposition analysis followed by a finite element analysis combined showed the true margin of safety of this particular crankshaft.

That is the reason for performing the finite element analysis.

If I had just wanted to do a calculation showing the comparison with DEMA and using the major orders, I would have referred to Dr. Chen's analysis who has had much more experience with using the DEMA code and thus would be able to select the major orders.

Q. So, Dr. Johnston, you don't know what the major orders are?

I'd like your answer, not Dr. McCarthy's.

DR. JOHNSTON: In writing the report, I did not have to select the major orders. I could give my interpretation of the major orders, but that would be similar to Dr. Chen's.

The major orders are obviously the orders which lead to the highest stresses, and the number of those that should be used.

According to Dr. Chen, it is customary to choose four or six.

I have reviewed; however, the American Bureau of Shipping calculations where they showed they just used two.

Q. So you don't know what the major orders are, do you?

DR. JOHNSTON: No.

I think I have an opinion as to what the majo ..ders — some of the major orders are; however, I did not use that in my analysis.

JUDGE BRENNER: That was some, s-o-m-e.

DR. JOHNSTON: Yes.

BY MR. SCHEIDT:

Q. Can you give us your opinion now as to which those major orders are?

DR. JOHNSTON: For example, for this particular crankshaft, the fourth order is probably the major order.

JUDGE BRENNER: I want to ask you about these particular crankshafts.

Now, if it varies among the three Shoreham diesels, you can tell me that also.

DR. JOHNSTON: No, it does not vary among the three Shoreham diesels.

The fourth order would be the most major order.

In addition to that, the five and a half order would be considered a major order.

Then those would be the two, for example, that the American Bureau of Shipping used.

If one wanted to go beyond that, one might choose the four and a half order or the two and a half order, but there is obviously a subset of all possible orders which do represent major orders, and which do lead to higher stresses than other orders.

For example, the twelvth order or the first order do not lead to significant stresses.

Q. Dr. Chen, perhaps you can answer this question.

DEMA doesn't specify how to determine which orders are major and which orders are not; does it?

MR. CHEN: All these calculations, you can't specify because there's so many different crankshafts and so many different mass elasticity, each crankshaft will give you for specific design, will give you different major orders.

But all the engineers know how to pick them. I know how to pick them.

Q. Dr. Chen, the question is what does DEMA consider appropriate to use as the major orders?

MR. CHEN: I would answer it this way, that if you use a TORVAP/R calculation, you simply find four or six large free end -- larger torsional amplitudes.

This can be confirmed also by using torsiograph, up to date torsiograph and then using harmonic analysis, and find out what are the few largest torsional amplitudes, and in the case of the crankshaft we're talking about, you will find that the fourth, or certainly the largest, like Dr. Johnston said, then there is other orders close to that.

Usually depending the rate of what the

rate of speed is.

If you have 450 RPM, and usually fourth order, five-and-a-half, four and a half, two-and-a-half, those orders are major, and ten, twelve orders or ten-and-a-half, eleven-and-a-half, eight-and-a-half, those are farther away, and we know engineers would not consider them as major orders.

But if you talk about same crankshaft running at 3,000 RPM, which is impossible, let's say that, then the other orders would be major orders, so it's not -- it takes a professional to design a crankshaft and interpret the data; and it's not that black and white, who are major orders.

You have to know how to design a crankshaft.

Q. Dr. Chen, so DEMA itself does not provide any guidelines as to choosing which are the major orders and which are not; does it?

MR. CHEN: The guideline is the engineering judgment.

If you have torsiograph data to break it down and see what are the -- those orders which give you the largest amplitudes are the major orders.

Then it depends how prudent -- how conservative an engineer is to select the most major

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ones.

The major one is fourth order and the others are significant orders.

Then the other orders are insignificant orders. There's three distinguished -- it's fourth order in this case.

Then you have moderate major which is three or four of them.

Then you have insignificant orders, and the time when we decide the code, nobody knew how to add two different modes together, vectorially or geometrically.

Now we know so here is your problem. May I try to explain this problem with --

DR. PISCHINGER: It dates back to the time when the possibilities of computers hadn't been so far.

I myself have even worked in this time, and each calculation of each of these orders was a lot of effort, and so the engineers got knowledge how to restrict on the most important orders, and the rules which have been made are -- have been set so that this was taken into account that you really hadn't -- you need not get to the last trifle of the orders.

But today with the computer program, it's really easy to sum up all orders, though one should have really updated the limits in order to accomplish with today's modern computer programs.

Q. Dr. Pischinger, prior to performing the work on this case for Shoreham, had you ever performed a calculation using the DEMA limits?

DR. PISCHINGER: Calculations using the DEMA limits means —

Q. Perhaps I should ask a more precise question.

Had you ever before this case used the DEMA recommendations in determining the adequacy of a crankshaft?

DR. PISCHINGER: No. I did not.

In Europe, DEMA has no meaning.

What I explained holds true to all sorts of — what I previously explained, holds true for all sorts of codes where stress limits are given.

MR. SCHEIDT: Judge Brenner, I would move at this time to strike his prior answer to the extent that it purports to explain what the DEMA code or the calculations and recommendations involved.

JUDGE BRENNER: You're going to be one

for two today, Mr. Scheidt, because --

MR. SCHEIDT: Fifty percent is never too bad.

JUDGE BRENNER: Your argument is a non sequitur, and the way you phrased the question that you withdrew proves the non sequitur.

The necessary assumption is that you need to use a DEMA limit performed like a calculation, and if you would have let Dr. Pischinger answer that one he would have explained it.

Perform the calculation and then you see if it meets some benchmark, and he's used it against other benchmarks in Europe, not the DEMA code, but, nevertheless, what he told you about calculating orders holds true, and then you take the result of the calculation and do what you want with it.

Some people agree with DEMA. Dr. Pischinger does not.

Q. Dr. Chen, how many major orders are in the replacement crankshaft at Shoreham?

MR. CHEN: Are you saying that how many major orders or how many orders?

Q. I'm asking you how many major orders are there on the -- with respect to the crankshafts at Shoreham, replacement crank shafts.

MR. CHEN: I believe I answered that major order at 450 RPM is the fourth order. That's the — the major order.

Q. Let me in asking the question, Dr. Chen, I'm referring to the term orders, major orders as it is used in DEMA.

MR. CHEN: I think I also testified a little bit earlier that DEMA does not specify exactly how many orders you have to use, simply because in one calculation, if you happen to be between high speed engines, between, let's say, four, and four and a half orders, then certainly those are the two — could be equally major orders.

Then in other crankshaft, they are — the orders are — does not — not one is the major, so you have to use four, six to give you the combined true sum of orders.

Q. And your calculations, you used six orders and twelve orders.

MR. CHEN: The software I used is the TORVAP/C.

I mentioned that TORVAP/C in my report that only allows you to put in the inputs of six major orders.

We do consider 20 orders, but we pick by my own engineering judgment the six largest stress at the free end, and we use those six major orders first, and later I'll check it with — in addition to the six, I add six more to it of descending orders, so I did consider twelve largest of the 20 orders I calculated.

Q. Dr. Chen, in your opinion, how many orders you decided to sum depends on how conservative you want to be in your analysis; isn't that true?

MR. CHEN: I don't — I would say that the more orders you use, the more orders are used — I used six orders and twelve orders of all modes, by the way. There's a difference between first mode, second mode, third mode, and if you really get into it, sometimes the first mode will cancel the second mode, so it's not that straightforward as conservative or not conservative.

I'm just citing that if you use the methods that are labeled as modal superposition or harmonic synthesis, it will reproduce your free end amplitude, and if you have strain gauge data, it will reproduce your strain gauge data more faithfully.

Q. Was the TORVAP/C program designed specifically for DEMA, Dr. Chen?

MR. CHEN: No. It was developed really for Bicera which is British Internal Combustion Institute, and it was used cited in the law -- it was using for many of UK engineers to satisfy law.

Q. So you used your own engineering judgments to determine which orders you were going to sum; isn't that true, Dr. Chen?

MR. CHEN: Certainly it takes some engineering judgment in each crankshaft involved, but you can see that TORVAP/C will only select -- only uses six orders or six orders in the industry is considered certainly sufficient numbers to use.

I have in the past before we have TORVAP/C used four orders, and --

DR. JOHNSTON: I'd like to add to that.

I think it might be helpful to turn to page 3-14 of Exhibit C-17, which shows not only Failure Analysis Associates' predictions for the amplitudes of the first sixteen orders, but also shows the amplitudes that were measured using a torsiograph, and I refer to the right-hand column of that particular table.

I think it's fairly easy, looking at that table to see that there are four fairly large orders.

The fourth order, the five-and-a-half

order, the one-and-a half order and the two-and-a-half order.

In addition, one might choose to include, you know, two or three more, but it's fairly apparent from looking at that that one can, in fact, fairly readily choose a subset of orders and term them major orders, and that it would not be necessary to include all of the orders shown.

Q. Dr. Chen, my questions to you were directed as to your -- the orders that you summed.

These are not your orders in Table 3.3; are they? These are not the orders that you calculated and summed; are they?

MR. CHEN: I can tell you what my major orders are, if you wish.

Q. Let's establish this first, Dr. Chen. These are not your figures on Page 3-14 of LILCO Exhibit C-17?

MR. CHEN: This is the set of calculations comparing a set of measurements.

This table shows close correlations.

Q. And they are comparing FaAA's calculations of the measurements against Stone and Webster's measurements; isn't that correct?

They're not your calculations, Dr. Chen?

MR. CHEN: No, it is not my calculations.

Q. Thank you.

MR. CHEN: Dr. Johnston mentioned that.

JUDGE BRENNER: Why don't you give us the six orders you used.

DR. JOHNSTON: We have the report here.

In Exhibit C-18, on page ten, just underneath the table, there is the — the orders used are indicated. They are the half order, the one and a half order, the two-and-a-half order, the fourth order, four-and-a-half order, and the five-and-a-half order.

I think you'll notice that set of six includes the four orders that I just mentioned as being evidently the most significant and major orders as observed from the Stone and Webster torsiograph test.

JUDGE BRENNER: I'm sorry. I missed the page reference, Dr. Johnston, to C-18.

DR. JOHNSTON: Page ten.

JUDGE BRENNER: Thank you.

DR. JOHNSTON: Just beneath the table.

MR. CHEN: I might add that page 11 also shows the same — the same exhibit, page 11 shows 16 of the 20 orders I used in the TORVAP/C calculations.

All you have to look at is the table in the middle of the page shows TDI test, Stone Webster test, Failure Analysis calculations and TORVAP/C calculations performed on that date.

It shows the sixteen largest orders that are picked from the twenty.

The others are very insignificant.

Then I picked six largest from here and then the six largest from here to perform my calculations.

BY MR. SCHEIDT:

Q. My next questions will relate to the Holzer analysis or the torsional critical speed analysis that was performed by TDI and was reviewed by FaAA.

I'm referring to page 24 of the testimony as a reference point.

Now, the stress level mentioned in the first answer on that page, 2980 for single, for the fourth order is a calculated measure; isn't that -- it's not a measurement; is it?

DR. JOHNSTON: That's correct.

Q. And a significant factor or input used to achieve that figure is the T sub N values used by TDI in its analysis, isn't that true?

DR. JOHNSTON: Yes, that's correct.

Q. Isn't it true that TDI used for the fourth order T sub N value of 27.7 psi in this calculation.

DR. JOHNSTON: That's correct.

Q. And that's shown on table 2.3 of Exhibit C-17.

DR. JOHNSTON: Yes.

Q. And that T sub N value is lower than the T sub N value that was used by FaAA in its dynamic torsional analysis, isn't that true?

DR. JOHNSTON: That is correct.

The value used by Failure Analysis Associates for the T sub N of the fourth order is shown in table 3.2 of the same exhibit and is 33.0 psi as opposed to 27.7 psi indicating a difference of — well, I'll calculate the percentage difference, indicating that the TDI value of T sub N that was used was approximately nineteen percent lower than the value used by Failure Analysis Associates.

And the stress level that the T sub N used by TDI results in is approximately 40 percent below the allowable limit of 5,000 psi.

The T sub N values — I beg your pardon, the computed stresses for a single order are directly proportional to the T sub N value, so that the T sub N value, in fact, would have had to have been increased by about 67 percent in order to show non compliance with DEMA.

Q. What were the calculations of the single order stress using the T sub N value for fourth order that FaAA used?

DR. JOHNSTON: I'll calculate it for you, if you just hold please.

If one uses the TDI Holzer forced vibration technique to calculate the single order stress for the fourth order, and one was to use the FaAA T sub N value, one would compute a stress of 3,550 psi, which, again, is well below the 5,000 psi limit allowed by DEMA.

Q. Do you believe, Dr. Johnston, that the T sub N value that was used by FaAA in its dynamic torsional analysis is a more appropriate T sub N value than the one applied by TDI?

MR. STROUPE: I'm going to object to the quesion based on the use of the word "appropriate."

I don't understand what he means.

JUDGE BRENNER: The objection is overruled.

DR. JOHNSTON: I think that the T sub N

value used by Failure Analysis is, indeed, more accurate than that used in this analysis by TDI, because of the fact that it was obtained from measurements on this specific engine and verified by correlation between the modal superposition model and the torsiograph test; however, the use of the more accurate T sub N value leads to no different conclusions than the T sub N values used by TDI.

And for that reason I do not find the TDI calculations to be inappropriate.

Q. But TDI's calculations underestimate the stresses that are present in the crankshaft; isn't that true?

DR. JOHNSTON: As I have just indicated, the stress using failure analysis T sub N would have been 3,550 as opposed to 2,980, so it is true that this underestimates the stress by approximately 19 percent, but because of the fact that there is a very large margin for the single order computation, I do not consider that significant.

Q. Isn't it true, Dr. Johnston, that TDI's method of calculating the stresses in the crankshaft will always predict the maximum stresses in the crank pin number eight for these EDG's?

DR. JOHNSTON: That is correct.

Q. And isn't it true that the maximum stresses in the replacement crankshafts are not located in crank pin number eight?

DR. JOHNSTON: The maximum stresses in this particular crankshaft occur in approximately crank pin number five because of the fact that there is an influence of more than one mode.

This is the reason for conducting our modal superposition analysis followed by a test program to verify the margin of safety that exists in these particular crankshafts.

Q. So TDI's method of analysis does not calculate maximum stresses in the proper location: isn't that true, Dr. Johnston, in the location of highest stress?

DR. JOHNSTON: The Holzer forced vibration technique that is used by TDI is not a technique that is designed to calculate a peak stress, whether it be at a location within the engine and certainly not to calculate a peak stress in a fillet.

There's a conventional technique that is used and may be used to compare with DEMA allowables.

Q. Wasn't it true, Dr. Johnston, that's original crankshafts did not fail in crank pin number eight?

DR. JOHNSTON: That is correct.

The crankshaft failed in crank pin number seven and had cracks in crank pins number five and number six; and further more, I might point out that the original 13 by 11 crankshaft did not meet DEMA.

Q. Wasn't the purpose of the DEMA recommendations -- isn't the purpose of the analysis that is used by TDI to show compliance or not with DEMA recommendations a prediction of the point of maximum stress in a crankshaft?

DR. JOHNSTON: The DEMA allowables are set as a result of experience gained in many crankshafts, and that experience has to be correlated with the analytical techniques that we use to analyze those stresses, so that if you build a code based on a stress value that's calculated by a certain technique, then that, indeed, is the appropriate calculation to perform -- to check with that particular code.

It is not necessarily, and certainly we do not believe it to be the correct calculation technique to actually compare -- to actually analyze the fatigue strength of this particular -- of the fatigue stress cycles that would be enforced upon this crankshaft.

And that's why we use other methods, too, but for the purposes of comparing with a DEMA allowable, this is a standard technique.

JUDGE BRENNER: While there's a pause, Dr. Chen, do you agree with Dr. Johnston that the area of the Shoreham TDI crankshaft that would have a maximum stress would be in the vicinity of the number five crank pin?

MR. CHEN: My torsional calculations show number five is the highest stress, but I might add that some of the other crank shaft sections also show fairly high stress and use the modal superposition methods, we are able to predict as far as torsion is concerned which is the highest stress level, but this is just nominal stress.

There's two more factors involved. You still have to look at stress concentration factor. You still have to look at other stress involved in the crank shaft.

It's my experience that other stresses involved in the crankshaft is more severe at number eight, simply because you're driving a very -- you're driving very heavy generators and you have some overhand load, and also other stress like bending and other things come into play, so we are just talking about torsionals number five has the highest torsional nominal stress, yes.

JUDGE BRENNER: Would the number five crank pin be correlated to the section between cylinder five and six?

MR. CHEN: In my calculations, it shows that number five cylinder — number five crank is labeled as shaft number between six and seven, but that's just terminologies.

JUDGE BRENNER: Well, that's where I got confused, because your results on page ten of exhibit C-18 show the — at least when you use TORVAP to sum six major orders, and then I believe it was twelve although my page is slightly obliterated in the copy with respect to twelve, that you had the highest stress, as you say in shaft section six to seven, and that's the same to you as the number five crank web area.

MR. CHEN: That's correct. We have to refer back to the terminology I used in the shaft sections.

DR. PISCHINGER: Page six.

MR. CHEN: Page six.

JUDGE BRENNER: Dr. Johnston, for your terminology, if you say crank pin number five, what

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shaft section is that?

DR. JOHNSTON: The highest stress location that I termed crank pin number five, I was trying to be brief.

It really means from halfway along crank pin number five to halfway along crank pin number six; and I think that in the FaAA report Exhibit C-17, if you look at page 3-15, which shows a table of the stresses at different locations, it explicitly says -- it shows that the highest stress is between cylinder number five and cylinder number six.

JUDGE BRENNER: Yes. I knew that much.

All right. It's about the time of adjournment. In any event, did you have one or two brief things, Mr. Scheidt that you wanted to get into?

MR. SCHEIDT: No, we can adjourn now.

JUDGE BRENNER: Perhaps we've reached the point of our daily fatigue stress limit. If we haven't, maybe the witnesses have in any event. They've been on all day or most of the day.

We'll adjourn now and resume at nine o'clock tomorrow morning.

(Whereupon, at 5:05 the hearing was

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adjourned, to be convened at 9:00 on September 18, 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