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July 25, 1984

DOCKETED
NOV 27 1984
DOCKETING & SERVICE BRANCH
SECY-NRC

BY FEDERAL EXPRESS

Mr. Howard C. Blanding
Assistant Vice President
American Bureau of Shipping
Technical Division, Machinery
Department
65 Broadway
New York, New York 10006

Dear Mr. Blanding:

During the July 16 depositions of Robert Woytowich, Robert Giuffra and yourself by Suffolk County, ABS personnel testified that the ABS, in issuing its May 3, 1984 letter to Transamerica Delaval Inc. ("TDI") concerning the Shoreham crankshafts, relied on strain gage test measurements, service experience and the shotpeening of the crankshafts. You also stated that if any of this material information supplied to the ABS by TDI were incomplete, incorrect or misleading, the ABS would have to reconsider the conclusions stated in the May 3 letter. In this connection we are notifying you of the following information:

1. Page 24 of TDI's submittal to ABS stated that a conservative minimal value of the increase in the fatigue endurance limit of the replacement crankshafts from shotpeening is 20 percent. The ABS used this 20 percent increased fatigue limit value in reaching the conclusions stated in the May 3 letter. TDI's Manager of Engineering testified in his deposition, however, that TDI had recommended against shotpeening the replacement crankshafts on the DSR-48 engines at Shoreham based upon experience and on the opinion of TDI's metallurgical consultant that shotpeening would not provide more than a 5 percent improvement in the fatigue strength of the crankshaft (see document 5 below at pages 45-48).

Two of the replacement crankshafts were determined to have been inadequately shotpeened in the lower third of the fillet (<u>see</u> documents 1 and 2 below). The surface texture of the shotpeening was reported to appear more like grit blasting than shotpeening, that is, as if it had been "gauged [sic] by sharp particles instead of dimpled by round, smooth particles" (<u>see</u> document 3 below at pages 63-70). These two crankshafts were re-shotpeened (<u>see</u> document 3 below at 64-65).

2. ABS used 1700 psi in its calculations for the maximum firing pressure. TDI Factory Test Logs reported firing pressures for the DSR-48 engines at Shoreham in excess of 1700 psi, and as high as 1800 psi (<u>see</u> document 6 below). TDI's Manager of Engineering testified in his deposition that the maximum firing pressure in the cylinder during operation of the DSR-48 engine was approximately 1800 psi at operation at overload of approximately 3900 kW (<u>see</u> document 5 below at 128-29). The Engine Cylinder Pressure Log for a DSR-48 engine at Shoreham shows firing pressure in excess of 1700 psi (<u>see</u> document 7 below). Mr. Museler, then the Technical Manager of the TDI Owners Group program and Director, Office of Nuclear, of Long Island Lighting Company, stated at a March 22, 1984 meeting between the staff of the Nuclear Regulatory Commission and the TDI Owners Group that the "normal" firing pressure on the DSR-48 engines at Shoreham is 1670 psi and 1750 psi at overload (<u>see</u> document 9 below). TDI's Instruction Manual states that the firing pressures are considered normal if within plus or minus 75 psi of the average for all cylinders and that the firing pressure limits for sustained operation is 200 psi between any two cylinders (<u>see</u> document 10 below).

3. Mr. Giuffra testified in his deposition to the effect that problems with a diesel engine would surface within 100 hours of operation. One of the original 11 x 13 inch crankshafts on the TDI DSR-48 engines at Shoreham fractured after 718 hours, 22 of which were at the 2-hour overload rating (≥3850 kW). The other two 11 x 13 inch crankshafts in the DSR-48 engines at Shoreham were found to have cracks after 646 and 818 hours of operation, 19 and 23 of which were at the 2-hour overload rating (<u>see</u> document 3 below at page 15).

4. Page 28 of TDI's submittal to the ABS showed that, as of April 1, 1984, EDGs 101, 102 and 103 at Shoreham had 114, 116 and 110 hours of operation at 3500 kW and above. One of the ABS deponents testified that he didn't know how many of those

hours were at loads actually above 3500 kW. Failure Analysis Associates reported that, as of April 30, 1984, Shoreham EDGs 101, 102 and 103 (with the replacement crankshafts) had 91.5, 70.5 and 47.5 hours of operation at loads between 100 and 110 percent load, and 6.5, 0 and 7 hours of operation at 110 percent load or greater, respectively (see document 4 below).

Page 28 of TDI's submittal to ABS referred to operating hours of DSR-48 engines at various installations. This information does not show whether any of the crankshafts had been inspected with dye penetrant, eddy current or other means of nondestructive examination for indications, or what the results were if such inspections had been made.

5. The ABS relied on the strain gage measurements submitted by TDI. During the test on the replacement crankshaft, the firing pressure was measured by inserting a piezoelectric pressure transducer (AVL 5007) in the air start valve of cylinder number 7. FaAA calculated the torque produced by this pressure and obtained a mechanical efficiency of 1.0 (see document 8 below). Firing pressures also were measured in the compression test cocks of cylinder numbers 5 and 7 with two piezoelectric pressure transducers (PCB Model 112A). SWEC reported that the strain measurements were accurate to within ±5 percent and that the output torque measurements had a probable error of 5 to 8 percent (see document 11 below at 7-3, 6-2, 6-3).

In the strain gage test on the failed crankshaft, different model transducers (PCB Model 111A) were installed in the compression test cocks of cylinder numbers 5 and 7. SWEC concluded from the recorded pressure measurements that the dynamic measurements were affected by the gaseous column and flow path geometry associated with the pressure test cock. These cylinder pressure measurements were unacceptably low (see document 3 below at 52).

6. FaAA performed a mode superposition analysis of the dynamic response of the replacement crankshafts at 3500 kW and obtained average torsional stress values of 3300 psi due to the 4th order and 5640 psi due to the summation of the orders (see document 3 below at 60, 62). 5640 psi exceeds the allowable stress levels under the 1984 ABS rules (see sheet 6 of 6 to ABS calculations).

7. The Shoreham engines are expected to run at the loads listed in document 12 below.

Enclosed are the following documents or information referred to above which were supplied to Suffolk County by either the Nuclear Regulatory Commission, TDI or Long Island Lighting Company:

1. Stone & Webster Engineering Corporation's ("S&W") Engineering & Design Coordination Report ("E&DCR") No. F-46109G, dated 9/16/83;

2. Interoffice memorandum dated September 20, 1983;

3. Pages 15-16 and 47-70 of Franklin Research Center's Technical Evaluation Report, Evaluation of Diesel Generator Failure at Shoreham Unit 1, Final Report, Failure Cause Evaluation, dated April 6, 1984;

4. Tables of loads on EDGs 101, 102 and 103;

5. Deposition testimony of G. E. Trussell, TDI's Manager of Engineering, May 7, 1984, pages 1, 45-48, and 128-129;

6. Test bed data for the TDI DSR-48 engines;

7. Appendix F to Shoreham Preoperational Test Results Review and Approval, Engine Cylinder Pressure Log for EDG 101;

8. Evaluation of Emergency Diesel Generator Crankshafts at Shoreham and Grand Gulf Nuclear Power Stations, Failure Analysis Associates, May 22, 1984, pages 3-2, 3-3, 3-12 and figure 3-1.

9. Statements of William J. Museler at the March 22, 1984 meeting between the Nuclear Regulatory Commission staff and the TDI Owners Group, pages 70-72.

10. TDI's Instruction Manual, Appendix II, Operating Pressures and Temperatures at 8-3.

11. Bercel, E. and Hall, J.R. "Field Test of Emergency Diesel Generator 103," Stone & Webster Engineering Corporation, April 1984, pages 6-2, 6-3, 7-3.

12. Shoreham Final Safety Analysis Report, Table 8.3.1-1.

Very truly yours,

Alan Roy Dynner

Alan Roy Dynner

ARD/ss
Enclosures

Document 1

10.498

STONE & WEBSTER ENGINEERING CORPORATION
ENGINEERING & DESIGN COORDINATION REPORT

NO. F-46109G

PROJECT / CLIENT: SHOREHAM NUCLEAR POWER STATION-UNIT 1, LONG ISLAND LIGHTING COMPANY R43 A/B

JOB NO 11600.03

REFERENCES:

PROBLEM DESCRIPTION:

Delaval has identified "holidays" or lack of shot peen coverage, in the fillet areas of the new diesel crankshafts, purchased in accordance with E&DCR F-46109C. These holidays have been dispositioned as functionally acceptable by TDI, however, recent analysis performed by Failure Analysis Associates indicate that 100% peening coverage is beneficial.

Please resolve.

RECEIVED DOCUMENT CONTROL SEP 16 1983 CONSTRUCTION OFFICE SHOREHAM PROJECT

TELECOPY DATE (REQUESTING PART) Sent Rcv'd

Requested By	Dept. or Div.	Tele. Ext.	Date	Needed By
J.C. Kammeyer	SEO	404	9/16/83	

PROBLEM SOLUTION:

Since the crankshafts are delievered to the site, Metal Improvements Co., a local firm with extensive experience in shot peening of crankshafts, will perform the rework. The fillet areas shall be repeened in accordance with the requirements of MIL-S-13165B to assure 100% coverage of the fillet areas. Peening shall be performed by Metal Improvements Co. on site and the crankshaft inspected by OQA for 100% peening at the fillet areas. Refer to attached procedure.

TDI QC inspection of journal bearing masking is required prior to commencing shot peening.

TDI approval for shot peening procedure has been obtained, written approval to be filed with R/R at close out.

AFFECTS WORK UNDER SPECIFICATION SH1-89

IMPLEMENTATION VERIFICATION ☐ IS ☒ IS NOT REQUIRED — VERIFIED BY [signature]

TELECOPY DATES (RESPONDING PART) Sent Rcv'd

Furnished By: [signature] / J.C. Kammeyer — Date 9/16/83

Responsible Lead Engr: J.C. Kammeyer / R Nayuch (Talcon) — Date 9/16/83

☐ INFORMATION ONLY
☐ DRAWING CHANGE
☒ Manual CHANGE
☐ PROCEDURE CHANGE
☐ ENG. SERV. SCOPE OF WORK CHANGE

Change will ☒ be incorporated in the following documents: R43/r Vol. II

Project Design Engr: NR — Date: —
Equipment Specialist: NR — Date: —
Qual. Sys. Div or Eng. Assur Div.: NR — Date: —
Materials Engr: [signature] — Date 9-16-83

FSAR CHANGE ☐ Yes ☒ No

CLIENT APPROVAL ☒ Required ☐ Not Rqd
Obtained Date 9/16/83
Reference Talcon w/ C.K. Seaman

☒ Nuclear Safety Related (QA Cat I)
☐ Not Nuclear Safety Related (☐ QA Cat II ☐ QA Cat III)

Project Engineer Approval & Date: J.C. Kammeyer 9/16/83 for P.J. Holden

CLIENT DISTRIBUTION-CLIENT HEADQTR
☐ Engineering
☐ Project Manager
☐
☐

HEADQUARTERS		FIELD DISTRIBUTION		CONST SUPERVISORS	
☒ Proj Engr	☐ Chief ___ Engr	☒ Originator	☒ G Rogers/LPC	☐ Structural	☐
☒ Proj Des Engr	☐ Chief ___ Des. Engr	☒ Client QA Mgr	☐	☐ Mechanical	☐
☐ Resp Engr	☐ Supt Const Serv	☒ Client Const. Insp.	☒ M H Milligan	☐ Electrical	☐
☐ Equip Spec	☐ Ch Engr-EA Div	☒ S&W FQC	☒ C K Seaman	☐ Piping	☐
☒ Mat'ls Engr	☒ R Nayuch	☒ S&W Res Engr	☒ P Martin	☐ Welding	☐
☐ QA-Qual Sys D.	☐	☐ Fld Des. Engr	☐ D Kelly	☐ Instrument	☐
☒ QA-PQC Div	☒ L Fusegni	☐ Head-Fld. Ext O.	☒ R Cardella	☐ Planning	☒ OCBA (?)
☐ QA-FQC Div	☒ J Dorg(?)	☒ T Brown	☒ E J Youngling	☒ Rec Mgr	☒ (?) Sisters

Transamerica
Delaval

Transamerica Delaval Inc
Engine and Compressor Div
) 85th Avenue
P.O. Box 2161
Oakland, California 94621
(415) 577-7400

ESDCR F4610
pg 2 of 8

Date: September 12, 1983

To: John Kammeyer

From: Ken Kropf

Subject: Diesel Generators TDI S/N 74010-12
Holidays in Shot-Peening on Crankshaft
#693, PC# 8162, HT# 821487

There are two areas on top of # 1 Pin directly adjacent to the crank pin and at the outer edge of the crank radius that have Holidays in the Shot-Peening. These holidays are in a relatively low stressed area of the crankshaft. I have looked at these areas and disposition them functionally acceptable.

The TDI procedure for shot peening the LILCO crankshaft is also attached.

Ken Kropf
Ken Kropf
Supervisor, Quality Control

cc: V. Dilworth
R. Giordanelli
R. Boyer
J. Gee
D. Wulf

SPECIAL PROCEDURE FOR LILCO R-8 CRANKSHAFT

Part Number 03-310-05-AK
Quality Control No. 693
Heat Number 021437
Pc. No. 8162

1. Prior to shot peen insure that all non peened surfaces (main and rod journals) are protected.

2. Set air pressure at 60 to 80 P.S.I.

3. Use .050 shot to peen fillets on rod journals and main bearing journals.

4. Use Almen strip and gauge to verify maximum intensity. (Ref. SAE J442-79)
   A. Secure Almen "A" strips in blocks.
   B. Make 1 pass on one strip.
   C. Make 2 passes on the next strip.
   D. Make 3 passes on the next strip.
   E. Measure intensity with Almen gauge.

5. Shot blast fillets at maximum intensity level

6. Inspect for full and complete intensity and coverage.

S. W. E. C.
PQC
INSPECTED 151

Shot Peen Procedure for Lilco R-8 Crankshaft, Part No. 03-310-05-AK	PAGE 1 OF 1
Transamerica Delaval Inc. — Transamerica Delaval Inc. Engine and Compressor Division	SPECIFICATION NO 1008-

8/25/83 [illegible]

LILCONUCL SHRM

SEPTEMBER 16, 1983

ATTN: MR. JOHN KAMMEYER

TRANSAMERICA DELAVAL (TDI) REITERATES THAT THE 12 X 13 INCH CRANKSHAFTS SUPPLIED TO LILCO DO NOT REQUIRE ANY SHOT PEENING. LILCO DIRECTED TDI TO SHOT PEEN THE FILLETS OF THOSE THREE SHAFTS AND TDI HAS COMPLIED BY SO DOING IN THE MANNER THAT HAS BEEN OUR STANDARD PRACTICE ON OTHER SIMILAR CRANKSHAFTS. BOTH TDI AND SWECO (LILCO'S REPRESENTATIVE) INSPECTED AND ACCEPTED THE SHOT PEENING PRIOR TO SHIPMENT OF THE TWO SHAFTS NOW ON-SITE.

LILCO HAS NOW ADVISED TDI THAT THIS SAME WORK HAS BEEN REINSPECTED AND IS JUDGED BY LILCO'S CONSULTANTS TO REQUIRE REWORK IN THE FORM OF FURTHER SHOT PEENING. WE DISAGREE BUT ARE WILLING TO OBSERVE SUCH REWORK AND VERIFY THAT BEARING SURFACES ARE NOT DAMAGED IN THE PROCESS.

WE ARE COMPLETELY WITHOUT PRIOR EXPERIENCE WITH RE-SHOT PEENED CRANKSHAFTS. FROM A TECHNICAL VIEWPOINT, WE AGREE THAT RE-SHOT PEENING THE CRANKSHAFT FILLETS MAY ENHANCE THE SURFACE IMPROVEMENT AND SEE NO REASON FOR LILCO NOT TO FOLLOW THE ADVICE OF ITS CONSULTANTS.

WE HAVE REVIEWED THE PROPOSED PROCEDURE AND FIND IT TO BE ACCEPTABLE FOR THE SHOT PEENING OF LARGE ENGINE CRANKSHAFTS.

REGARDS
GEOFF KING
MANAGER, PRODUCT ENGINEERING
TRANSAMERICA DELAVAL INC.
LILCONUCL SHRM
.....
ENTERPRISE OAK

ATTACHMENT TO
E & DCR NO F-46109G
Pg 4 of 4

Document 2

INTEROFFICE MEMORANDUM

SUBJECT DIESEL CRANKSHAFT FILLETS, PEENING

J.O. OR W.O. NO 11600.37

DATE SEPTEMBER 20, 1983

FROM GARY V. LUTHER

TO D. E. ELLIS

C

2454

(2)

Preliminary analysis performed by FaAA (as of this date) finds that the lower 1/3 of the reentry fillet at the crankshaft pin junction is the most critical area with respect to crankshaft failure. The reasons given are:

(1) High stress at loading (the crankshaft may be near a harmonic at its loaded running speed.

(2) A residual stress (determined by x-ray diffraction) at the fillets caused apparently by machining.

(3) Surface finish at the fillets. Although the finish does not appear to be rough to the naked eye (or by feel), I have seen scanning electron microscope photographs of cracks in initial stages of propagation. The cracks appear to be initiating at one of the radially machined "valleys" of the fillet.

In order to reduce the residual tensile stresses at the fillet (and also to reduce the degree of valley alignment with the primary tensile stress planes), we have specified peening to be performed (at TDI).

However, review of the as-received cranks found that they were inadequately peened at locations of interest (to FaAA) e.g. the lower 1/3 of the fillet. FaAA recommended that the peening be redone by a "Metal Improvement Co." , specialists in controlled peening.

MIC already performs peening to crankshaft fillets for other diesel manufacturers.

MIC's equipment was transported to the site and the peening was performed in a building erected to house the crankshaft.

MIC reported that the fatigue life of a properly peened crankshaft can be increased by 100% by proper peening.

<u>QC Checks - Peening</u>

100% peening is defined as areas where the surface is totally dimpled. They have invented a "peenscan method" to verify 100% peened surfaces. The process utilizes an ultraviolet solution (the process is somewhat similar to a UV magnaflux check) which the UV sensitive solution is applied to the area to be peened. 100% peening is defined by a total removal of the ultraviolet sensitive solution. An ultraviolet light is used to verify its removal.

<u>MIC-GL - Conversations</u>

I questioned the MIC engineer on repeening previously peened surfaces and his reply was that peening typically becomes detrimental to fatigue life only if the peening abrades a critical section. He also stated that their equipment is designed for accessability and control and that their operators are experienced enough so that abrasion of peened sections is not a problem.

Attached is a sample of MIC's shot; you will note its uniformly round geometry which is much "better" than commercial cleaning shot. The tape which the shot is attached to is similar to duct tape and is used for masking areas specified as not to be peened.

Overall, I was impressed with the company's control and expertise. The company essentially wrote MIL-S-13165 (which we invoked on the crankshaft). MIL-S-13165 is much more definitive overall in the peening process than any SAE specification I have seen. I requested that they send a product brochure to Boston describing their processes and any data they they have concerning the beneficial effects for other applications.

Other applications they cited may be reduction of residual stress on turbine shafts, and reduction of residual tensile stresses where stress corrosion cracking is a concern.

Gary Luther
G. V. Luther

P.S. The new crankshafts reentry fillet geometry is <u>much</u> better than the old one.

Document 3

TECHNICAL EVALUATION REPORT

EVALUATION OF DIESEL GENERATOR FAILURE AT SHOREHAM UNIT 1

FINAL REPORT, FAILURE CAUSE EVALUATION

NRC DOCKET NO. 50-322

NRC TAC NO. --

NRC CONTRACT NO. NRC-03-81-130

FRC PROJECT C5506

FRC ASSIGNMENT 20

FRC TASK 426

Prepared by

Franklin Research Center
20th and Race Streets
Philadelphia, PA 19103

Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

Author: R. C. Herrick

FRC Group Leader: S. Ahmed

Lead NRC Engineer: R. J. Giardina

April 6, 1984

Prepared by:	Reviewed by:	Approved by:
R. C. Herrick		
Principal Author	Project Manager	Department Director (Acting)
Date: 4/3/84	Date:	Date:

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

test program, including all mechanical, electrical and qualification tests, was completed for all three diesel generators."

In August 1983, all three diesels underwent a cylinder head stud replacement program, and one diesel generator completed the high load retest [15]. LILCO's summary continues, stating that "one remaining demonstration of diesel capability was scheduled prior to fuel load; the integrated emergency core cooling system and emergency diesel generator operational demonstration."

LILCO reported [15] that as of the August 12, 1983 crankshaft fracture, the diesel generators had accumulated 2182 hours of operation as follows:

DG 101 -- 646 hours
DG 102 -- 718 hours
DG 103 -- 818 hours.

In response to a request for information by the NRC regarding the total number of operating hours on each diesel generator and the total number of hours at 3900 kW or greater, LILCO responded [16] as follows:

	Total Operating Hours on Each DG Unit			Total Operating Hours for Each DG Unit at 2-hour Overload Rating ($\geq$ 3850 kW) (These hours included in total operating hours)		
DG Unit	At TDI	At Shoreham	Total	At TDI	At Shoreham	Total
101	128	518	646	3	16	19
102	30	688	718	3	19	22
103	40	778	818	3	20	23

3.2.5.2 Review of Conditions at the Time of Crankshaft Failure

In response to a request for information by the NRC about the test procedures in use at the time of the crankshaft failure, LILCO responded with the following description of the test [17]:

"Cylinder heads on DG 102 were replaced under R/RR R43-1001 with new design stress relieved heads. With all eight cylinders equipped with the new heads, the 102 DG was run for 12 hours to allow hot torquing of the exhaust header bolts and air start valve nuts. Following this run, a retest of the engine was begun under 8.7-R43-042. The specific scope of the retest under this 8.7 Form was to:

1. Verify proper diesel generator start to synchronous speed and rated voltage in less than 10 seconds.

2. Verify prop r DG operation for four hours at the continous load rating.

3. Verify proper DG operation for 2 hours at the two hour overload rating.

Refer to the response to NRC Request for Information II.2, pages 10.5 through 10.17, for a copy of the retest procedure 8.7-R43-042, as completed up until the time of the failure of DG 102."

On page 10.1 of Reference 18, LILCO provided the following detailed description of the events just prior to the failure:

"The diesel generator prior to the performance of 8.7-R43/42 was in its normal standby condition. An interim operating instruction was performed to ensure proper breaker positions, proper valve lineup and correct initial conditions. The diesel engine was started from its remote location, the main control room. Proper starting, acceleration to synchronous speed and rated voltage within 10 seconds was verified by the test engineer and the OQA inspector. Plant Operator synchronized the diesel generator to BUS 102 by closing ACB 102-8 and then proceeded to increase the diesel generator load to 3500KW in less than 60 seconds. Once at the 3500KW/300KVar load the operator was instructed to maintain this load for four hours. He was instructed that any deviations, caused by the LILCO grid, away from 3500KW/300KVars should be corrected. Another plant operator was stationed in the engine room with verbal communications established between operators via headsets. During the course of the four hour full load run, a LILCO technician was also stationed in the diesel engine room with the task of recording all pertinent test information every 30 minutes. No abnormal readings were observed by either operator nor was the data written down by the technician found to be out of its normal operating range as specified by the engine manufacturer for this size load.

Since this test was handled similar to a Station Surveillance Procedure no special test equipment was utilized for data recording. All data written down was taken off of normal plant gauges either in the main control room or in the diesel engine room. The two exceptions were the generators bearing temperature and the generator stator temperature, both

material in the above calculation yields a minimum allowable crankpin diameter of d = 10.84 in. This is less than the 11.00-in actual crankpin diameter. In summary, if full credit were taken for the actual crankshaft material properties, the 11.00-in crankpin diameter of the diesel generators just meets the minimum ABS crankpin requirements as shown by calculations performed as a part of this review.

ABS Paragraph 34.17.4, Solid Crankshaft Web Dimensions

In order to provide adequate bending stiffness in the web, ABS requires that the web dimensions satisfy the following inequality:

$$wt^2 \geq 0.35\ d^2$$

where w = 21.0 inches, width of web

t = 4.5 inches, web thickness

d = 11.00 inches, crankpin diameter.

Thus,

$$(21)(4.5)^2 \geq 0.35(11.0)^2$$

$$425 \geq 42.4$$

and the inequality appears to be satisfied. (The values for w and t were acquired informally by a telephone conversation with Dr. Wells, FaAA, on February 9, 1984, and are assumed to be sufficiently accurate for this calculation.)

Summary of ABS Rules Application

Comparison of the TDI 13 x 11 crankshaft design with the ABS rules indicated that the crankshaft geometrical proportions were within the ABS rules, but the dynamic stresses in the crankpin were not. Thus, the ABS rules are significantly more conservative with respect to harmonically induced stress than the DEMA rules, or about half the DEMA recommended limits. Again, this reflects the conservative design believed to be required for safety at sea, and probably is derived from the culmination of long-term experience in that industry.

4.2.4 Summary of Crankshaft Design Review

The review of this section on crankshaft methodology and design may be summarized by the following statements:

- o The DEMA rules [2] are not design specifications and standards. Supplementary specifications and standards are required.
- o It is advisable to employ the more comprehensive direct or modified direct solution of the mathematical model equations for torsional dynamics. With the present development of computer methods and accessibility of computer systems, the direct solution methods are not more labor intensive than the present computerized tabular methods and do provide more comprehensive design assistance.
- o TDI used Tn values for torsional excitation that are very low compared to values recognized in the industry since at least 1942 [36].
- o The TDI crankshaft (11 x 13) does not meet the DEMA or ABS rules for dynamic stress when the revised TDI values of Tn are employed.

4.3 REVIEW OF CRANKSHAFT DYNAMIC TESTING

Dynamic testing of the crankshaft is regarded in this review as the essential element of the failure investigation because it is only through carefully conducted measurements that the actual engine dynamics and local component stresses are confirmed. Accordingly, great attention was paid to each aspect of the test program.

Dynamic testing of DG 101 using an instrumented crankshaft was performed on September 20 and 28, 1983 at the Shoreham Nuclear Power Station. Reviews of preparations and procedures and an account of test observations were reported previously [1].

Instrumentation for the measurement and recording of vital dynamic data included that are shown in Section 3.2.4.1

Since the completion of testing, the recorded data were reduced and reported [37] by Stone and Webster, and the implications for the crankshaft

failure investigation were reviewed and reported [29] by FaAA. This section is primarily a review and evaluation of the reported test data [37] and the failure investigation conclusions [29] that were reached.

4.3.1 Instrumentation, Signal Conditioning, and Data Recording

Reference 37 provides a description and statement of applicability of transducers employed, including those for strain, torque, torsional shaft displacement, cylinder pressure, generator voltage and current, linear vibration, and the combination of crankshaft position and rotational speed. A table listing their pertinent characteristics and applicable ranges is also shown. The instrumentation was evaluated and its installation observed by the reviewer at the time of dynamic testing.

For the most part, data output from the transducers was good. Earlier problems of strain gages and data transmitters on the rotating crankshaft were largely corrected before completion of testing on September 28, 1983, although the reported data [37] do include noisy, but apparently functioning, strain gage signals, e.g., on the No. 7 crankpin fillet. Also, the transducers for cylinder pressure seemed to function satisfactorily but appeared to provide pressure data lower in value than the actual pressure. The application of instrumentation in these environments is difficult and the experienced experimental test engineer anticipates certain aberrations in these data channels. Indeed, the essence of the test engineer's work is to plan and conduct the test to maximize the good data extracted. Data from the strain gages on the crankshaft were telemetered to nonrotating receivers and were conditioned and recorded along with the other data on a 14-channel, FM mode tape recorder. With proper planning of signal channels prior to a test run, this afforded an opportunity to record simultaneous events on parallel channels. The signal conditioning and recording equipment are described in Reference 37.

The application of transducers, signal conditioning, and data recorders was reviewed and found to be satisfactory.

4.3.2 Calibration Procedures

Measured values are not necessarily more accurate than analytical estimates; experimental measurements are only as accurate as the accuracy of their calibration, and then only if the proper instrument was chosen for the task.

4.3.2.1 Strain Gage and Torque Bridge Calibration

Fillet strain gages and the torque bridge (employing strain gage) were calibrated by the shunt resistance method, wherein a precision resistor of known value is shunted in succession across the available arms of the bridge circuit.

Shunt resistance of the strain gages provides calibration not only of the strain gages, but also of the conditioning circuitry and recording equipment. However, it calibrates the gage only for measurement of surface strain in the metal on which the gage is located. This is sufficient calibration for the crankpin fillet gages which were for the measurement of surface strain.

Calibration of the torque bridge, which used strain gages, required additional procedures because the measured quantity was that of shaft torque and not strain at a point. Consequently, the test engineers employed static torque tests and test operation of the engine at zero electrical output to confirm the calibration of the torque bridge.

The static torque test yielded measured torque plotted against applied mechanical torque as shown in Figures A-10 and A-11 of Reference 37. Considerable hysteresis is noted in these figures due to the friction in the engine and possibly due, in part, to strain gages that are not fully exercised following their installation. Industry experience has shown that the relationship would be much more linear in actual operation, where the bearing surfaces would be operating on developed oil films to greatly reduce hysteresis due to friction in the engine, and the strain gages would become "exercised" for greater linearity.

The zero-output tests of the instrumented engine are discussed in Section A.2.2 of Reference 37, which includes a table of values measured at four

electrical loads. The normalized values of "kW/1000 lb-ft" showed a spread of +4% and -6% about an arithmetic mean value. Using linear regression, the mean ratio of the measured values of "kW/1000 lb-ft" was calculated by Stone and Webster to be 1.21. Although Reference 37 explains this to be the stress concentration in the shaft on which the strain gages are mounted, evaluation during this review indicated that the actual stress concentration is on the order of 1.16 and that the balance of the factor is due to the experimental measurement spread of the "kW/1000 lb-ft" values previously discussed.

Shifts in zero reference of the data recordings were investigated as a part of the data analysis as discussed in Section A.3 of Reference 37. The overall error due to static strain ranged from 1.0 to 4.2%. Thus, the static offset does affect the calculation of principal stresses by a small percentage because these are based upon both the static and instantaneous cyclic stress. It should be noted, however, that the stress range of the cyclic stresses is not affected by this offset.

4.3.2.2 Calibration of the Torsional Vibration Displacement Transducer

The torsional vibration transducer is the unit attached to the gear case end of the crankshaft for the direct measurement of vibrational amplitude. Sections 3.2.2, 4.3, 6.3, and A.4 of Reference 37 describe the application and calibration of this unit, wherein calibration is performed easily by means of fixed limits on displacement built into the unit.

A problem that arose with the use of the transducer was corrected during data reduction. As described in Reference 37, an internal filter selection switch remained set to a 10-Hz cutoff frequency. This attenuated all signal components above 10 Hz. Data reduction procedures were developed to amplify the attenuated signal components in an effort to correct the error. The procedure was reviewed, and the results of the error-correcting efforts shown in Reference 37 were evaluated and found to be satisfactory.

4.3.2.3 Calibration of Accelerometers

Sections 3.2.5 and 4.5 of Reference 37 cover the application and calibration of accelerometers for linear vibration measurement. The accelerometers

were calibrated with the use of a B&K Model 4291 calibrator, which could serve as a transfer standard from the National Bureau of Standards.

This review showed that any use of this transfer standard capability was not stated in Reference 37 and that the calibration source was not known. Although these data were not necessary in forming a conclusion regarding the cause of failure, calibration of the accelerometers and other instrumentation should nevertheless be traceable to the National Bureau of Standards.

4.3.2.4 Calibration of Cylinder Pressure Instrumentation

Sections 3.1.4, 3.2.3, 4.4, and 7.3.5 of Reference 37 describe the measurement of cylinder pressure and its calibration. Time history pressure measurement was attempted by means of precalibrated piezoelectric transducers installed in the compression test cocks of engine cylinders 5 and 7. Calibration of the data signal circuitry between the transducer and the tape recorder was performed using the B&K Model 4291 calibrator mentioned previously.

The cylinder pressure measurements were unacceptably low. Efforts by Stone and Webster and FaAA following these tests concluded that the gas flow path geometry (see Figure A.4, Reference 37) was responsible. Accurate cylinder pressure measurement was not necessary in this test for conclusions regarding the cause of failure.

4.3.3 Review of the Experimental Data

Dynamic tests of engine operation were run at zero-output load (variable speed tests) and at loads of 100 kW, 1695 kW, 1706 kW, 1750 kW, 2250 kW, 2550 kW, and 3500 kW, with constant speed (450 rpm) operation. Data for these tests were reduced by Stone and Webster and are presented as charts in References 29 and 37.

The test data as presented [24, 37] are dominated by presentations of torque and crankpin fillet strain. Torque, as presented in Figure 4-21 of Reference 29, is characterized by a 30-Hz oscillation of varying amplitude superimposed upon a steady-state value. Torque oscillatory amplitudes for

3500-kW operation reach a value of ±175,000 ft-lb (350,000 ft-lb, peak-to-peak torque range) superimposed upon a steady torque of 57,000 ft-lb. Note that this cyclic torque is a little over 3 times (6 times for peak-to-peak range) the steady torque required to produce an electrical output of 3500 kW from the generator. This single amplitude ratio of 3 stands in contrast to the ABS rules [3] where the single amplitude dynamic component is expected to be on the order of the value of the steady-state component (power transmitted). This is explained as follows. Refer to Section 4.2.3.4 of this report and note that the allowable crankpin single-order torsional stress, using the example of ABS Grade 4 steel, is ±2679 psi. For the 100% load rating of the diesel generators (3500-kW output), the engine torque at the flywheel shaft (torque bridge location) is 57,040 ft-lb, which yields a crankpin torsional shear stress of 2619 psi. This is very close to the limiting torsional stress level allowed by the ABS rules. This example was calculated for the 100% load rating of 3500 kW, the maximum load in the torsional dynamic tests performed. For the intermittent 3900-kW diesel generator loads projected for actual service, the steady state, and cyclic stresses would be proportionally higher.

The engine firing rate is 30 Hz. This engine firing rate is sufficiently close to the first mode torsional natural frequency of 35.5 Hz to produce the large dynamic response in the absence of significant damping.

Measured fillet strains on Crank No. 5 varied to a maximum peak-to-peak range of 1800 microstrain (1800×10^{-6} inch/inch) as reported for stain gage 5-1 in Figure 4-21 of Reference 29. Table 6-2 of Reference 29 reports the major principal stress component of the measured strains to be 57,300 psi at Crank No. 5, corresponding to a measured total peak positive torque of 230,000 ft-lb (cyclic and steady-state) and negative torque of -153,000 ft-lb.

In the absence of direct access to the data and data reduction instrumentation, observation of the diesel generator tests plus analytic investigations of the data reported in References 29 and 37 performed during this review provide basic arrangement with the range and characteristics of torque and crankpin fillet stress reported by References 29 and 37. Note that these are measured values subjected to the measurement errors discussed previously. However, it does appear that these values are accurate to within ±10%.

In addition to indicating high cyclic torques and stresses in the crankshaft, the test program yielded the following observations, with which this review concurs:

- The rotor-stator electrical coupling within the generator which acted to couple the electrical load inertia to the engine dynamic model produced varying generator output current at 3.75 Hz when connected to the electric power grid, but did not contribute to the failure of the crankshafts.

- Operation at 0.8, 0.9, and 1.0 power factors at the 2500-kW load range indicated that operation in this range of power factor did not contribute to the crankshaft failure or dynamics of the system.

- The 30-Hz major dynamic response of the engine is not compounded by any observed interaction with the electric loads, electric power grid, or plant loads.

- The sudden initiation of plant loads was observed to cause a smooth-orderly response of the engine and generator and was not seen to cause cyclic fluctuations.

- Connection of the diesel generator to the electric power grid was observed to be smooth and without significant transients, although it is realized that considerable care was taken at the time to make a proper connection. Connection of generators to the electric power grid without adequate synchronization can be damaging.

4.4 REVIEW OF FaAA DYNAMIC MODEL AND CRANKSHAFT STRESS ANALYSIS

4.4.1 Dynamic Response Model

In the course of the failure investigation, FaAA prepared and used a digital computer dynamic response model. From a discussion,* it was learned that the model is generally of the mode-superposition type discussed in Section 4.2.2.1 of this report. Reference 29 indicates that the model used the same basic lumped-parameter (inertias and spring constants) model as formulated by TDI (Appendix A) with the addition of the rotor-stator equivalent spring constant and the electrical load inertia (see Figure 2 also).

* Discussion with Dr. P. Johnston, FaAA, during test of DG 103 on January 7, 1984, at the Shoreham Nuclear Power Station.

FaAA's computer model output, as indicated by Figures 5-3 through 5-6 of Reference 29, has a remarkable similarity in character and amplitude to the values measured by the engine test. FaAA did not initially provide, in its report [29], the list of Tn values employed in its mathematical model. When it was suggested that the Tn values would be valuable for comparison to TDI's design values and to those from other published sources, FaAA made them available.* Table 8 includes FaAA's values with accepted values from Lloyds Register and Ker Wilson which were included here from Table 5 to facilitate comparison. Comparison with values employed by TDI was made using the TDI values of Table 6. In these comparisons, it was observed that the FaAA values compared favorably with those of Lloyds Register and Ker Wilson. The FaAA values were more than twice TDI's design values (TDI 1974-1975 list in Table 6) in the critical range of orders 4.0, 4.5, and 5.0, and even greater for other orders. Thus, the Tn values for FaAA's mathematical model for which FaAA reported [29] excellent agreement of computed dynamic response with that experimentally measured further confirms the validity of published Tn values over that employed by TDI for design.

Even if FaAA's excitation had been prepared only to achieve the same dynamic response amplitudes as measured in the engine tests, the model would have provided a highly useful interpolation function in portraying the dynamic action at points not available for measurement.

As discussed in Section 4.2.2.1, computer models following from the direct solution of the dynamic equations are very powerful in describing the full dynamics and interactions of a system. FaAA's computer model confirms this. The first task for the model was the prediction of the available cyclic life of DG 101 remaining throughout the course of diesel generator testing on September 20 and 28, 1983. Here, initial dynamic response data measured at the beginning of each test session were introduced to the computer model for comparison and prediction of the available life cycles remaining.

* Telephone call from Dr. P. Johnston, FaAA, March 9, 1984.

Table 8. Comparison of FaAA's Tn Values with Those of Lloyds and Ker Wilson

Vibration Order	FaAA*	Lloyds Register**	Ker Wilson***
0.5	74.5	80.0	77.0
1.0	86.0	88.0	79.0
1.5	75.1	83.0	75.0
2.0	75.6	69.0	66.0
2.5	54.0	57.5	55.0
3.0	12.3	47.5	43.0
3.5	37.7	38.5	32.0
4.0	28.7	30.5	25.0
4.5	24.7	23.6	19.0
5.0	20.7	18.0	15.0
5.5	16.9	13.8	11.0
6.0	13.8	10.5	8.9
6.5	11.2	8.5	7.3
7.0	9.4	6.8	6.0

* Calculated independently by FaAA. Includes effects of reciprocating masses.

** From Table 5. Not known what effects, such as reciprocating masses, are included.

*** From Table 5. Values for cylinder pressure only.

4.4.2 Crankshaft Stress Analysis

4.4.2.1 Finite-Element Model

FaAA formulated a finite-element structural mathematical model using three-dimensional, eight-node, isoparametric elements to represent one throw of the crankshaft. With application of torques from the dynamic response analysis, the model had the capability to indicate the highly stressed points in the complex crankshaft geometry. Unless extremely fine element grids are employed, finite-element models generally underestimate the stress concentration at local regions. Accordingly, FaAA used the same element distributions in an axisymmetric model of the same diameter and fillet radius so that the lack of stress concentration definition could be assessed by comparison to well-established values [38]. The ratio of the established value and the finite-element stress concentration factor was used as a multiplier for the final stresses predicted in the fillet region by the crankshaft throw finite-element model. This was reviewed and found acceptable. The alternative method of using many more elements in the fillet would have been much more costly in both modeling and computer run time.

FaAA did not include a description of its method of torsional load application in its report [29]. However, when it was shown that the method of torsional load application employed by FaAA in the finite-element model was needed to complete the review of FaAA's crankshaft analysis, Dr. Wells (FaAA) provided a verbal description of the torsional loading method during a document review at the Shoreham Nuclear Power Station on March 8, 1984. The loading method was said to consist of a unit angular displacement applied to the journal end of the crank-throw finite-element model, plus a lateral displacement constraint applied to the side of the journal to represent the lateral constraint provided by the journal bearing. The axial location of the lateral constraint representing the journal-bearing reaction was said to have been varied to study its effect upon the computed stresses in the crankpin fillet. This effect was said to be relatively small. During the review of the crank-throw finite-element analysis and method of loading, it was noted that the unit angular displacement method of torsional load application along with the lateral displacement constraint to induce the journal-bearing

reaction is a generally accepted method, which was deemed acceptable by this review.

4.4.2.2 Bending Stresses

On pages 6-8 and 6-11 of Reference 29, FaAA discussed an investigation of bending stresses in the finite-element model due to an effective piston load at top-dead-center. When the associated bending stresses were indicated to be on the order of 4500 psi, as compared to approximately 40,000 psi for the torque load, the contribution of the connecting rod load in consideration of the fillet stresses was considered to be negligible, especially when the maximum fillet stresses occured when the crank was 130 degrees or so after top-dead-center.

Bending stresses, however, did appear to play a part in the stressing of the fillet as indicated by Figure B-100 in Reference 29. This bending action however, appeared to be local bending in the web and crankpin as part of the gross torsional loading. Consequently, it became a part of the stress concentrating mechanism that caused the highly stressed region to develop at an angle of approximately 130 degrees from the 12 o'clock position on the crankpin.

4.4.2.3 Crankshaft Stress Analysis Summary

The usefulness of a comprehensive stress model is readily apparent. The stresses predicted by the finite-element model appear to be in good agreement with experimentally measured values, even acknowledging the fact that the experimentally measured values contain an inherent error band of up to about $\pm 10\%$.

Although the use of finite-element models for theoretical analysis, as well as for extending experimental investigations to regions not measurable, is to be strongly encouraged, the validity of the failure investigation was considered during this review to be most relevant in the experimental measurement of crankshaft fillet stresses in actual engine operation. Analytic techniques, such as the dynamic model and the finite-element crank-throw model, while quite powerful, were looked upon in this review as supplemental and confirming investigations.

4.5 REVIEW OF REPLACEMENT CRANKSHAFT DESIGN

Following failure of the crankshaft of the Shoreham diesel generators, the engine manufacturer, TDI recommended the use of an improved crankshaft design, designated the 13 x 12 crankshaft. Whereas both the failed crankshaft (13 x 11) and the recommended replacements had 13-inch main journal diameters, the replacement crankshaft featured an increase in the crankpin diameter from 11 to 12 inches, as well as an increase in the crankpin fillet radius from one-half to three-quarters of an inch. Analyses of the replacement crankshaft by FaAA [39] and TDI [40] are reviewed in this section of the report.

4.5.1 Review of Analysis by Transamerica Delaval, Inc (TDI)

TDI used the same method of analysis as shown in Appendix A for the analysis of the original 13 x 11 crankshafts, with the exception that they substituted the Tn values shown in Group 4 of Table 6 of this report. Here the Tn value for the 4th order is 27.62 as compared to the previous value of 13.30.

In summary, although the critical 4th order Tn excitation value was doubled, the following considerations produced a reduction in the calculated stress for comparison to the DEMA-recommended values:

- o The larger crankpin permitted a 22% reduction in crankpin nominal torsional stress.
- o The increased natural frequency from 35.5 to 38.7 Hz reduced the dynamic magnifier for a 30-Hz excitation from 3.51 to 2.51.

This yielded a 4th order stress of 2990 psi as calculated by TDI for comparison to the DEMA recommendation of <5000 psi.

4.5.2 Review of FaAA Dynamic Response Analysis and Crankshaft Stress Analysis

4.5.2.1 Response Analysis

FaAA employed its computer dynamic model using mode superposition to analyze the dynamic response with all significant modes considered. Inertia and spring constant elements for the model are shown in Table 3-1 of Reference 39, and the resulting natural frequencies are shown in Table 3-4 of that same

reference. The dynamic response was computed by FaAA for "full load". The use of the term "full load" does not carry full definition since the design rating of the diesel generator is 3500 kW, but it is expected to operate at 3900 kW for short periods. For this review, 3500-kW generator output is inferred to be "full load".

Comparison of TDI and FaAA dynamic stress values to the DEMA recommendations follows:

Method of Analysis	Average Torsional Stress (psi) Due to 4th Order	Average Torsional Stress (psi) Due to Summation of Orders
TDI Analysis	2990	--
FaAA Modal Superposition	3300	5640
DEMA Recommendation	<5000	<7000

Comparison of these stresses to those updated stresses for the 13 x 11 crankshaft, as shown in Table 7 of this report, indicates reductions in stress by a factor of 1.79.

Comparison of these stresses to the ABS rules, similar to that shown in Section 4.2.3.4 of this report, indicates that the ABS rules may or may not be satisfied depending upon the interpretation that would be approved by the ABS following its review.

Assuming that an ABS Grade 4 steel was used for the crankshaft, the ABS allowable stress for a single harmonic is 2680 psi (see Section 4.2.3.4), whereas the calculated stress (TDI) is 2990 psi. Thus, TDI's stress of 2990 psi and FaAA's stress of 3300 psi were both in excess of the ABS allowable stress for a single harmonic using a nominal ABS Grade 4 material.

The actual mechanical properties of the replacement crankshaft material, however, were shown by the quality control documents at the Shoreham plant to be those provided in Table 9. Whereas Appendix B shows an ABS Grade 4 material to have an ultimate tensile of 83,000 psi, the minimum ultimate tensile

Table 9. Properties of Replacement 13 x 12 Crankshafts

Mechanical Properties

Crankshaft Number	Yield Point (psi)	Ultimate Stress (psi)	Elongation (%)	Production Area (%)	Brinnel Hardness	Sample Location
693 (DG 103)	58,310	100,360	25.0	54.1	205	--
	59,470	106,460	24.0	58.9	212	--
694 (DG 102)	57,290	101,820	25.0	50.9	210	--
	58,310	106,460	25.0	48.7	215	--
695 (DG 101)	52,650	100,800	24.0	50.9	205	Top
	48,590	100,800	23.0	49.8	210	Bottom

Chemical Analysis

Crankshaft Number	Heat	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Cr (%)	Al (%)
693 (DG 103)	821-487	0.50	0.05	0.70	0.006	0.010	0.63	0.003
694 (DG 102)	821-487	0.50	0.05	0.70	0.006	0.010	0.63	0.003
695 (DG-101)	811-167	0.46	0.12	0.65	0.010	0.008	0.69	--

strength of the replacement crankshaft materials as shown in Table 9 is 100,360 psi. To take full advantage of this material, an allowable value of 3090 psi for a single harmonic could be presented to ABS for approval in accordance with Note 4 of ABS Table 34.3 in Appendix B.

If full advantage of the material is to be taken, then it is also appropriate to use the full calculated dynamic response due to a single harmonic exciting factor. TDI's stress of 2990 psi was calculated using only the first mode response. Although TDI's analysis does show a small response for the second and third modes of torsional vibration, the second and third modes are seen to add very little to the first mode stress of 2990 psi. Thus, should the interpretation of the ABS rules discussed above be accepted by ABS, TDI's single harmonic stress would be within the ABS limits. However, FaAA's calculated stres of 3300 psi for a single harmonic excitation, based upon a somewhat higher value of Tn and upon greater modal participation, would not.

ABS also requires that the total vibratory stress from all harmonic excitation not exceed 150% of the allowable stress for a single harmonic exciting factor. For a nominal ABS Grade 4 material, this allowable stress is 4020 psi. For the interpretation of the ABS rules to use the full properties, the allowable stress is 4640 psi. TDI's total stresses cannot be compared to these ABS allowables because their analysis methods do not facilitate such summation of stresses. FaAA's calculated torsional stress for the summation of excitation orders is 5640 psi, which is well beyond even the interpreted ABS allowable stresses.

4.5.2.2 Crankshaft Stress Analysis

FaAA used the finite-element method of analysis reviewed in Section 4.4.2 of this report to compute the stress magnitude and distribution for the replacement crankshaft.

Stresses were reported to be reduced from the previous cyclic principal stress range of 60,000 psi to a range of 37,000 psi. This constitutes a reduction by a factor of 1.78 to a cyclic range that is only 56% of the former cyclic range. The reduction was due to the larger crankpin and increased

stiffness with resulting increased natural frequencies as previously discussed, and was supplemented by the increase in the crankpin fillet radius from one-half to three-quarters of an inch. The analysis was considered to be acceptable.

4.5.3 Crankshaft Shotpeening

FaAA reported [39] that shotpeening was introduced to the crankshaft processing in an effort to assure a "consistent, high level of compressive residual stress in the surface and to eliminate machining marks." The report continued by stating that the fillets "will be inspected by a high-resolution, eddy-current method after the break-in run."

Shotpeening has a long history of use in closing microscopic surface cracks and establishing a surface layer of the material in compressive stress. Although the basic idea is good, it was noted during the review that while various levels of shotpeening are available, no description of the process was provided.

Accordingly, the NRC arranged for a document review at the Shoreham Nuclear Power Station on March 8, 1984, during which quality control documents pertaining to crankshaft shotpeening were reviewed, and an informal discussion was held with Dr. Wells of FaAA. It was learned from Dr. Wells that two of the three replacement crankshafts, Nos. 693 (DG 103) and 694 (DG 102), arrived from TDI with the crankpin fillets already shotpeened.

The crankshafts were inspected and the results of the inspection are described by Stone and Webster Engineering Corporation's Coordination Report No. F-46109-G [41] as follows:

> "Problem Description: Delaval has identified 'holidays' or lack of peen coverage in the fillet areas of new diesel crankshafts purchased in accordance with E&DCR F-46109-C. These 'holidays' have been dispositioned as functionally acceptable by TDI, however, recent analysis performed by Failure Analysis Associates indicates that 100% peening coverage is beneficial."

In conjunction with the review of documents on March 8, 1984, photographs of the original shotpeening supplied by TDI were reviewed. Although the

photographs did not provide the desired detail, the photographs gave an impression of surface texture more like grit blasting than shotpeening, i.e., the surface appeared to have been gauged by sharp particles instead of dimpled by round, smooth particles. Although the photographs provided only a limited view of the fillet surfaces, this evaluation of the initial shotpeening concurs with the results of the inspection [41] by Stone and Webster Engineering Corporation.

Stone and Webster's Coordination Report No. F-46109-G [41] provided a recommended solution as follows:

> "Problem Solution: Since the crankshafts are delivered to the site, Metal Improvement Company, a local firm with expertise in shotpeening will perform the rework. The fillet areas shall be repeened in accordance with the requirements of MIL-S-13165B to assure 100% coverage of the fillet areas. Peening shall be performed by Metal Improvement Company on site and the crankshafts inspected by OQA for 100% peening at the fillet areas."

Accordingly, LILCO Repair/Rework Request R/RR R43-1632 specified shotpeening to include the following parameters:

- o Shot size; MI-550
- o Intensity, 0.008-0.010, Almen "C" test strips
- o MIL-S-13165B, Amendment 2.

Quality control documents were reviewed and indicated that the Almen test strips for the repeening provided readings within the specified intensity of 0.008 to 0.010 inch (arc height) with the exception of one test strip which was measured at 0.011 inch.

Photographs of the repeened surface were reviewed and show an improvement in surface texture, indicating an improvement in the quality of shotpeening of the crankpin fillets.

Crankshaft No. 695 for DG 101 was received at the Shoreham plant direct from the supplier, Krupp-Stahl in Germany, without shotpeening. Crankshaft No. 695 was shotpeened at the Shoreham plant to the same specifications as those described for crankshaft No. 693 and No. 694 above. Records reviewed at the Shoreham plant showed that the Almen test strips for crankshaft No. 695

shotpeening indicated that the intensities remained within the specified range of 0.008 to 0.010 inch arc height.

Shotpeening of this intensity is shown by Figure 4 to induce a compressive stress to a depth of from 0.027 to 0.034 inch, with the induced stress distributed as shown in Figure 5. Figures 4 and 5 are taken from Reference 42.

The purpose of shotpeening is to induce a compressive stress in the material at the surface of the crankpin fillets. Since the smooth surface is being disturbed by the particle impacts, it is necessary, once shotpeening is begun, to assure that the shotpeening coverage is uniform and of an intensity, with the right size of smooth shot, to achieve a suitable depth of material in compressive stress. Otherwise, improper shotpeening could serve as a source of added stress concentrations to make the crankshaft more susceptible to fatigue.

The actual peened surface were not available for inspection in the course of this review; therefore, this evaluation was made using the specified parameters, recorded Almen test strip measurements, and photographs of the peened surface. The shotpeening performed at the Shoreham plant is acceptable for the new crankshaft (No. 695) not subjected to shotpeening in advance and will serve to increase the fatigue life of the crankpin fillets. Inspection of crankshaft Nos. 693 and 694 revealed inadequate initial shotpeening; for these crankshafts, the rework shotpeening discussed above would be sufficient to counter the undesirable effects of the previous shotpeening, provided that the shotpeened surfaces that were photographed and made available for this review were representative of all crankpin fillet shotpeening. With this provision, the rework shotpeening is acceptable.

As an alternative to shotpeening, a surface layer under compressive stress can be induced into crankpin fillets by rolling techniques. This is accomplished by pressing a rolling element against the fillet surface with sufficient force to produce stresses in the fillet surface material that are just beyond the yield point. With the proper design of rolling element, the distribution of induced compressive stresses can be controlled to an ideal

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

6"

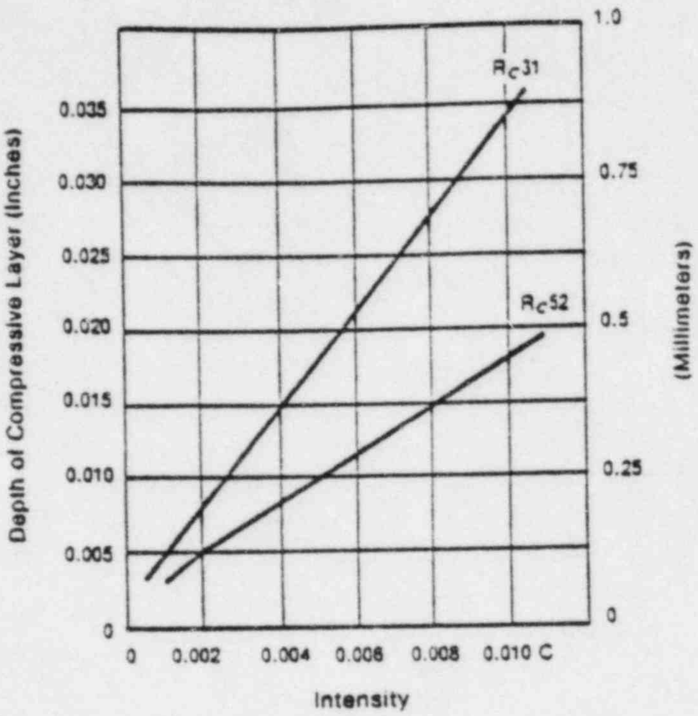


Figure 4. Depth and Compressive Stress vs. Almen Intensity for Steel [from Reference 42]

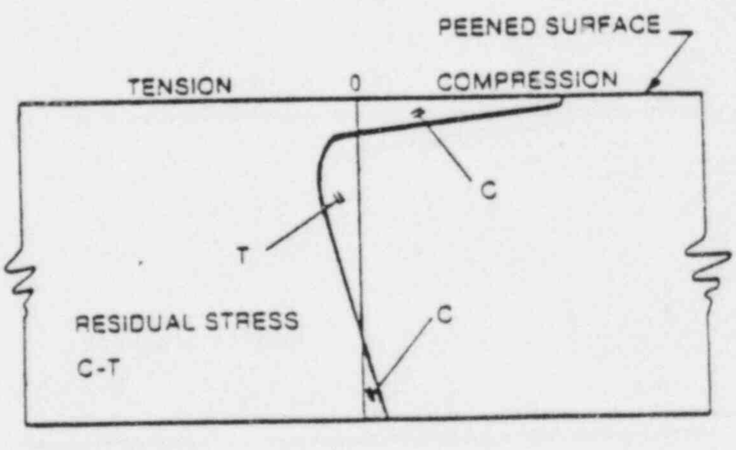


Figure 5. Distribution of Stress in Shotpeened Beam with No External Load [from Reference 42]

profile of magnitude and depth in addition to providing a smooth fillet surface for optimum fatigue resistance. Fillet rolling provides many advantages; however, there are fillet geometeries for which it is difficult to design a roller, e.g., recessed fillets similar to those of the TDI crankshafts. In addition, the technique requires the proper machinery to hold, load, and rotate the crankshaft and roller. Where this technique is possible, benefits follow. Lacking the means, shotpeening is recommended.

4.5.4 Summary of Replacement Crankshaft Design

The increase in crankpin diameter from 11.00 to 12.00 inches provided a significant crankpin stress reduction by reducing the direct torsional stress in the crankpin due to larger cross section and by stiffening the shaft to produce a higher natural frequency and thus reduce the dynamic multiplication factor.

Stresses calculated by TDI and FaAA were within the DEMA [2] recommendations for a single harmonic excitation. FaAA's summation of stresses for all excitation orders was also within DEMA's recommended values. TDI's analysis did not permit comparison of total stresses with those recommended by DEMA.

TDI's crankpin stress for single harmonic excitation does not satisfy the ABS limiting values [3] for ABS Grade 4 steel, except through an interpretation of the rules in which full advantage of the crankshaft material properties is taken. Such interpretation would require study and approval by ABS. TDI's analysis did not permit the comparison of total stress due to summation of orders with the ABS allowable values. Crankpin torsional stresses calculated by FaAA for both single harmonic excitation and summation of orders were in excess of ABS allowable values, including the higher allowable values determined by an interpretation of the ABS rules that used the full material properties of the crankshaft material.

Crankpin fillet shotpeening of the replacement crankshafts was evaluated through the review of documentation and photographs at the Shoreham plant.

Crankshafts No. 693 (DG 103) and No. 694 (DG 102) were found to have been previously shotpeened by TDI. When inspection at the Shoreham plant indicated that the initial shotpeening was unsatisfactory, the crankpin fillets were repeened at the Shoreham plant. Crankshaft No. 695 (DG 101), received direct from the supplier in Germany, was not initially shotpeened by TDI and was shotpeened only at the Shoreham plant. The crankshafts could not be inspected directly, and the shotpeening was evaluated only through the review of documentation and inspection of photographs of local regions. The shotpeening and rework shotpeening performed at the Shoreham plant were found to be acceptable insofar as the photographs inspected are representative of all shotpeened surfaces.

It must be noted that all of the TDI and FaAA stresses reviewed herein pertain to the 3500-kW electrical output loading (100% design load) and not to the short-term 3900-kW load required by the Shoreham plant.

5. CONCLUSIONS

Based on the findings of the failure investigation reviewed herein, it is concluded that:

- The crankshaft of diesel generator 102 failed in high cycle fatigue.
- Sufficient cause for the high cycle fatigue failure was crankshaft design based upon exceptionally low values of cyclic torque excitation (Tn) coupled with a natural frequency fairly close to the dominant excitation frequency.
- The specified design standards were not definitive and contributed to the failure by not providing design review material by which the design would have been evaluated and found to be in question prior to the diesel generator's application as safe shutdown equipment.

With respect to the replacement crankshaft design, it is concluded that:

- The combined static and dynamic effects of a 1.00-inch increase in crankpin diameter from 11.00 to 12.00 inches serve to reduce the crankshaft stresses calculated by TDI and FaAA to within the DEMA recommended values for single order excitation and for summation of order excitation.
- Although stresses from TDI's analysis for the replacement crankshaft do not satisfy the ABS rules for a single harmonic using a nominal Grade 4 material, they would just meet an interpretation of the ABS rules for a single harmonic wherein the actual properties of the crankshaft material are used. However, such interpretation of the ABS rules is subject to review and approval by ABS.
- TDI did not present an analysis by which their summation of stresses from all orders can be compared to the ABS limiting value for that condition.
- FaAA's crankshaft analysis predicts higher dynamic stresses due to (1) the use of slightly larger amplitudes of excitation (Tn values) than those used by TDI and (2) the superposition of modes resulting from the direct solution of the equations of crankshaft dynamics. Vibratory stresses computed by FaAA do not satisfy the ABS requirements for a single vibratory order or for the summation of orders, even considering an interpretation of the ABS rules to fully use the mechanical properties of the crankshaft steel.

- All analysis of stresses performed by TDI and FaAA pertained to the 3500-kW full load condition and not to the 3900-kW short-term overload required by the Shoreham plant.
- Crankpin shotpeening of one crankshaft and rework shotpeening of two crankshafts performed at the Shoreham plant were found to be acceptable only insofar as the evaluation from documents and photographs of localized shotpeened areas is representative of all crankpin fillet areas.

From the broad evaluations performed in the course of this review, it is summarily concluded that a set of standards more definitive than DEMA's "Standard Practices for Low and Medium Speed Stationary Diesel and Gas Engines" is required for diesel engines essential for safe shutdown of the Shoreham plant; that "Rules for Building and Classing Steel Vessels" by the American Bureau of Shipping is representative of definitive standards for safety at sea; and that, with the possible exception of TDI's stress for a single harmonic, the stresses evaluated in this review do not meet the requirements of the ABS standard.

Document 4

FaAA-84-5-4
03315A/RKT

DESIGN REVIEW OF TDI R-4 AND RV-4 SERIES EMERGENCY DIESEL GENERATOR CYLINDER BLOCKS AND LINERS

****

This report is final, pending confirmatory reviews
required by FaAA's QA operating procedures.

****

Prepared by
Failure Analysis Associates
Palo Alto, California

Prepared for

TDI Diesel Generator Owners Group

June 1984

TABLE 1-1

ENGINE 101 LOAD HISTORY
SHOREHAM NUCLEAR POWER STATION

Event and Date	Hours at Load, L (%)					
	L<75	75<L<100	L=100	100<L<110	L>110	Total Hours, All Loads
Original Crankshaft Hours	164.0	262.5	188.5	--	19.0	634
Crankshaft replaced Restart 12/29/83 Testing Hours	78.0	179.0	20.0	91.0	4.5	372.5
Outage 3/18/84 Block Inspection 3/20/84						
Qual. Testing Hours 4/10/84	43.0	10.0	29.5	.5	2.0	85
Total	285.0	451.5	238.0	91.5	25.5	1091.5

TABLE 1-2

ENGINE 102 LOAD HISTORY
SHOREHAM NUCLEAR POWER STATION

Event and Date	Hours at Load, L (%)					Total Hours, All Loads
	L<75	75<L<100	L=100	100<L<110	L>110	
Original Crankshaft Hours	83.0	325.0	259.0	22.0	--	689
Crankshaft Replaced Restart 12-22-83 Testing Hours	34.5	183.0	36.5	70.0	--	324
Outage 2/09/84 Block Inspection 2/10/84						
Qual. Testing Hours	90.0	3.5	16.0	0.5	--	110
Block Inspection 3/08/84						
Total Hours	207.5	511.5	311.5	92.5	--	[illegible]

TABLE 1-3

ENGINE 103 LOAD HISTORY
SHOREHAM NUCLEAR POWER STATION

Event and Date	Hours at Load, L (%)					Total Hours, All Loads
	L<75	75<L<100	L=100	100<L<110	L>110	
Original Crankshaft Hours	103.0	432.0	257.0	---	23.0	815
Crankshaft Replaced Restart 12/17/83 Testing Hours	67.0	170.5	69.0	34.5	6.0	347
Outage 3/11/84 Block Inspection 3/11/84 Qual. Testing Hours	64.5	5.5	24.5	13.0	1.0	108.5
Block Failure 4/14/84 Block Inspection 4/15/84 Total Hours	234.5	608.0	350.5	47.5	30.0	1270.5

Document 5

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

---oOo---

COPY

In the matter of LONG ISLAND LIGHTING COMPANY (Shoreham Nuclear Power Station, Unit 1)	DOCKET NO. 50-322-OL

DEPOSITION OF GERALD EDGAR TRUSSELL

May 7, 1984

VOLUME I - Morning Session

REPORTED BY:
MARION G. KOLB, CSR NO. 4381

TOOKER & ANTZ
CERTIFIED SHORTHAND REPORTERS
681 MARKET STREET, SUITE 925
SAN FRANCISCO, CALIFORNIA 94105
415/392-0650

A. Yes.
Q. And what is that name?
A. Shot peening.
Q. Did Delaval recommend that the replacement crank shaft be shot peened?
A. No.
Q. Did Delaval recommend that the replacement crank shaft not be shot peened?
A. I don't recall.
Q. Who was responsible in your organization for supplying the replacement crank shaft to LILCO?
A. Supply -- can you give me the question one more time?
Q. Who was responsible in your organization for the supplying of the replacement crank shaft for LILCO? And it may be more than one person. I am asking who.
A. As to the supplies, the parts manager.
Q. Yes. Who was responsible for giving the recommendation as to whether or not the replacement crank shaft should be shot peened?
A. I was.
Q. And do you now recall what your recommendation was in that regard?
A. My recollection is that I recommended against shot peening.
Q. Why did you recommend against shot peening?
A. The detailed drawing for that part did not call for shot peening.

Q. Who prepared the detailed drawing for that part?
A. I don't know.
Q. Was it Delaval who supplied the detailed drawing for that part?
A. Yes.
Q. Was there any discussion within the Delaval organization concerning whether or not the detailed drawing should or should not provide for shot peening of the replacement crank shaft?
A. Yes.
Q. What was the basis for the conclusion that it should not contain the requirements for shot peening?
A. The basis for that conclusion lay in an opinion that mechanical improvement by shot peening did not substantially improve the fatigue strength of the crank shaft.
Q. Did it improve the strength of the crank shaft at all?
A. Yes.
Q. Are there disadvantages to shot peening the crank shaft?
MR. SMITH: You are talking about the specific shaft in question here, I assume?
MR. DYNNER: Yes, right.
THE WITNESS: No.
MR. DYNNER: Q. So as I understand your testimony -- please correct me if I'm wrong -- there are no disadvantages to the shot peening in this crank shaft,

there was an advantage in that it somewhat increased the strength of the crank shaft, and yet you recommended against shot peening; is that correct?

A. That's correct.

Q. On what was that recommendation based?

MS. TARLETZ: Asked and answered.

MR. SMITH: I will join in that objection.

MR. DYNNER: Q. Aside from the fact that the detailed drawings did not call for the shot peening.

MR. SMITH: The question has been asked and answered.

MR. DYNNER: I don't think so.

THE WITNESS: What is the question?

MR. DYNNER: Q. The question is: On what was your recommendation against shot peening based aside from your prior testimony that -- when I asked the question previously -- that it was based upon the fact that the design drawings did not call for shot peening?

MR. SMITH: Well, note my objection to the form because I don't think that was -- I think the record will show that that was not the only basis against the recommendation that the witness has already testified to.

THE WITNESS: The recommendation against shot peening was based in part on, A, the experience that shot peening did not provide a substantial improvement in the fatigue strength of the shaft, and in part on a discussion with, I believe it was, Professor Wallace.

Q. Well, what did Professor Wallace have to say

about the shot peening?

A. I'm going to have to paraphrase the thing, but I believe Jack indicated to us that the shot peening technique is section sensitive and since we were involved here with a heavy section, the improvement would not be substantial.

Q. What does "section sensitive" mean?

A. I would like to give an example that would provide a comparison.

Shot peening a thin piece of steel of the same specifications of the crank shaft would substantially improve its fatigue strength while applying the same surface improvement technique to a thick section, like a crank shaft, would not provide a substantial improvement in the fatigue strength of the piece.

MS. TARLETZ: Could I have that answer read back, please.

(Question and answer read.)

MS. TARLETZ: Thank you.

MR. DYNNER: Q. Mr. Trussell, what do you mean by a substantial improvement?

A. Something more than five percent.

Q. Did anyone disagree with your recommendation against shot peening the replacement crank shaft?

A. Are you asking for a specific name?

Q. Anyone.

A. Someone did.

Q. Who?

Q. What load level was postulated in connection with the stress analysis of the AE piston performed by Mr. Beshouri?

MR. SMITH: What do you mean "postulated"?

MR. DYNNER: Q. Assumed, taken into consideration, utilized.

THE WITNESS: Yes, I believe it was as high as 2,000 PSI combustion zoned pressure.

MR. DYNNER: Q. Is that the pressure inside the cylinder head, this cylinder you are talking about?

A. Yes.

Q. And does the pressure in the cylinder of the DSR 48 engine ever reach 2,000 PSI?

A. I think you have to -- I don't know which engine you are talking about.

Q. DSR 48 engine.

A. Not to my knowledge.

Q. Well, how high does the pressure in the cylinder reach in the DSR 48 engine?

MS. TARLETZ: Under what application?

MR. DYNNER: Q. Can you answer that question?

MR. SMITH: I join in that objection.

MR. DYNNER: Q. What is maximum pressure in the cylinder during operation of the DSR 48 engine of the same type as at Shoreham?

MR. SMITH: At any time?

MR. DYNNER: Maximum pressure in the cylinder.

THE WITNESS: I think approximately 1800 PSI.

MR. DYNNER: Q. And is that full load?

A. I believe that is overload.

Q. All right. What is the overload condition at which that pressure is reached in the engines at Shoreham, the kw rating, if you know that?

A. I believe it's approximately 3900 kw.

MR. SMITH: It is now 5:31 according to my watch. In any event, if you have one or two more questions on this line, go ahead, but I am going to call an end to the day.

MR. DYNNER: That covers the questions along this particular line.

(Whereupon the deposition adjourned at 5:32 p.m.)

Document 6

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 1 A

CUSTOMER Lilco

MODEL DSR-48

TEST STAND NUCLEAR JOB NO 2609 ENGINE NO 74010

FULL LOAD RATING 9880 BHP @ 450 RPM 225 BMEP

LINE	DATE	TIME ON LOAD	TIME THIS LOG	% LOAD (Nom.)	DYNAMOMETER RPM	SCALE (lb/in)	BHP (Corr.)	BMEP	DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	TOTAL KW	GEN EFF	BHP (Corr.)	BMEP	GOV LOAD LIMIT
1	11/5	—	1410		INITIAL START													
2			1435															
3			1450															
4	11/6		1035		START UNIT TO CHECK SWITCH GEAR													
5	11/6	1900	1900		450													
6	11/7	0815	0830		450		2680	116						2000				
7	11/7	1445	1500		450		2144	97						1600				
8	11/7	1500	1545		450		2010	93						1500 1400				
9		1545	1600		450		2550	116						2000				
10		[illegible]	1630		450		2814	125						2100				

FUEL PUMP RACK POSITION (mm) — RHEOSTATS (KVO)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1																				
2																				
3																				
4																				
5																				
6											1000	1000								
7											1100	500								
8											1000		500							
9											1000		1050							
10											1000	500	500							

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW

LINE	BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR MANIF (in hg) LB	RB	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δ (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr.) in Hg	AIR (°F)
1																																							
2																																							
3																																							
4																																							
5																																							
6																											132												
7									16																		128												
8									17																		138												
9									24.5																		138												
10									24.8																		139												

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC / REMARKS

LINE	MANIF (in Hg)	API GRAVITY AS READ @ °F	API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	lbs/bhp hr	(Corr.) lb/bhp hr	MANIF (psig or in hg)	LHV Btu/ft³	TO GAS METER psig (or) in hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr.)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1																						
2	24.5																					
3	28.0																					SHUT UNIT DOWN FOR 15 MIN. 1051 ACC CK
4																						
5																						
6	35.5																					
7	35.5																					START & RUN UNIT TO SET & CHECK ELEC. GOV.
8	35.5																					
9	35.5																					
10	35.5																					

INJECTION IGNITION TIMING °BTDC 23 LB RB

FUEL OIL SPEC

LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT LF RF LR RR

OPERATOR [illegible]

ENGINEER [illegible]

DATE 11/3/75

ENGINE AND COMPRESSOR DIVISION OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 B

CUSTOMER LILCO MODEL DSR-48 TYPE SERVICE STATIONARY JOB NO 2609 ENGINE NO 74010 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFFB	LFB	RFT	RFB	LBT	LRB	RBT	RBTB	RBB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1																																				1
2											270				280	275	275	290	80	275	100	270	290													2
3																																				3
4											290				340	340	345	360	335	340	340	340	240													4
5																																				5
6											660				760	705	670	745	670	720	695	720														6
7											650				710	670	670	680	655	665	675	680														7
8											650				705	670	660	680	650	665	665	675														8
9											660				755	715	700	720	680	700	715	710														9
10											685				760	710	705	725	680	710	715	720														10

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	FIRING PRESSURES - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1																																	1
2	3.5	114	132																														2
3	24	++																															3
4	24	115	125																														4
5																																	5
6	24	153	173																														6
7	24	152	173																														7
8	24	154	170																														8
9	24	154	172																														9
10	24.5	153	17[illegible]																														10

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in. H_2O	REMARKS	LINE
1																1
2		54.5		31.5				196	195							2
3																3
4		58.0		30.0				156	155							4
5																5
6		55.0		27.0				171	180							6
7		55.0		27.5				175	181							7
8		55.0		28.0				171	180							8
9		55.0		27.0				170	181							9
10		5?.0		27.5				167	181							10

LEGEND: L, LB LEFT BANK F - ENGINE FRONT AT NO. 1 CYLINDER; R, RB RIGHT BANK R - ENGINE REAR (FLYWHEEL END); (AS VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF 66
RR

OPERATOR [signature]
ENGINEER [signature]
WITNESS

DATE 11/3/75
LOG B
JOB NO 2609 010

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 2 — A

CUSTOMER LILCO — MODEL DSR-48 — TEST STAND 4421 OAR — JOB NO 2604 — ENGINE NO 74010

FULL LOAD RATING 4550 — BHP @ 450 RPM 225 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	THIS LOG	LOAD (Nom.)	DYNAMOMETER LOAD DATA RPM	SCALE (lbs)	BHP (Corr.)	BMEP	A.C. GENERATOR LOAD DATA DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	TOTAL KW	GEN EFF	BHP (Corr.)	BMEP	GOV LOAD LIMIT
1	11-7		1705		450													
2	11/8		1020															
3		1150	1250	~~4/2~~	450		4187	193						3000				
4		1305	1400		450		4880	225						3500				
5		1410	1510		450		5366	248						3850				
6	11/12	1330	1630		450													
7	11/13	1135	1615		450													
8	11/14	0910	1100		450													
9	11/14	1115	1215		450		4880	225						3500				
10	11/14	1955	1555		450		4880	225						3500				

LINE	FUEL PUMP RACK POSITION (MM) 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	RLCSTATS (KW) 1R	2R	3R	4R	5R	6R	TOTAL 7R	8R	9R	10R
1																				
2																				
3	32.0	32.0	32.0	31.5	32.0	32.0	31.5	32.0			1000	1000	1000							
4	38.5	38.0	38.0	38.5	37.5	38.0	38.0	38.0			1175	1150	1175							
5	42.5	42.0	43.0	43.0	42.5	42.0	43.0	43.0			1275	1300	1300							
6																				
7																				
8																				
9	37.5	37.5	38.0	38.5	38.0	38.0	37.5	38.5			1750	1750								
10	37.5	37.5	37.5	38.0	38.0	38.0	37.0	38.0			1750	1750								

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES

LINE	BLOWER INLET (in. H_2O) LF	RF	LR	RR	BLOWER DISCHARGE (in. hg) LF	RF	LR	RR	AIR MANIF (in. hg) LB	RB	TURBINE INLET (in. hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H_2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE ΔP (in. H_2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (in. hg)	AIR (°F)
1									24.6																		128												
2																																							
3									31.5																		137												
4									32.0																		140												
5									32.5																		190												
6																																							
7																																							
8																																							
9									51.5																		138												
10									52.5																		190												

LINE	FUEL OIL DATA MANIF (psig)	API GRAVITY AS READ	@ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	DIESEL BSFC lb/hr	Btu/bhp-hr	(Corr.) lb/bhp-hr	FUEL GAS DATA MANIF (psig or in. hg)	LHV (Btu/ft³)	TO GAS METER press (in. hg)	°F	CORR FACTOR	GAS BSFC ft³ MEAS	TIME (sec)	ft³/hr (Corr.)	Btu/bhp-hr	DUAL FUEL BSFC PILOT Btu/bhp-hr	GAS Btu/bhp-hr	TOTAL Btu/bhp-hr
1	35.5																					
2																						
3	33.5																					
4	32.8	36.8	80	35.9	18365	1990	2791	1733		.359												
5	32.6	36.6	82	35.1	18380	2100	3192	1948		.361												
6																						
7																						
8																						
9	32.5	36.4	76	35.3	18310	1320	2757	1727		.358												
10	32.0																					

REMARKS

INSTALLED GOV. FROM ACTION ELECTRONIC TESTER CORP. SERIAL #1327104

(line 2) START UNIT TO SET GOV.

(line 9) CHANGED T.C. INLET ORIFICE TO 3.690

INJECTION/IGNITION TIMING °BTDC 23° LB RB

FUEL OIL S

LUBE OIL :

AIR FLOW NOZZLE COEFFICIENT

LF

LR — BEYR NOR

OPERATOR D Clements

ENGINEER R. C. Bernick

WITNESS

DATE 11-7-75

RATING 20

A

DELAVAL

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG 2 — 8

CUSTOMER L I L Co — MODEL DSR-48 — TYPE SERVICE STATIONARY — JOB NO 2604 — ENGINE NO 74010 — DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LBT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1											680				760	715	710	725	680	710	715	720													
2																																			
3											735				850	820	800	800	780	800	825	790													
4											750				900	880	855	895	890	895	815	835													
5											765				920	910	880	880	875	875	900	880													
6																																			
7																																			
8																																			
9											735				860	850	840	815	840	820	850	820													
10											740				870	860	845	845	835	835	850	820													

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	FIRING PRESSURES PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	245	132	172					153		172																						
2																																
3	245	153	168																													
4	245	153	174									1580	1580	1580	1580	1600	1560	1580	1590													
5	245	153	175									1700	1680	1695	1690	1720	1690	1690	1700													
6																																
7																																
8																																
9	250	149	165					69		76		1590	1580	1595	1580	1590	1570	1590	1580													
10	250	151	166					70		77																						

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in H2O	REMARKS
1		55		27.5				161	181						
2															
3		55		25.5				165	180					1.3	
4		55		26.0				163	180					.9	
5		55		26.0				162	180					.5	
6															
7															
8															
9		54.5		25.0				161	180					1.1	
10		54.5		25.0				160	181					.8	

LEGEND: L LB LEFT BANK F ENGINE FRONT AT NO 1 CYLINDER; R RT RIGHT BANK R ENGINE REAR FLYWHEEL END; D [illegible]

TURBOCHARGER MAKE & MODEL: LF GEC

OPERATOR: [illegible signature] — ENGINEER: [illegible signature] — WITNESS

E13

DATE 11-7-75 — LOG — PAGE 26 — 8

DELAVAL

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 3 — A

CUSTOMER Lilco MODEL DSR-48 TEST STAND Nuclear JOB NO 2609 ENGINE NO 74010 FULL LOAD RATING 4880 BHP @ 450 RPM 225 BMEP

Line	Date	Wall Clock Time On Load	Wall Clock Time Chg Log	% Load	Dyna RPM	Scale	BHP (Corr)	BMEP	Disc Revs	Time	Power Factor	AC Volts	AC Amps	Total KW	Gen Eff	BHP (Corr)	BMEP	Gov Load Limit
1	11/1	0930	1030		450		4880	225						3500				
2	11/22	0930			450	Unit	Shut	Down -	Ground	Fault				2300				
3	11/23	1015	1056		450	Unit	Shut	Down	- Ground	Fault								
4		1305	1318		450	Unit	Shut	Down	- Ground	Fault								
5		1330	1345		450													
6		1500	1600		450		4015	185						3000				
7	11/24	1405	1530		450													
8	11/25	1110	1600		450													
9	11/25	1400	1600		450													
10	11/26	1030			450													

Fuel Pump Rack Position (MM) — Readings KW

Line	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1											1750	1750								
2																				
3																				27.2
4																				
5																				28.1
6											1500	1500								28.2
7																				
8																				31.8
9																				
10																				34.6

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE

Line	Blower Inlet (in H_2O) LF/RF/LB/RB	Blower Discharge (in hg) LF/RF/LB/RB	Air Manif (in hg) LB	Air Manif RB	Turbine Inlet (in hg)	Turbine Exhaust (in H_2O)	Blower Inlet (°F)	Blower Discharge (°F)	Air Manif (°F) LB	Air Manif RB	Turbocharger RPM	Nozzle Δ (in H_2O)	Air Flow SCFM Total	Ambient Baro (in hg)	Air (°F)
1			510						138					30.03	72
2															
3															
4															
5															
6			10.5						139					30.24	
7															
8															
9															
10															

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC / REMARKS

Line	Mano (and)	API Gravity As Read @ °F	°F	API Corrected to 60°F	LHV (Btu/lb)	Lbs Meas	Time (sec)	lb/hr	Btu/bhp-hr	(Corr) lb/bhp-hr	Gas Data	Gas BSFC	Dual Fuel BSFC	Remarks
1	32.5	36.7	60	35.3	18390	375	787	1715		.355				Changed 3.0 inlet orifice to 3.890
2														
3														
4														
5														
6	31.5													Ground Fault Disconnected
7														Drained & Refilled Water Resistors 1-2-3
8														
9														Started to trouble shoot control panel
10														

INJECTION IGNITION TIMING °BTDC 23 LB RB

FUEL OIL SP

LUBE OIL SP

AIR FLOW NOZZLE COEFFICIENT LF LB RF RB

OPERATOR [signature]

ENGINEER [signature]

WITNESS

E13

DATE 11/1/75 LOG NO 3 RATIO 2.6 A

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — DELAVAL

POWER ENGINE FACTORY TEST LOG — LOG 3 B

CUSTOMER: Lilco   MODEL: DSR-48   TYPE SERVICE: STATIONARY   JOB NO: 2609   ENGINE NO: 74010   DIRECTION OF ROTATION: CW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR
1											740			
2														
3														
4														
5														
6											715			
7														
8														
9														
10														

LINE	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	865	855	840	840	830	830	850	845													
2																					
3																					
4																					
5																					
6	810	790	800	795	780	785	800	775													
7																					
8																					
9																					
10																					

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1	250	161	165					61		62	
2											
3											
4											
5											
6	250	154	110					66		78	
7											
8											
9											
10											

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS (in H_2O)	REMARKS
1		550		27.0				172	177					.9	
2															
3															
4															
5															
6		55.0		26.5				163	180					1.3	
7															
8															
9															
10															

LEGEND: L, LB - LEFT BANK; F - ENGINE FRONT AT NO. 1 CYLINDER; R, RT - RIGHT BANK; R - ENGINE REAR FLYWHEEL END

TURBOCHARGER MAKE & MODEL: LF EL

OPERATOR: [signature]   ENGINEER: [signature]   WITNESS:

DATE: 11/17/75   LOG: 3 B   RUN NO: 26

DELAVAL

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — -300 START TEST-

POWER ENGINE FACTORY TEST LOG — LOG A

CUSTOMER LILCO — MODEL DSR-48 — TEST STAND NUCLEAR, JOB NO 2609 — ENGINE NO 74010 — FULL LOAD RATING 3500 KW — RPM 450 — SHEET 2

LINE	DATE	WALL CLOCK TIME ON LOAD	THIS LOG	% LOAD	RPM	SCALE	BHP (Corr)	BMEP	DISC REVS	TIME (sec)	POWER FACTOR	AC VOLTS	AC AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT	10R
1	12/4	1413	1430		450		[illegible]	[illegible]	240	65		4160	300	2200					
2	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	141	[illegible]	75		[illegible]	300	[illegible]					
3	12/5	0043	[illegible]55		450		[illegible]	140	240	80		4160	300	2175					
4	12/5	0355	0408		450		2266	137	240	65		4160	295	2125					
5	12/5	0702	0715		450		2251	135	240	40		4160	290	[illegible]					
6	12/5	1238	1304		450		[illegible]	135	240	100		4160	290	2100					60.3
7	12/5	[illegible]	1253		450		2256	135	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]					62.6
8	12/6	0144	0156		450		2211	[illegible]	237	120		4160	285	2050					64.7
9	12/6	0495	0557		450		2256	133	240	125		4160	28[illegible]	2075					65.8
10		[illegible]			[illegible]		2266	137	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]					[illegible]

FUEL PUMP RACK POSITION (MM): 1L 2L 3L 4L 5L 6L 7L 8L 9L 10L 1R 2R 3R 4R 5R 6R 7R 8R 9R 10R

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE / AMBIENT

LINE	AIR MANIF (in Hg) LB	EXHAUST (°F) LB	AMBIENT AIR (°F)
1	228	131	73
2	227	131	71
3	255	130	
4	25.0	128	
5	24.0	130	74
6	24.5	132	71
7	[illegible]	128	71
8	25.5	126	69
9	25.0	128	66
10	[illegible]	130	76

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF (psig)
1	34.2
2	33.7
3	34.0
4	34.5
5	33.5
6	33.3
7	32[illegible]
8	34.0
9	34.3
10	[illegible]

REMARKS: STARTING AIR PSI 240

INJECTION/IGNITION TIMING °BTDC — LB — RB

FUEL OIL SP — LUBE INLET

AIR FLOW NOZZLE COEFFICIENT — LF — LR — RF — RR

OPERATOR [illegible] — ENGINEER [illegible] — WITNESS [illegible]

DATE 12/4/75 — LOG NO — JOB NO

A

ENGINE AND COMPRESSOR DIVISION OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG B

CUSTOMER LILCO   MODEL DSR-48   TYPE SERVICE NUCLEAR STANDBY   JOB NO 2609   ENGINE NO 74010   DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP B - BOTTOM) LTTL	LTTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1											690				740	715	755	740	730	745	730	740														1
2											690				730	710	720	740	720	740	725	735														2
3											660				720	700	743	735	722	738	721	738														3
4											675				719	698	740	725	720	738	718	735														4
5											665				715	695	739	722	719	737	715	723														5
6											680				720	690	735	730	715	730	710	730														6
7											680				720	690	735	730	715	735	715	725														7
8											685				718	690	740	723	715	730	710	725														8
9											675				719	690	740	722	718	730	710	723														9
10											680				720	700	740	725	720	735	720	710														10

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (PSI) F	R	FIRING PRESSURES - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1	25.5										12.0																						1
2	25.2										12.0																						2
3	25.5										13.0																						3
4	25.51										13.0																						4
5	25.5										13.0																						5
6	25.5										13.2																						6
7	25.5										13.3																						7
8	25.5										13.2																						8
9	25.0										13.0																						9
10	25.5										13.2																						10

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS "in H2O	REMARKS	LINE
1		54.0		25.5												1
2		56.0		[illegible]												2
3		54.5		26.5												3
4		55.5		22.5												4
5		55.5		27.5												5
6		54.0		26.5												6
7		56.5		26.7												7
8		52.5		26.5												8
9		55.5		27.0												9
10		54.5		27.0												10

LEGEND: L LB LEFT BANK F ENGINE FRONT AT END CYLINDER; R RB RIGHT BANK R ENGINE REAR FLYWHEEL END; (AS VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF
LR
RF RR

OPERATOR [signature]   12/4/75
ENGINEER [signature]
WITNESS [signature]
JOB NO 2609

B

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG A

CUSTOMER [illegible] MODEL [illegible] TEST STAND [illegible] JOB NO 2609 ENGINE NO 74010 FULL LOAD RATING [illegible] BHP @ 450 RPM BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD	DYNAMOMETER RPM	SCALE (lb)	BHP (Corr)	BMEP	A.C. GENERATOR DISC REVS	TIME (sec)	TIME FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT	FUEL PUMP RACK POSITION (MM) 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	[illegible]	1500			450		3030	142	240	190			300	2200					75.8																			
2	12/6	1845			450		3025	143	280	150			308	2225					70.4																			
3	12/7	2015			450		3030	142	210	160			308	2200					72.2																			
4	12/7	[illegible]			450		2966	137	[illegible]	170			291	2125					75.2																			
5	12/7	[illegible]			450		2833	133	240	180			[illegible]	[illegible]																								
6	12/7	1757			450		3036	140	240	190			300	2175					78.2																			
7	12/7	2226			450		3051	138	275	200			275	2150					80.1																			
8	12/8	0338			450		2946	134	240	205			295	2075					81.5																			
9	12/8	0635			450		2931	135	240	210			270	2100					81.2																			
10	12/8	[illegible]			450		2931	135	240	210			[illegible]	[illegible]																								

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE

LINE	BLOWER INLET (in H_2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR MANIF (in hg) LR	RR	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H_2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LR	RR	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE ΔP (in H_2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr) in hg	AMBIENT AIR (°F)
1									25.5																													[illegible]	[illegible]
2									26.5																													30.16	77
3									26.5																													30.18	70
4									[illegible]																														[illegible]
5									[illegible]																														73
6									25.5																													30.13	72
7									27.5																													30.12	73
8									25.0																													30.09	68
9									24.0																													30.07	70
10																																							

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF (in hg)	API GRAVITY AS READ @ °F	API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	MANIF (in hg)	LHV (Btu/ft³)	TO GAS METER (in hg)	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1	34.2																					
2	33.5																					
3	34.0																					
4	34.1																					
5	34.0																					
6	33.9																					
7	33.0																					
8	34.0																					
9	34.0																					
10	[illegible]																					

INJECTION IGNITION TIMING °BTDC ______ LB ______ RB

FUEL OIL SPEC

LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT LF ______ RF ______ LR ______ RR ______

OPERATOR [illegible] ENGINEER [illegible] WITNESS [illegible]

DATE [illegible] LOG NO ______ JOB NO [illegible]

A

DELAVAL

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 5 — 8

CUSTOMER [illegible] MODEL DSR-48 TYPE SERVICE STANDBY JOB NO. 2609 ENGINE NO. 7440 DIRECTION OF ROTATION [illegible] CW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFT	LFTB	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1											670				740	710	755	750	735	750	755	740													
2											685				742	710	759	744	738	745	739	750													
3											680				730	705	744	739	722	742	730	740													
4											675				725	715	740	725	715	735	710	735													
5											660				740	695	745	740	725	740	730	735													
6											682				730	705	745	739	723	741	722	740													
7											690				739	705	745	740	725	742	722	741													
8											680				725	705	745	738	720	742	720	738													
9											675				723	700	745	735	715	740	720	735													
10											670				715	700	745	730	725	740	720	735													

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) PSI	R	FIRING PRESSURES PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	25.5									13.5																						
2	25.5									13.5																						
3	25.5									13.2																						
4	25.5									13.5																						
5	25.5									13.9																						
6	25.5									13.4																						
7	25.5									13.2																						
8	25.5									13.3																						
9	25.5									13.3																						
10	25.0									13.2																						

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in H2O	REMARKS
1		54.0		26.9											
2		54.5		26.8											
3		55.5		27.9											
4		54.0		26.9											
5		55.5		[illegible]											
6		55.0		[illegible]											
7		55.0		27.5											
8		55.5		27.7											
9		55.0		27.7											
10		54.5		27.0											

LEGEND: L LB LEFT BANK F ENGINE FRONT AT NO. 1 CYLINDER
R RB RIGHT BANK R ENGINE REAR FLYWHEEL END
[illegible] FLYWHEEL END

TURBOCHARGER MAKE & MODEL
LF
LR

OPERATOR [illegible] DATE [illegible]
ENGINEER [illegible]
WITNESS [illegible]

8

- RED QUICK START TEST -

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

LOG 2 A

CUSTOMER LILCO MODEL DSR-48 TEST STAND 23 JOB NO. 2604 ENGINE NO. 74010-12 FULL LOAD RATING 4880 BHP @ 450 RPM 225 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	THIS LOG	% LOAD (Nom.)	DYNAMOMETER LOAD DATA DYNA CONST RPM	SCALE (lb/in)	BHP (Corr)	BMEP	A.C. GENERATOR LOAD DATA KWH METER CONST WSCF REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT	FUEL PUMP RACK POSITION (MM) 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	7-16	350			450				STARTING PSI						.2	35		AFTER START PSI								—												
2	7-16	425			450										.2	38																						
3	7-16	1434			450										.2	50										208												
4	7-16	1441			450										.2	91										212												
5	7-16	1508			450										.2	90										197												
6	7-16	1513			450										.2	46										198												
7	7-16	1518			450										.2	35										201												
8	7-16	1524			450										.2	45										207												
9	7-16	1527			450										2	58										212												
10	7-16	1534			450										2	45										224												

LINE	TURBOCHARGER PRESSURES BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR MANIF (in hg) LR	RR	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR	TURBOCHARGER TEMPERATURES BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LR	RR	AIR FLOW NOZZLE SIZE 12" TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr) in hg	AIR (°F)
1 1	7-16	1538				450											2	45											235										
1 2	7-16	1545				450											2	56											230										
1 3	7-16	1559				450											2	59											200										
1 4	7-17	924				450											2	57											205										
1 5	7-17	946				450											2	55											200										
1 6	7-17	1006				450											2	62											225										
1 7	7-17	1017				450											2	46											210										
1 8	7-17	1024				450											2	51											211										
1 9	7-17	1000				450											2	43											220										
2 10	7-17	1051				450											2	00											176										

LINE	FUEL OIL DATA MANIF (level)	API GRAVITY AS READ @ °F	API Corrected To 60°F	LHV (Btu/lb)	DIESEL BSFC LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	FUEL GAS DATA MANIF (psig or in hg)	LHV Btu/ft³	TO GAS METER psig (or) in hg	°F	CORR FACTOR	GAS BSFC ft³ MEAS	TIME (sec)	ft³ hr (Corr)	Btu/bhp hr	DUAL FUEL BSFC PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
2 1	7-17	1056		450								151								139		
2 2	7-17	1059		450								125								118		
2 3	7-17	1101		450								100								96		
2 4	7-17	1105		450								77								75		
2 5	7-17	1101		450								247								205		
2 6	7-17	1151		450								250								215		
2 7	7-17	1157		450								233								205		
8																						
9																						
10																						

INJECTION IGNITION TIMING °BTDC 23° LB RB

FUEL OIL SPE F.O.

LUBE OIL SF L-21

AIR FLOW NOZZLE COEFFICIENT .112283

OPERATOR D. Cline

ENGINEER

WITNESS

DATE 9/16 '85

LOG NO

JOB NO 26

A

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG 1 A

CUSTOMER LILCO — MODEL DSR-48 — TEST STAND 23 — JOB NO 2604 — ENGINE NO 74010 — FULL LOAD RATING 4880 BHP @ 450 RPM 225 BMEP

DYNA CONST 5252

LINE	DATE	WALL CLOCK TIME ON LOAD	THIS LOG	% LOAD (Nom)	DYNAMOMETER RPM	SCALE (lbs)	BHP (Corr)	BMEP	DISC REVS	TIME (sec)	POWER FACTOR	AC VOLTS	AC AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT
1	9/11	1255		25	450	14157	1213	56										
2	9/11	0235	0335	50	450	28688	2458	113										
3	9/11	0700	0800	75	450	42763	3664	169										
4	9/11	0915	1015	100	450	56955	4880	225										
5	9/11	1120	1220	100	450	56955	4880	225										
6	9/11	1600	1700	110	450	62650	5368	248										
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (MM)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	19.5	20.0	20.0	20.5	19.5	20.0	20.0	20.5												
2	25.0	26.5	26.0	25.5	25.0	25.5	26.0	25.0												
3	29.0	30.0	30.0	31.0	30.0	30.0	30.5	30.5												
4	38.0	38.5	38.5	39.0	39.0	38.5	38.5	39.0												
5	39.0	39.0	38.0	38.0	37.5	38.0	38.0	38.5												
6	43.0	43.0	43.0	44.0	43.0	43.0	43.0	44.0												
7																				
8																				
9																				
10																				

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR MANIF (in hg) LB	RB	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR
1	-4.8				8.0				7.9									
2	-10.5				20.5				20.4									
3	-18.3				34.5				34.5									
4	-30.6				50.8				50.8									
5	-30.6				50.7				49.9									
6	-37.1				58.9				58.5									
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES — AIR FLOW NOZZLE SIZE 12

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr) in hg	AIR (°F)
1	67				125				123						2.8				4884	29.76	67
2	64				184				162						6.3				7348	29.77	64
3	62				244				165						10.8				9635	29.74	62
4	61				315				157						17.9				12420	29.76	61
5	64				317				161						17.5				12247	29.77	64
6	66				362				160						21.1				13411	29.72	66
7																					
8																					
9																					
10																					

FUEL OIL DATA — DIESEL BSFC

LINE	MANIF (psig)	API GRAVITY AS READ	@ °F	API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr
1	39.5	38.0	85	36.2	18420	550	3047	650		.642
2	38.5	38.0	80	36.5	18425	650	2654	881		.363
3	38.0	37.8	77	36.6	18430	836	3266			
4	36.5	37.8	80	36.8	18435	1494	3077	1748		.363
5	37.0	37.7	78	36.4	18420	1484	3047	1753		.364
6	36.5	38.2	88	36.2	18420	1500	2697	2002		.378
7										
8										
9										
10										

FUEL GAS DATA — GAS BSFC — DUAL FUEL BSFC — REMARKS

LINE	MANIF (psig in hg)	LHV Btu/ft³	TO GAS METER orig (in) in hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

INJECTION IGNITION TIMING °BTDC 23 LB RB
FUEL OIL SP F-10
LUBE OIL S L-21

AIR FLOW NOZZLE COEFFICIENT
LF /2283
LR

OPERATOR J. POPPENK
ENGINEER R. KAISER
WITNESS —

DATE 9-11-75
LOG NO 1 A
SHEET 2

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 B

CUSTOMER LILCO — MODEL DSR-48 — TYPE SERVICE NUC, STANDBY — JOB NO 2604 — ENGINE NO. 74010 — DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) CW

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1											563				624	621	631	627	605	618	632	642													
2											712				739	748	746	730	750	734	747	744													
3											765				847	837	816	801	829	817	827	806													
4											816				950	942	910	887	920	906	928	890													
5											817				951	941	913	889	920	908	929	893													
6											865				1028	1016	981	964	987	980	987	962													
7																																			
8																																			
9																																			
10																																			

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	FIRING PRESSURES - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	17.0	154	161	157				102		109		600	600	605	600	615	590	600	610													
2	17.0	152	165	158				106		180		760	770	800	770	800	800	800	800 *													
3	17.0	146	162	183				104		214		1180	1200	1200	1140	1180	1200	1160	1200 *													
4	17.0	147	168	158				105		224		1400	1340	1390	1405	1410	1410	1395	1390 *													
5	16.5	142	163	152				106		215		1610	1600	1590	1570	1590	1580	1570	1600													
6	17.0	146	170	157				107		209		1700	1690	1690	1680	1680	1680	1690	1690													
7																																
8																																
9																																
10																																

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS (In H2O)
1	76.5	55.0		29.0				167	166					-1.9
2	76.	57		29.0				167	170					-1.8
3	76	57		28				155	172					-1.3
4	76	65		27				155	176					-0.5
5	76	54.5		26.5				165	175					-0.5
6	75	55		26				155	177					-0.2
7														
8														
9														
10														

REMARKS

* FIRING PRESSURES LOW DUE TO FAULTY INDICATOR.

LEGEND: L, LB - LEFT BANK; R, RB - RIGHT BANK; F - ENGINE FRONT AT NO. 1 CYLINDER; R - ENGINE REAR FLYWHEEL END; (CW) - VIEWED FROM FLYWHEEL END

TURBOCHARGER MAKE & MODEL: ELBC090

OPERATOR J. POPPENK — DATE 9-11-75

ENGINEER R. KAILER — LOG 1 B

WITNESS — — JOB NO 4

- Nuclear Testisland -

DELAVAL

EN COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — A

CUST. L.I.L.C.O MODEL DSR-48 TEST STAND Nuck JOB NO 2606 ENGINE NO 74012 FULL LOAD RATING 3500 KW BHP 4880 RPM 450 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD	DYNAMOMETER LOAD DATA RPM	SCALE (lb)	BHP (Corr)	BMEP	A.C. GENERATOR LOAD DATA DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT
1	4/2	1407	1425	0	300									0		0	0	
2	4/2	1535	1600		450							4160		1300		1805	84	
3	4/5	0900	1105		449							4160		2000		2791	121	
4	4/5	1195	1300	100%	450							4160		3500		4880	225	
5	4/6	1520	0900		450							4160		1500		2094	97	
6	4/7	1600	1900		450							4160		1500		2094	97	
7	4/8	1630	1200		450							4160		2000		2791	121	
8	4/8	1300	1600	100%	450							4160		3500		4880	225	
9	4/9	0745	1100		450							4160		2300		3210	148	
10	4/9	1410	1545	100%	450							4160		3500		4880	225	

FUEL PUMP RACK POSITION (MM) Water [illegible]

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	A 1R	B 2R	C 3R	D 4R	E 5R	F 6R	7R	8R	9R	10R [illegible]
1																				19.5
2																				
3	38																			20.9
4	1250	1250	1000								1250	1250	1000							21.3
5																				23.6
6																				
7																				24.6
8																				27.5
9																				29.6
10	37.5										1000	1000	1500							29.9

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE / AMBIENT

LINE	BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in Hg) LF	RF	LR	RR	AIR MANIF P LB	RB	TURBINE INLET (in Hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	BARO (Corr) in Hg	AIR (°F)
1																																							
2																																							
3																																							
4									510																		144											29.40	
5																																							
6																																							
7																																							
8																																							
9																																							
10									510																		144											29.87	

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF (psig)	API GRAVITY AS READ @ °F	API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	MANIF (psig or in Hg)	LHV Btu/ft³	TO GAS METER Press (in) in Hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr
1																					
2																					
3																					
4	320																				
5																					
6																					
7																					
8																					
9																					
10	[illegible]																				

REMARKS

1. Start unit for 15min. run. Then
2. shut down for Heat check. OK. W
3. Run unit with 1300KW load to check
4. electrical switch gear.

10. Run unit at 100% for heat balance [illegible]

INJECTION IGNITION TIMING °BTDC ______ LB ______ RB ______

FUEL OIL SPEC

LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT LF ______ RF ______ LR ______ RR ______ (FLYWHEEL END)

OPERATOR D Cline

ENGINEER

WITNESS

DATE 4/2/78

LOG NO 1 A

JOB NO 2606

- Ducker Teststand -

DELAVAL

ET ... COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG 1 B

CUS. L.I.L.C.O. MODEL DSR-48 TYPE SERVICE Standby JOB NO 2606 ENGINE NO 74012 DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) L

EXHAUST TEMPERATURES - °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR
1														
2														
3														
4											735			
5														
6														
7														
8														
9														
10											750			

LINE	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2																					
3																					
4	825		860	860	810	840	855	820	735												
5																					
6																					
7																					
8																					
9																					
10	850	845	860	840	810	870	860	835													

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1											
2											
3											
4	24.0	155	168					70.0		69.0	
5											
6											
7											
8											
9											
10	23.5	162	173					72.0		86.0	

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2																					
3																					
4	1590	1600	1590	1620	1620	1560	1600	1570													
5																					
6																					
7																					
8																					
9																					
10																					

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in H2O	REMARKS
1															
2															
3															
4	5	57.0		25.5				161	180						
5															
6															
7															
8															
9															
10		56.5		35.0				169	171						

LEGEND: L, LB LEFT BANK; R, RB RIGHT BANK; F ENGINE FRONT AT NO. 1 CYLINDER; R ENGINE REAR, FLYWHEEL END (WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL: LF ____ RF ____ LR ____ RR ____ (BB - Brown Boveri, DE - Delaval, EI - Elliott)

OPERATOR ____ DATE ____
ENGINEER ____ LOG 1 B
WITNESS ____ JOB NO ____

- Nuclear Teststand -

DELAVAL

COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 2 A

CUSTOMER L.I.L.C.O. — MODEL DSR 48 — TEST STAND Nuch... — JOB NO 2606 — ENGINE NO 74012 — FULL LOAD RATING 3500 KW BHP @ 450 RPM 225 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	THIS LOG	% LOAD	DYNAMOMETER RPM	SCALE (lb)	BHP (Corr)	BMEP	DISC REVS	TIME (sec)	POWER FACTOR	AC VOLTS	AC AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R Accel Meter
1	1/9	1745	1645	100	450							4160		3500		4880	225		375										1200	1200	1150							32.0
2	1/12	846																																				33.4
3																																						
4																																						
5																																						
6																																						
7																																						
8																																						
9																																						
10																																						

FUEL PUMP RACK POSITION (MM) Readings KW

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE / AMBIENT

LINE	BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR MANIF (in hg) LB	RB	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE ΔH (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	BARO (Corr) in hg	AIR (°F)
1									520																		145												
2																																							
3																																							
4																																							
5																																							
6																																							
7																																							
8																																							
9																																							
10																																							

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF (psig)	API GRAVITY AS READ (°F)	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	MANIF (psig or in hg)	LHV Btu/ft³	TO GAS METER psig (or) in hg	Tg	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1	38.0																					
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						

INJECTION/IGNITION TIMING °BTDC ______ LB ______ RB
FUEL OIL SPEC
LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT
LF ______ RF ______
LR ______ RR ______
(FLYWHEEL END)

OPERATOR D. [illegible]
ENGINEER
WITNESS

DATE 4/12/76
LOG NO 2 A
JOB NO 2606

DELAVAL

EN — COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG 2 B

CUS. L. I. L. C. O. — MODEL DSR-48 — TYPE SERVICE Standby — JOB NO 2606 — ENGINE NO 74012 — DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) ✓

EXHAUST TEMPERATURES - °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR
1											750			
2														
3														
4														
5														
6														
7														
8														
9														
10														

LINE	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	850	845	879	810	810	810	860	835													
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE [°F]	FROM ENGINE [°F]	TURBOCHARGER WATER OUTLET [°F] LF	RF	LR	RR	AFTERCOOLER WATER INLET [°F] F	R	OUTLET [°F] F	R
1	10.5	175	175								
2											
3											
4											
5											
6											
7											
8											
9											
10											

LINE	FIRING PRESSURES - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	LUBRICATING OIL PRESSURE PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " H_2O	REMARKS
1		55.0		21.0				162	180						
2															
3															
4															
5															
6															
7															
8															
9															
10															

LEGEND: L, LB LEFT BANK; F ENGINE FRONT ATTD. 1 CYLINDER; R, RB RIGHT BANK; R ENGINE REAR, FLYWHEEL END (WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF ______ RF ______
LR ______ RR ______
BB Brown Boveri DE Delaval EI Elliott

OPERATOR D Cline
ENGINEER
WITNESS

DATE 4/12/78
LOG 2 B
JOB NO 2606

— MAXIMUM LOAD TEST —

DELAVAL ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 3 A

CUSTOMER LILCO MODEL DSR-48 TEST STAND No. 4R JOB NO 2606 ENGINE NO 74012 FULL LOAD RATING 3500 KW RPM 450 · 225 BMEP

LINE	DATE	WALL CLOCK TIME: DY LOAD	WALL CLOCK TIME: THIS LOG	% LOAD (Nom)	DYNAMOMETER LOAD DATA: RPM	SCALE (lb)	BHP (Corr)	BMEP	A C GENERATOR LOAD DATA: DISC REVS	TIME (sec)	POWER FACTOR	A C VOLTS	A C AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT
1	4/12	16-00		115	450							4160	540	3117		4498	253	
2																5368	248	
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (MM) Rheostats KEE? Hour Meter

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	430										1600	1600	900							357
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

— END OF MAXIMUM LOAD TEST —

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in. H_2O) LF	RF	LR	RR	BLOWER DISCHARGE (in. hg) LF	RF	LR	RR	AIR MANIF (in hg) LR	RR	TURBINE INLET (in. hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H_2O) LF	RF	LR	RR
1									62									
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE / AMBIENT

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LR	RR	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE ΔP (in. H_2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	BARO (Corr) in hg	AIR (°F)
1									145											29.87	77
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF TEMP	API GRAVITY AS READ @ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	MANIF (psig or in hg)	LHV Btu/ft³	TO GAS METER psig (or) in hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1	355																					
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						

INJECTION IGNITION TIMING °BTDC ______ LB ______ RB
FUEL OIL SPEC
LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT
LF ______ RF ______
LR ______ RR ______
(FLYWHEEL END)

OPERATOR [illegible signature]
ENGINEER [illegible signature]
WITNESS [illegible signature]

DATE 4-12-76
LOG NO 3 A
JOB NO 2606

DELAVAL

AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

CUSTOMER LILCO MODEL DSR-48 TYPE SERVICE GEN. JOB NO 2606 ENGINE NO 74012

POWER ENGINE FACTORY TEST LOG LOG 3 B

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END)

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET LTTL	LFTR	LTB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR
1											805			
2														
3														
4														
5														
6														
7														
8														
9														
10														

EXHAUST ELBOWS

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	839	835	858	827	850																
2	939	935	938	929	950	946	940	910													
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER Raw water PSI	IN	OUT	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1	23	165	174	13	75	90					
2											
3											
4											
5											
6											
7											
8											
9											
10											

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	1660	1720	1720	1760	1760	1700	1720	1730													
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

LINE	LUBRICATING OIL PRESSURE PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS	REMARKS
1		55.5		27.5				163	180						
2															
3															
4															
5															
6															
7															
8															
9															
10															

LEGEND L LB LEFT BANK F ENGINE FRONT AT NO 1 CYLINDER
R RB RIGHT BANK R ENGINE REAR, FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF ______ RF ______
LR ______ RR ______

OPERATOR [illegible] DATE 4-12-76
ENGINEER [illegible] LOG 3 B
WITNESS JOB NO 2606

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG 1 — A

CUSTOMER LILCO — MODEL DSR-48 — TEST STAND 23 — JOB NO. 2606 — ENGINE NO. 74012 — FULL LOAD RATING 4880 BHP @ 450 RPM 225 BMEP

	LINE	DATE	WALL CLOCK TIME ON LOAD	THIS LOG	LOAD (Nom.)	DYNA RPM	SCALE (lb)	BHP (Corr.)	BMEP	DISC REVS	TIME (sec)	POWER FACTOR	AC VOLTS	AC AMPS	KW	GEN EFF	BHP (Corr.)	BMEP	GOV LOAD LIMIT	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
	1	3/17	1700	1715	–	185						Start For 15 Min								ok																			
	2	3/18	1315	1415	25	220	14156	593	56										20½	18	18.3	18.2	18	18	18.3	18	18												
	3	3/18	1415	1435	–	185	0	0	0			Cold Compression																											
	4	3/18	2145	2245	25	360	14166	701	56											18.0	18.0	18.0	18.5	18.5	18.0	18.0	18.0												
	5	3/18	2245	2345	25	360	14166	971	56											18.0	18.0	18.0	18.5	18.5	18.0	18.0	18.0												
	6	3/19	0315	0415	50	390	29558	2103	112											25.0	25.0	24.5	25.0	25.0	25.0	25.0	25.0												
2	7	3/19	0415	0515	50	450	29688	2458	113											26.0	25.0	25.0	24.0	25.0	25.0	26.0	25.0												
3	8	3/19	1530	1630	75	450	42763	3664	169										45½	29	29	29.3	29.3	29	29.2	29	29												
4	9	3/19	1630	1730	100	450	56256	4880	225											38.0	38.0	38.0	38.5	38.5	38.0	38.0	38.0												
5	10	3/19	1730	1830	100	450	56255	4880	225											38.0	38.0	38.0	38.5	38.5	38.0	38.0	38.0												

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES

LINE	BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR MANIF (in hg) LB	RB	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE ΔP (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr.) in hg	AIR (°F)
1																																							
2					1.1				1.0										66				75				75											29.95	
3																																							
4	2.9				1.8				1.8										77	71			81				83											30.06	71
5	5.5				1.2				1.1										71				96				100											30.06	71
6	13.2				14.3				14.1										71				146				152											30.12	71
7	17.3				19.6				19.0										70				170				172							10.3					30.12	70
8	19.5				32.2				31.6										63				227				162							10.7					30.12	67
9	33.4				52.1				52.3										67				278				167							12.6					30.14	67
10	33.6				52.7				52.3										67				277				165							12.7					30.14	67

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF (psig)	API GRAVITY AS READ	@ °F	API Corrected To 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr.) lb/bhp hr	MANIF (psig or in hg)	LHV Btu/ft³	TO GAS METER psig (or) in hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr.)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1																							
2																							
3																							1 hr. insp. All ok.
4	35																						2115 Start unit up for warm up
5	35																						Shut down to fix Air Leaks
6	32	36.4	78	34.6	18180	540	2727	752.4		.361													0530 Shut Down to Fix intake elbows
7	33.5	36.6	80	34.6	18380	720	2918	888.2		.365													Leaking Air
8	32.5	36.0	76	34.9	18387	1070	2976	1294		.357													1450 Start
9	31.0	36.2	77	35.0	18387	1280	2587	1780		.369													
10	40	36.2	77	35.0	18387	1350	2721	1786		.370													

INJECTION/IGNITION TIMING °BTDC 23° LB ___ RB ___

FUEL OIL SPEC ___

LUBE OIL SPEC ___

Form D-4173 (R-5)

AIR FLOW NOZZLE COEFFICIENT LF ___ RF ___ LR ___ RR ___ (FLYWHEEL)

OPERATOR #4-15 G Fleming #8-10 G Fleming — DATE 3-17-74

ENGINEER ___ LOG NO. ___

WITNESS ___ JOB NO. 2606

A

DELAVAL

ETP — COMPRESSOR DIVISION OAKLAND CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG — B

CUST LILCO — MODEL DSR-48 — TYPE SERVICE Stationary — JOB NO 2606 — ENGINE NO 74012 — DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) /

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																																			
2											431				456	422	471	464	461	477	466	431													
3																																			
4											461				180	444	189	185	170	507	489	458													
5											521				555	510	557	562	551	597	567	546													
6											712				746	664	717	729	733	780	765	712													
7											747				787	712	780	782	766	832	795	753													
8											752				830	749	810	830	830	851	823	790													
9											825				930	942	952	953	955	945	943	932													
10											826				936	950	951	933	955	950	951	940													

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	FIRING PRESSURES - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	14																															
2	12.5	121	124	124				65	66			625	625	625	615	645	625	615	625													
3																																
4	16	145	147	148				67	67			600	600	600	610	610	610	610	600													
5	24	156	160	159				67	68			600	600	600	620	620	620	620	620													
6	26.8	153	161	159				68	69			820	820	830	830	840	830	820	840													
7	22.0	155	163	161				82	101			820	820	820	830	840	840	830	840													
8	30	154	163	161				122	139			1210	1220	1200	1265	1215	1205	1240	1245													
9	31.5	155	167	164				162	194			1650	1640	1620	1700	1680	1630	1820	1640													
10	31.5	155	168	165				158	190			1650	1640	1620	1700	1680	1630	1620	1640													

LINE	LUBRICATING OIL PRESSURE PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS IN H2O	REMARKS
1															
2		50		28				111	112					.2	
3															
4		50.5		28				126	130					.2	
5		55		29				147	151					.2	
6		54.5		27.2				157	167					.9	
7		55		27.0				157	170					.7	
8		55		25				158	171					.7	
9		55		24				157	177					0	
10		55		24				157	177					0	

LEGEND L, LB LEFT BANK F ENGINE FRONT AT NO. 1 CYLINDER
R, RB RIGHT BANK R ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF ____ RF ____
LR ____ RR ____

OPERATOR #4+5 [illegible] #8-10 [illegible] — DATE 3-17-76
ENGINEER — LOG 1 — B
WITNESS — JOB NO 2606

DELAVAL

EF — COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG A

CUS. — L.L.CO — MODEL DBR-48 — TEST STAND 2. — JOB NO 2606 — ENGINE NO 71012 — FULL LOAD RATING 4880 — RPM 450 RP. — 25 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD	DYNAMOMETER RPM	SCALE	BHP (Corr)	BMEP	DISC REVS	TIME	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	3/17	1850	1935	25	450	1415.1	1215	55											18.0	18.0	18.0	18.5	18.5	18.0	18.0	18.0												
2	3/18	2000	2100	110	450	6265	5368	248											42.0	42.0	42.0	42.5	42.5	42.0	42.0	42.0												
3																																						
4																																						
5																																						
6																																						
7																																						
8																																						
9																																						
10																																						

LINE	BLOWER INLET LF	BLOWER INLET RF	BLOWER INLET LR	BLOWER INLET RR	BLOWER DISCHARGE LF	BLOWER DISCHARGE RF	BLOWER DISCHARGE LR	BLOWER DISCHARGE RR	AIR MANIF LB	AIR MANIF RB	TURBINE INLET LF	TURBINE INLET RF	TURBINE INLET LR	TURBINE INLET RR	TURBINE EXHAUST LF	TURBINE EXHAUST RF	TURBINE EXHAUST LR	TURBINE EXHAUST RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE LF	RF	LR	RR	AIR FLOW SCFM TOTAL	BARO (Corr) in hg	AIR (°F)
1	5.5				8.6				8.4										65				118				126						29						65
2	328				601				598										64				329				167						206						64
3																																							
4																																							
5																																							
6																																							
7																																							
8																																							
9																																							
10																																							

LINE	MANIF	API GRAVITY AS READ	@ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	MANIF	LHV Btu/ft³	TO GAS METER press in hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1	345	36.0	76	35.4	18377	350	2644	477		.377													
2	320	36.0	75	35.2	18575	1460	2615	2010		.379													
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							

INJECTION IGNITION TIMING °BTDC 23° LB ____ RB ____
FUEL OIL SPEC
LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT
LF ____ RF ____
LR ____ RR ____
(FLYWHEEL END)

OPERATOR [signature]
ENGINEER
WITNESS

DATE 3-17-76
LOG NO 2 A
JOB NO 2606

COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG — B

CUSTOMER Lilco MODEL DSR-48 TYPE SERVICE Stationary JOB NO 2606 ENGINE NO 74012

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END)

EXHAUST TEMPERATURES °F

LINE	Turbine Inlet LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	Turbine Exhaust LF	RF	LR	RR	Exhaust Elbows 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1											578				571	672	659	574	622	616	683	672													
2											869				997	1009	1025	985	1017	1008	1001	983													
3																																			
4																																			
5																																			
6																																			
7																																			
8																																			
9																																			
10																																			

LINE	Engine Water PSIG to Engine	To Engine (°F)	From Engine (°F)	Turbocharger Water Outlet (°F) LF	RF	LR	RR	Aftercooler Water Inlet (°F) F	R	Outlet (°F) F	R	Firing Pressures PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	32	151	135	157				144	139			600	680	600	620	640	620	650	650													
2	32	154	168	165				157	198			1700	1220	1700	1800	1740	1700	1700	1660													
3																																
4																																
5																																
6																																
7																																
8																																
9																																
10																																

LINE	Lubricating Oil Pressure PSIG From Pump	To Engine	Cam Header	To Turbocharger LF	RF	LR	RR	Lubricating Oil Temperature °F To Engine	From Engine	Turbocharger Drain LF	RF	LR	RR	Crank Case Press In H_2O	Remarks
1		55		28				157	167					-1.6	
2		55		215				157	178					-.3	
3															
4															
5															
6															
7															
8															
9															
10															

LEGEND: L LB LEFT BANK F ENGINE FRONT AT NO 1 CYLINDER
R RB RIGHT BANK R ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF ____ RF ____
LR ____ RR ____

OPERATOR G. Lewing
ENGINEER
WITNESS

DATE 3-19-76
LOG 2 B
JOB NO 2606

NO COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

CUSTOMER LILCO MODEL DSR-48 TEST STAND 2. JOB NO 2606 ENGINE NO 74012 FULL LOAD RATING 4880 BHP @ 450 RPM .25 BMEP LOG 1 A

LINE	DATE	WALL CLOCK TIME: ON LOAD	WALL CLOCK TIME: THIS LOG	% LOAD	DYNAMOMETER LOAD DATA: RPM	SCALE	BHP (Corr)	BMEP	AC GEN: DISC REVS	TIME	POWER FACTOR	AC VOLTS	AC AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT
1	3/19	1850	1950	25	450	14157	1213	56										
2	3/19	0415	0515	50	450	28688	2458	113										
3	3/19	1530	1630	75	450	42763	3664	169										
4	3/19	1630	1730	100	450	56155	4880	225										
5	3/19	1730	1830	100	450	56155	4880	225										
6	3/19	2000	2100	110	450	62650	5368	248										

FUEL PUMP RACK POSITION (MM)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	18.0	18.0	18.0	18.5	18.5	18.0	18.0	18.0												
2	26.0	25.0	25.0	26.0	25.0	25.0	26.0	25.0												
3	29.0	29.0	29.3	29.3	29.0	29.7	29.0	29.0												
4	38.0	38.0	38.0	38.5	38.5	38.0	38.0	38.0												
5	38.0	38.0	38.0	38.5	38.5	38.0	38.0	38.0												
6	42.0	42.0	42.0	42.5	42.5	42.0	42.0	42.0												

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in H_2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR INLET (in hg) LB	RB	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H_2O) LF	RF	LR	RR
1	5.5				8.6				8.4									
2	17.3				19.6				19.0									
3	19.5				32.2				31.6									
4	33.4				52.7				52.3									
5	33.6				52.7				52.3									
6	39.8				60.1				58.8									

TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE ► 12"

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in H_2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr) in hg	AIR (°F)
1	65				118				126						2.9				5012	30.14	65
2	70				170				172						10.3				9397	30.12	70
3	63				229				162						10.9				9695	30.12	67
4	67				298				167						12.6				12323	30.14	67
5	67				299				165						12.7				12358	30.14	67
6	64				329				167						20.6				13370	30.14	64

FUEL OIL DATA / DIESEL BSFC

LINE	WEIGHT (oz/gl)	API GRAVITY AS READ	°F	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp-hr	(Corr) lb/bhp-hr
1	34.5	36.0	76	35.4	18317	350	2644	477		.397
2	33.5	36.6	80	34.6	18380	720	2918	888		.365
3	32.5	36.0	76	34.9	18381	1070	2976	1294		.357
4	31.0	36.2	77	35.0	18381	1280	2589	1780		.369
5	31.0	36.2	77	35.0	18389	1350	2721	1786		.370
6	300	36.0	75	35.2	18395	1460	2615	2010		.379

FUEL GAS DATA (BARO, LHV, TO GAS METER: PRESS, °F, CORR FACTOR) / GAS BSFC (ft^3 MEAS, TIME, ft^3/hr (Corr), Btu/bhp-hr) / DUAL FUEL BSFC (PILOT, GAS, TOTAL Btu/bhp-hr) / REMARKS — no entries.

INJECTION/IGNITION TIMING °BTDC 23° LB RB

FUEL OIL SPEC F-10

LUBE OIL SPEC L-21

AIR FLOW NOZZLE COEFFICIENT LF 12283 RF LR RR (FLYWHEEL END)

OPERATOR LEVERING
ENGINEER D. REID
WITNESS —

DATE 3-19-76
LOG NO 1 A
JOB NO 2606

DELAVAL

DE LAVAL COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG — LOG B

CUS. LILCO — MODEL DSR-48 — TYPE SERVICE STATIONARY — JOB NO. 2606 — ENGINE NO. 74012 — DIRECTION OF ROTATION

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1											578				571	672	659	594	622	616	683	672													
2											737				787	712	780	782	816	832	795	753													
3											752				830	749	810	830	830	853	823	790													
4											825				930	942	952	953	955	945	943	932													
5											826				936	950	951	933	955	950	951	940													
6											869				997	1009	1025	985	1017	1008	1001	983													
7																																			
8																																			
9																																			
10																																			

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	FIRING PRESSURES - PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	32	151	155	154				144	139			600	680	600	620	640	620	650	650													
2	27	155	163	161				87	101			820	820	820	830	840	840	830	840													
3	30	154	163	161				122	139			1210	1220	1200	1255	1245	1205	1240	1245													
4	31.5	155	167	164				162	194			1650	1640	1620	1700	1680	1630	1620	1640													
5	31.5	155	168	165				158	190			1650	1640	1620	1700	1680	1630	1620	1640													
6	32	154	168	165				157	198			1700	1720	1700	1800	1790	1700	1700	1660													
7																																
8																																
9																																
10																																

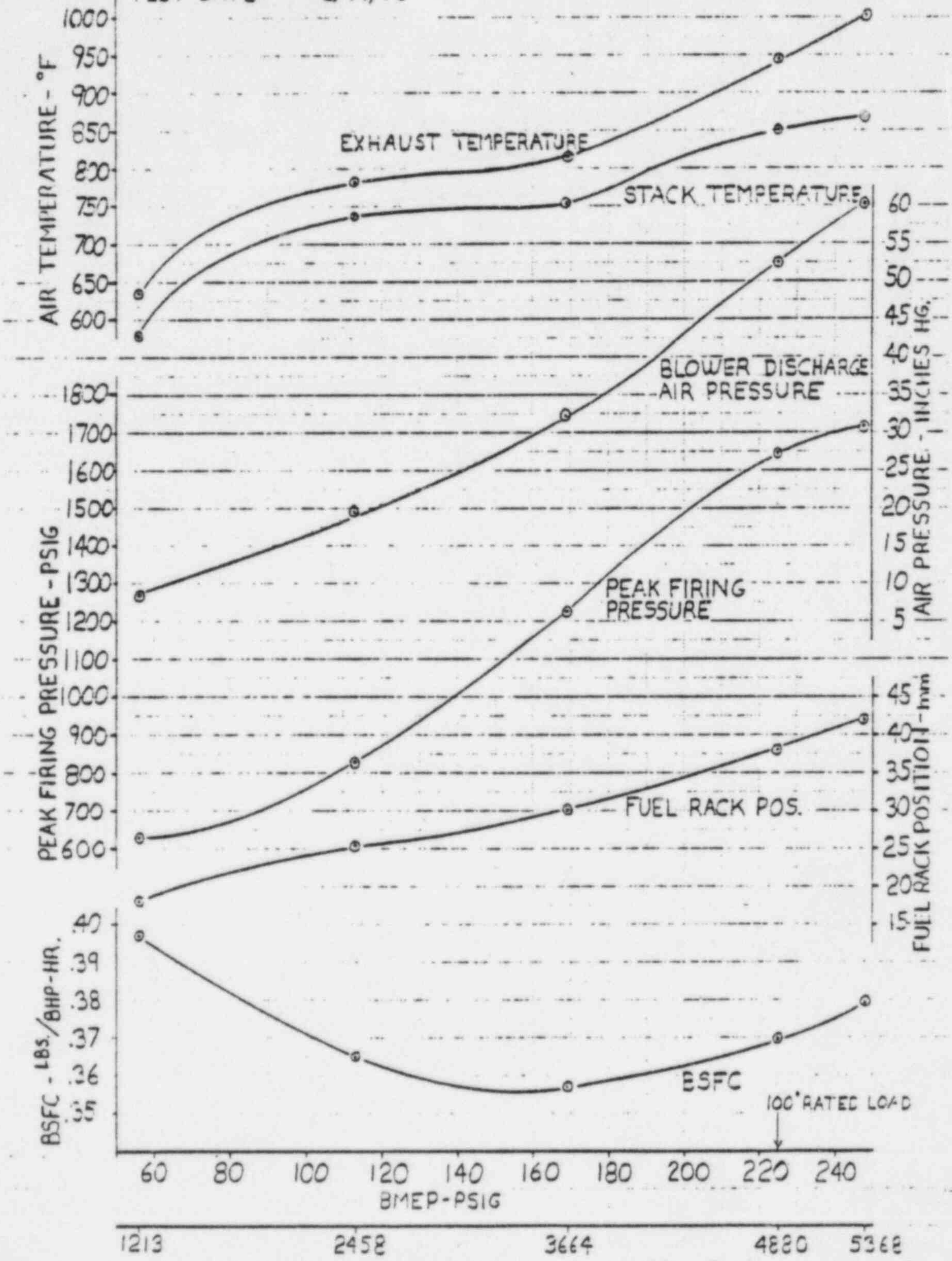
LINE	LUBRICATING OIL PRESSURE PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS. " H_2O	REMARKS
1		55		28				157	167					-1.6	
2		55		27				157	170					-.7	
3		55		25				158	171					-.7	
4		55		24				157	177					0	
5		55		24				157	177					0	
6		55		23.5				157	178					+.3	
7															
8															
9															
10															

LEGEND: L LB LEFT BANK F - ENGINE FRONT AT NO. 1 CYLINDER
R RB RIGHT BANK R - ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

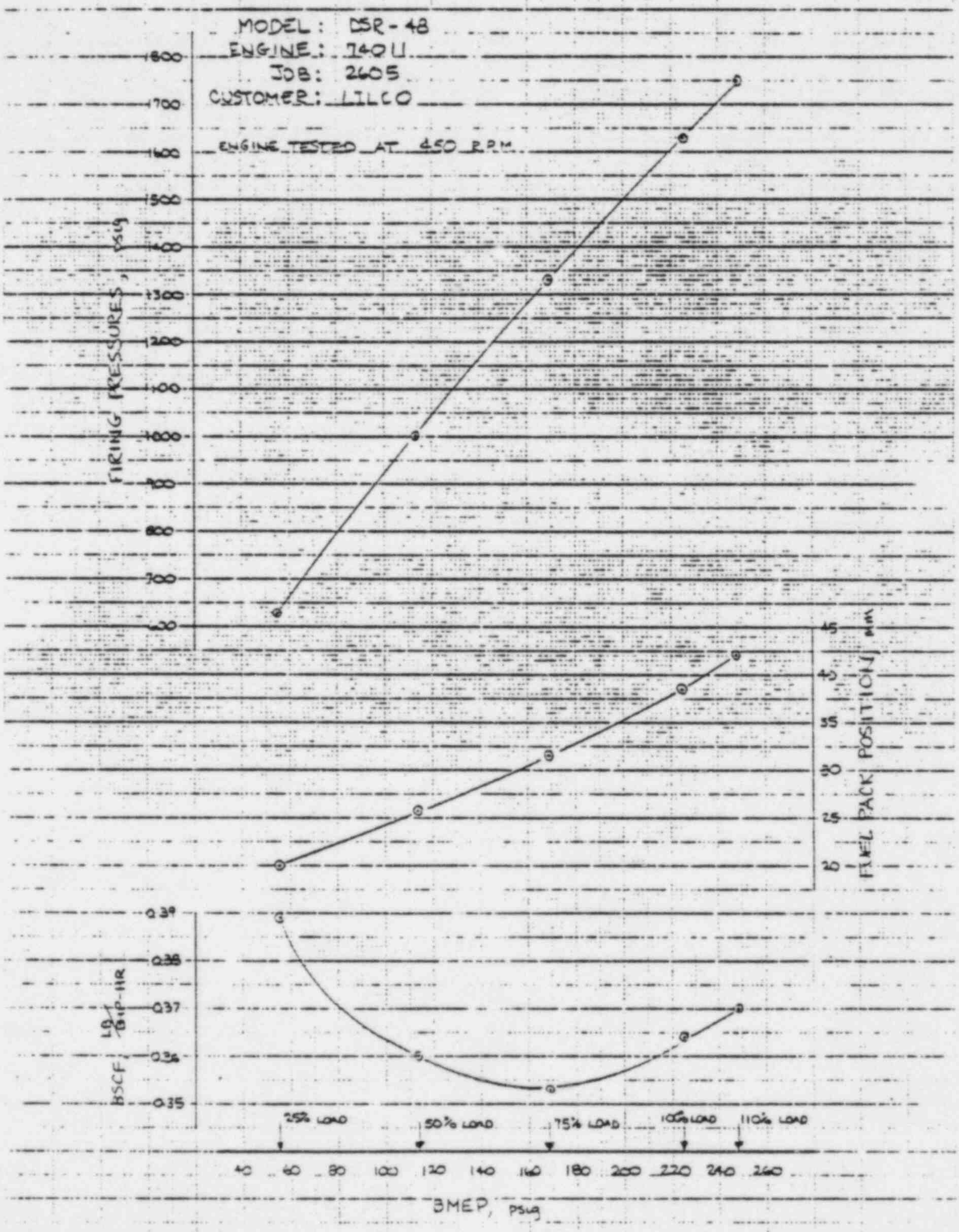
TURBOCHARGER MAKE & MODEL
LF EL BC090 RF
LR RR

OPERATOR LEVERING — DATE 3-19-76
ENGINEER D. REID — LOG 1 B
WITNESS — — JOB NO. 2606

CUSTOMER: LILCO
ENGINE MODEL: DSR-48
ENGINE NO.: 74012
JOB NO.: 2606
RATED RPM/BHP: 450/4890
TEST DATE: 3/19/76



D. FEID 5/27/76


MODEL: DSR-48
ENGINE: 74011
JOB: 2605
CUSTOMER: LILCO
ENGINE TESTED AT 450 R.P.M.
FIRING PRESSURES, psig
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
FUEL PACK POSITION, mm
45
40
35
30
25
20
BSCF, LB/BHP-HR
0.39
0.38
0.37
0.36
0.35
25% LOAD
50% LOAD
75% LOAD
100% LOAD
110% LOAD
40
60
80
100
120
140
160
180
200
220
240
260
BMEP, psig

DELAVAL — COMPRESSOR DIVISION, OAKLAND CALIFORNIA

CUSTOMER: LILCO — MODEL DSR-48 — TYPE SERVICE NUC. STBY. — JOB NO. 2605 — ENGINE NO. 74011

POWER ENGINE FACTORY TEST LOG — LOG 1 B

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END): ~

Exhaust Temperatures °F

Line	Turbine Exhaust LF	1L	2L	3L	4L	5L	6L	7L	8L	AVG
1	622	675	677	648	673	634	647	656	654	658
2	727	775	801	751	715	758	795	753	759	763
3	779	850	854	831	852	856	832	857	875	851
4	813	959	944	925	933	919	920	930	939	934
5	814	956	943	920	935	912	914	927	936	930
6	853	1017	1001	979	981	971	964	984	981	985
7										
8										
9										
10										

Engine Water / Turbocharger Water / Firing Pressures - PSIG

Line	Engine Water PSIG to Engine	To Engine (°F)	From Engine (°F)	Turbocharger Water Outlet LF (°F)	1L	2L	3L	4L	5L	6L	7L	8L	AVG
1	31	154	158	157	620	620	620	640	620	640	630	640	629
2	29	153	161	158	1000	1020	980	1000	980	1020	1000	1020	1003
3	29	154	164	151	1320	1330	1300	1340	1330	1350	1340	1320	1329
4	31	153	166	162	1620	1620	1600	1640	1630	1630	1640	1640	1628
5	31	154	166	162	1620	1620	1600	1650	1630	1640	1640	1650	1631
6	31.5	154	168	163	1700	1690	1700	1750	1710	1730	1740	1750	1721
7													
8													
9													
10													

Lubricating Oil Pressure PSIG / Lubricating Oil Temperature °F

Line	From Pump	To Engine	Cam Header	To Turbocharger LF	RF	LR	RR	Temp To Engine	From Engine	Turbocharger Drain LF	RF	LR	RR	Crank Case Press (" H2O)	Remarks
1	60	55		29.5				157	167					-1.2	
2		55		29				157	170					-0.9	
3		55		28				156	173					-0.5	
4		55		26.5				156	176					-0.1	
5		55		26.5				156	176					-0.1	
6	60	55		26				156	177					-0.2	
7															
8															
9															
10															

LEGEND: L LB LEFT BANK; R RB RIGHT BANK; F ENGINE FRONT AT NO. 1 CYLINDER; R ENGINE REAR FLYWHEEL END (WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL: LF EL BC090; RF; LR; RR — BB Brown Boveri; DL Delaval; EL Elliott

OPERATOR: Kapperman
ENGINEER: R. Kaisel
WITNESS: –

DATE: 1-24-76
LOG: 1 B
JOB NO: 2605

RK 12776

DELAVAL

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG

CUSTOMER LILCO MODEL DSR-48 TEST STAND 2 JOB NO 2605 ENGINE NO 74011 LOG 1 A

FULL LOAD RATING 4880 BHP @ 450 R 225 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD	DYNAMOMETER LOAD DATA RPM	SCALE (lbs)	BHP (Corr)	BMEP	A.C. GENERATOR LOAD DATA DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT
1	1/24	1605	1705	25	450	14157	1213	56										
2	1/24	0845	0945	50	450	28688	2458	113										
3	1/24	1015	1115	75	450	42763	3664	169										
4	1/24	1245	1345	100	450	56995	4880	225										
5	1/24	1345	1445	100	450	56995	4880	225										
6	1/24	1705	1805	110	450	62650	5368	248										
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (MM)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0												
2	25.5	25.0	25.8	25.8	25.5	25.5	25.7	25.5												
3	31.0	31.0	31.7	31.6	31.5	31.6	31.5	31.5												
4	38.0	38.2	38.6	38.7	38.5	38.2	38.5	38.5												
5	38.5	38.5	38.7	38.6	38.5	38.3	38.5	38.5												
6	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0												
7																				
8																				
9																				
10																				

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in. H₂O) LF	RF	LR	RR	BLOWER DISCHARGE (in. hg) LF	RF	LR	RR	AIR MANIF (in. hg) LB	RB	TURBINE INLET (in. hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H₂O) LF	RF	LR	RR
1	4.7				8.1				8.1									
2	10.4				20.4				20.2									
3	18.2				32.9				32.7									
4	30.9				50.3				50.0									
5	30.1				50.2				49.9									
6	36.0				56.9				56.6									
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE ► 12"

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in. H₂O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	AMBIENT BARO (Corr) in hg	AIR (°F)
1	66				122				134						2.9				4992	29.96	66
2	67				185				180						6.4				7416	30.02	67
3	66				243				163						11.2				9820	30.02	66
4	62				314				164		16500				19.1				12865	29.98	62
5	62				314				164		16500				18.4				12623	29.96	62
6	67				352				163						22.0				13741	29.98	67
7																					
8																					
9																					
10																					

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF level	API GRAVITY AS READ	@ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	MANIF (psig or in hg)	LHV Btu/ft³	TO GAS METER press (psi) or in hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1	39	36.6	76	35.4	18390	314	2423	467		.389													
2	38	36.4	75	35.4	18390	774	3186	875		.360													
3	37	36.5	76	35.4	18390	1080	3043	1278		.353													
4	36	36.5	76	35.4	18390	1510	3090	1759		.364													
5	36	36.4	75	35.4	18390	1510	3104	1751		.363													
6	35	36.6	76	35.4	18390	1480	2715	1962		.370													
7																							
8																							
9																							
10																							

INJECTION IGNITION TIMING °BTDC 23 LB RB
FUEL OIL SPEC F-10
LUBE OIL SPEC L-21

AIR FLOW NOZZLE COEFFICIENT
LF 12283 RF
LR RR
(FLYWHEEL END)

OPERATOR KAPPERMAN
ENGINEER R. KAISER
WITNESS –

DATE 1-24-76
LOG NO 1 A
JOB NO 2605

RK 12776

DELAVAL — ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA — POWER ENGINE FACTORY TEST LOG

Customer: LILCO | Model: DSR-48 | Test Stand: 2 | Job No. 2605 | Engine No. 74011 | Full Load Rating: 4880 BHP @ 450 RPM, 225 BMEP | Log 1 | A

2
3
4
5

Line	Date	Wall Clock Time On Load	This Log	% Load (Nom.)	Dynamometer RPM	Scale (lb-in)	BHP (Corr)	BMEP	Disc Revs	Time (sec)	Power Factor	AC Volts	AC Amps	KW	Gen Eff	BHP (Corr)	BMEP	Gov Load Limit	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	Line
1	23 1/22	0705	0720			15	Min	Heat	Check																														1
2		0910	1010	25	220	14156	593	56										20%	18.5																				2
3	1/23	1830	1930	25	260	14160	701	56											18.5																				3
4	1/23	1930	2030	25	360	14166	971	56											18.5																				4
5	1/24	0715	0815	50	310	28558	2103	112											25.0																				5
6	1/24	0845	0945	50	450	28666	2458	113											25.5	25.0	25.8	25.8	25.5	25.5	25.7	25.5													6
7	1/24	1015	1115	75	450	42163	3664	169											31.0	31.0	31.7	31.6	31.5	31.6	31.5	31.5													7
8	1/24	1245	1345	100	450	56955	4880	225											38.0	38.2	38.6	38.7	38.5	38.2	38.5	38.5													8
9	1/24	1345	1445	100	450	56955	4880	225											38.5	38.5	38.7	38.6	38.5	38.3	38.5	38.5													9
10	1/24	1450		25	450	14457	1213	56																															10

Air flow nozzle size ▶ 12

Line	Blower Inlet (in H2O) LF	RF	LR	RR	Blower Discharge (in Hg) LF	RF	LR	RR	Air Manif LB	RB	Turbine Inlet (in Hg) LF	RF	LR	RR	Turbine Exhaust (in H2O) LF	RF	LR	RR	Blower Inlet (°F) LF	RF	LR	RR	Blower Discharge (°F) LF	RF	LR	RR	Air Manif (°F) LB	RB	Turbocharger RPM LF	RF	LR	RR	Nozzle Δh (in H2O) LF	RF	LR	RR	Air Flow SCFM Total	Baro (Corr) in Hg	Air (°F)	Line
1																																								1
2	1.2				.9				.9										65				77				76						.8					29.95	65	2
3	2.0	1.3			2.0				1.9										66				86				86						.7					29.90	66	3
4	2.9				4.8				4.6										67				106				105						1.9					29.90	67	4
5	7.1				14.1				14.8										65				158				158						4.9					29.98	65	5
6	10.4				20.4				20.2										67				185				180						6.4					30.02	67	6
7	18.2				32.9				32.7										66				243				163						11.2					30.02	66	7
8	30.9				50.3				50.0										62				314				164		16500				19.1					29.98	62	8
9	30.1				50.7				49.9										62				314				164		16500				18.4					29.76	62	9
10	4.7				8.0				7.8										66				125				157						3.0					29.76	66	10

Line	Manif (in Hg)	API Gravity As Read	@ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS Meas	Time (sec)	Diesel BSFC lb/hr	Btu/bhp-hr	(Corr) lb/bhp-hr	Manif (in Hg)	LHV Btu/ft³	To Gas Meter Press (in Hg)	°F	Corr Factor	ft³ Meas	Time (sec)	ft³/hr (Corr)	Gas BSFC Btu/bhp-hr	Dual Fuel Pilot Btu/bhp-hr	Gas Btu/bhp-hr	Total Btu/bhp-hr	Line
1																							1
2																							2
3	48																						3
4	48																						4
5	41	36.4	75	35.3	18345	612	3220			.356													5
6	38	36.4	75	35.3	18355	774	3186			.357													6
7	37	36.5	76	35.4	18400	1080	3043			.352													7
8	36	36.5	76	35.4	18400	1570	3010			.361													8
9	36	36.4	75	35.3	18377	1510	3104			.362													9
10	31	36.4	25	35.3	18345																		10

REMARKS

0920 Start 1045 Stop
1815 START
2030 Shutdown (Fuel Leak)
2045 START 2045 (Shutdown)
ADJ O.S. & GOV
CHECK #5 VALVE ADJ.

STOP UNIT DUE TO #5 INT. ROCKER ARM

Injection/Ignition Timing °BTDC: LB 23 RB
Fuel Oil Spec: F-10
Lube Oil Spec: L-21

Air Flow Nozzle Coefficient LF 12283 RF — LR — RR (Flywheel End)

Operator: J.C. Poppen / LINES-10
Engineer:
Witness:

Date: 23 Jan 76 | Log No. 1 | Job No. 2605 | A

A

DELAVAL ENGINE & COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 1 B

CUSTOMER: LILCO — MODEL: DSR-48 — TYPE SERVICE: Gen — JOB NO: 2605 — ENGINE NO: 74011 — DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END): CW

EXHAUST TEMPERATURES - °F

	LINE	Turbine Inlet (T - Top, B - Bottom) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	Turbine Exhaust LF	RF	LR	RR	Exhaust Elbows 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
	1																																				1
	2															477	476	458	463	459	462	450	433														2
	3															481	460	472	466	466	471	461	460														3
	4											503				554	546	541	534	537	541	534	541													541	4
	5											690				720	699	682	685	688	703	692	695														5
2	6											727				775	801	751	715	758	795	753	759														6
3	7											779				850	854	831	852	856	832	857	875														7
4	8											813				959	944	925	935	919	920	930	939														8
5	9											814				956	943	920	935	912	914	927	936														9
	10											572				648	655	643	662	617	632	649	644														10

ENGINE WATER / TURBOCHARGER WATER / AFTERCOOLER WATER / FIRING PRESSURES - PSIG

LINE	Engine Water PSIG to Engine	To Engine (°F)	From Engine (°F)	Turbocharger Water Outlet (°F) LF	RF	LR	RR	Aftercooler Water Inlet (°F) F	R	Outlet (°F) F	R	Firing Pressures 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1																																	1
2	14	119	122	122																													2
3	14	152	153	152																													3
4	24	159	161	159																													4
5	26	155	162	161																													5
6	29	153	161	158								1000	1020	980	1000	980	1020	1000	1020														6
7	29	154	164	151								1320	1330	1300	1340	1330	1350	1340	1320														7
8	31	153	166	162								1620	1620	1600	1640	1630	1630	1640	1640														8
9	31	154	166	162								1620	1620	1600	1650	1630	1640	1640	1650														9
10	27.5	155	159	157																													10

LUBRICATING OIL

LINE	Lubricating Oil Pressure - PSIG From Pump	To Engine	Cam Header	To Turbocharger LF	RF	LR	RR	Lubricating Oil Temperature °F To Engine	From Engine	Turbocharger Drain LF	RF	LR	RR	Crank Case Press. In. H_2O	Remarks	LINE
1																1
2		51		30				114	117					1.2		2
3		47		28				128	133					1.3		3
4		55		30				152	157					1.3		4
5		53		28.5				156	162					-.9	Noise in Turbo	5
6		55		29				157	170					-.9		6
7		55		28				156	173					-.5		7
8		55		26.5				156	176					-0.1		8
9		55		26.5				156	176					-0.1		9
10		56		27.5				156	167					-0.4		10

LEGEND: L, LB - LEFT BANK; F - ENGINE FRONT AT NO. 1 CYLINDER; R, RB - RIGHT BANK; R - ENGINE REAR, FLYWHEEL END (WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL: LF EL ___ RF ___ LR ___ RR ___ (BB - Brown Boveri, DE - Delaval, EL - Elliott)

OPERATOR: JC Poppend — LINE 5-10 — DATE: 23 Jan 76

ENGINEER: ___ — LOG: 1 B

WITNESS: ___ — JOB NO: 2605

DELAVAL — [illegible] COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 2 A

CO. ..R LILCO — MODEL DSR48 — TEST STAND 2 — JOB NO 2605 — ENGINE NO 74011 — FULL LOAD RATING 4880 BHP @ 450 R — 25 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	THIS LOG	% LOAD (Nom)	DYNAMOMETER LOAD DATA RPM	SCALE (lbs)	BHP (Corr)	BMEP	A.C. GENERATOR LOAD DATA DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT
1	1/24	1605	1705	25	450	14157	1213	56										
2	1/24	1705	1805	110	450	62650	5368	246										
3									SET OVERSPEED TRIP 495 RPM - SET GOV. SPEED 220 RPM TO 460 RPM.									
4																		
5																		
6																		
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (MM)

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R
1	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0												
2	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0												

TURBOCHARGER PRESSURES / TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE / AMBIENT

LINE	BLOWER INLET (in H2O) LF	RF	LR	RR	BLOWER DISCHARGE (in hg) LF	RF	LR	RR	AIR MANIF (in hg) LB	RB	TURBINE INLET (in hg) LF	RF	LR	RR	TURBINE EXHAUST (in H2O) LF	RF	LR	RR	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LB	RB	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE Δh (in H2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	BARO (Corr) in hg	AIR (°F)
1	4.7				8.1				8.1										66				122				134						29					29.76	66
2	36.6				56.9				56.6										61				352				163						220					29.98	67

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	MANIF (level)	API GRAVITY AS READ	@ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	GAS MANIF Press in hg	LHV Btu/ft3	TO GAS METER Press (in) in hg	°F	CORR FACTOR	ft3 MEAS	TIME (sec)	ft3/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr
1	37	36.6	76	35.0	18376	314	2423			.387												
2	35	36.6	76	35.0	18370	1480	3715			.369												

REMARKS

SHUT ENGINE down 1805
1945 START Engine.

CHANGED VALVE SPRING ON
#5 INLET VALVES ALL OK.

INJECTION IGNITION TIMING °BTDC 25 LB ____ RB
FUEL OIL SPEC F-10
LUBE OIL SPEC L-21

AIR FLOW NOZZLE COEFFICIENT
LF 12283 RF ____
LR ____ RR ____ (FLYWHEEL END)

OPERATOR Kapparoni
ENGINEER
WITNESS

DATE 1-24-76
LOG NO 3 A
JOB NO 2605

DELAVAL

ST — CO COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

CL 4 LILCO

MODEL DSR48 TYPE SERVICE STA JOB NO 2605 ENGINE NO 74011

POWER ENGINE FACTORY TEST LOG — LOG 2 B

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) .W

EXHAUST TEMPERATURES - °F

Line	Turbine Inlet (T - Top, B - Bottom) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	Turbine Exhaust LF	RF	LR	RR
1											622			
2											853			
3														
4														
5														
6														
7														
8														
9														
10														

Line	Exhaust Elbows 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	620	620	620	640	620	640	630	640			625	671	648	673	634	647	656	654			
2	1740	1695	1700	1750	1710	1730	1740	1750			1011	1001	979	981	971	964	984	981			
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

Line	Engine Water PSIG to Engine	To Engine (°F)	From Engine (°F)	Turbocharger Water Outlet (°F) LF	RF	LR	RR	Aftercooler Water Inlet (°F) F	R	Outlet (°F) F	R
1	31	154	158	157							
2	31.5	154	168	163							
3											
4											
5											
6											
7											
8											
9											
10											

FIRING PRESSURES - PSIG

Line	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1	620	620	620	640	620	640	630	640													
2	1700	1690	1700	1750	1710	1730	1740	1750													
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

Line	Lubricating Oil Pressure - PSIG From Pump	To Engine	Cam Header	To Turbocharger LF	RF	LR	RR	Lubricating Oil Temperature °F To Engine	From Engine	Turbocharger Drain LF	RF	LR	RR	Crank Case Press (in. H_2O)	Remarks
1	60	55		27.5				157	167					1.2	
2	60	55		26				156	177					.2	
3															
4															
5															
6															
7															
8															
9															
10															

LEGEND: L LB LEFT BANK F ENGINE FRONT AT NO 1 CYLINDER
R RB RIGHT BANK R ENGINE REAR FLYWHEEL END
(WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER: MAKE & MODEL
LF EL RF
LR RR
BB - Brown Boveri DE - Delaval El - Elliott

OPERATOR Kapperman
ENGINEER
WITNESS

DATE 1-24-76
LOG 2 B
JOB NO 2605

DELAVAL

IMO COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 3 A

FOR L.I.L.C.O. MODEL DSR-48 TEST STAND Dec — JOB NO 2605 ENGINE NO 74011 FULL LOAD RATING 3500 KW BHP 4800 : 225 BMEP

Line	Date	Wall Clock Time On Load	Wall Clock Time This Log	% Load	Dyna: RPM	Dyna: Scale (lb)	Dyna: BHP (Corr)	Dyna: BMEP	AC Gen: Disc Revs	AC Gen: Time (sec)	AC Gen: Power Factor	AC Gen: AC Volts	AC Gen: AC Amps	AC Gen: Total KW	AC Gen: Gen Eff	AC Gen: BHP (Corr)	AC Gen: BMEP	Gov Load Limit
1	2/26	1500	1515	0	300													
2	2/27	1315	1415		450													
3	2/28	0915	1100		450													
4	2/28	1530	1630	100	450							4160	480	3500				
5	3/1	1300	1630															
6																		
7																		
8																		
9																		
10																		

3/1 —

Fuel Pump Rack Position (MM) — Water Resistance KW

Line	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R (Recep. Astar)
1																				1.2
2																				
3											600	600	700							
4											1250	1250	1100							
5																				9.6
6																				
7																				
8																				
9																				
10																				

TURBOCHARGER PRESSURES

Line	Blower Inlet (in H_2O) LF	RF	LR	RR	Blower Discharge (in hg) LF	RF	LR	RR	Air Manif (in hg) LB	RB	Turbine Inlet (in hg) LF	RF	LR	RR	Turbine Exhaust (in H_2O) LF	RF	LR	RR
1																		
2																		
3																		
4									18.5									
5																		
6																		
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES / AIR FLOW / AMBIENT

Line	Blower Inlet (°F) LF	RF	LR	RR	Blower Discharge (°F) LF	RF	LR	RR	Air Manif (°F) LB	RB	Turbocharger RPM LF	RF	LR	RR	Nozzle ΔP (in H_2O) LF	RF	LR	RR	Air Flow SCFM Total	Baro (Corr) in hg	Air (°F)
1																					
2																					
3																					
4									144											29.90	
5																					
6																					
7																					
8																					
9																					
10																					

AIR FLOW NOZZLE SIZE ►

Line	Fuel Oil: Range (level)	API Gravity As Read @ °F	API Corrected To 60°F	LHV (Btu/lb)	Lbs Meas	Diesel BSFC: Time (sec)	lb/hr	Btu/bhp hr	(Corr) Btu/bhp hr	Fuel Gas: Range (press in hg)	LHV Btu/ft³	To Gas Meter: Press (in) hg	°F	Corr Factor	Gas BSFC: ft³ Meas	Time (sec)	ft³/hr (Corr)	Btu/bhp hr	Dual Fuel BSFC: Pilot Btu/bhp hr	Gas Btu/bhp hr	Total Btu/bhp hr
1																					
2																					
3																					
4	32.5																				
5																					
6																					
7																					
8																					
9																					
10																					

REMARKS

1 Started unit for 15 min. run. Heatcheck (k)
2 Started unit to set up gov. for load
3 Shut unit down to check test stand
4 electrical circuits.
5 Started unit to bring it to op. temp.

INJECTION IGNITION TIMING °BTDC ______ LB ______ RB

FUEL OIL SPEC

LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT
LF ______ RF ______
LR ______ RR ______
(FLYWHEEL END)

OPERATOR D. Ellis 1.4
ENGINEER
WITNESS

DATE 2/26
LOG NO 3 A
JOB NO 2605

DELAVAL

IC COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

CL. L.I.L.C.O.

MODEL DSR-48 TYPE SERVICE Nuclear Stn JOB NO 2605 ENGINE NO 74011

POWER ENGINE FACTORY TEST LOG — LOG 3 B

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END) J

EXHAUST TEMPERATURES °F

LINE	TURBINE INLET (T - TOP B - BOTTOM) LFTL	LFTR	LFB	RFT	RFB	LRT	LRB	RRTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

LINE	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2																					
3																					
4	830	850	865	825	835	820	790	845													
5																					
6																					
7																					
8																					
9																					
10																					

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R
1											
2											
3											
4	230	153	169						67	78	
5											
6											
7											
8											
9											
10											

FIRING PRESSURES - PSIG

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG
1																					
2																					
3																					
4	1590	1570	1580	1570	1595	1585	1610	1580													
5																					
6																					
7																					
8																					
9																					
10																					

LINE	LUBRICATING OIL PRESSURE - PSIG FROM PUMP	TO ENGINE	L.O. HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " H2O	REMARKS
1															
2															
3															
4		56.0		26.5				162	177					1.3	
5															
6															
7															
8															
9															
10															

LEGEND: L, LB - LEFT BANK; R, RB - RIGHT BANK; F - ENGINE FRONT AT NO. 1 CYLINDER; R - ENGINE REAR, FLYWHEEL END (WHEN VIEWED FROM FLYWHEEL END)

TURBOCHARGER MAKE & MODEL
LF ______ RF ______
LR ______ RR ______
BB - Brown Boveri TK - Elliott

OPERATOR DeWolf

ENGINEER

WITNESS

DATE 2/26/76

LOG 3 B

JOB NO 2605

DELAVAL

NO COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 4 A

CUSTOMER L.I.L.CO. MODEL DSR-48 TEST STAND DUS. JOB NO 2005 ENGINE NO 74011 FULL LOAD RATING 3500 kW RPM 450 at 225 BMEP

LINE	DATE	WALL CLOCK TIME ON LOAD	WALL CLOCK TIME THIS LOG	% LOAD (Nom)	DYNAMOMETER LOAD DATA RPM	SCALE (lb)	BHP (Corr)	BMEP	A C GENERATOR LOAD DATA DISC REVS	TIME (sec)	POWER FACTOR	A.C. VOLTS	A.C. AMPS	KW	GEN EFF	BHP (Corr)	BMEP	GOV LOAD LIMIT
1	3/2	1339	1933	115	480							4160	540	3171				
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

FUEL PUMP RACK POSITION (MM) Wattk R4C051975 - 1500

LINE	1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R (Hour Meter)
1	4.20										13.20	13.14	13.x							9.0
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

TURBOCHARGER PRESSURES

LINE	BLOWER INLET (in. H_2O) LF	RF	LR	RR	BLOWER DISCHARGE (in. hg) LF	RF	LR	RR	AIR MANIF (in. hg) LR	RR	TURBINE INLET (in. hg) LF	RF	LR	RR	TURBINE EXHAUST (in. H_2O) LF	RF	LR	RR
1									57									
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

TURBOCHARGER TEMPERATURES / AIR FLOW NOZZLE SIZE / AMBIENT

LINE	BLOWER INLET (°F) LF	RF	LR	RR	BLOWER DISCHARGE (°F) LF	RF	LR	RR	AIR MANIF (°F) LR	RR	TURBOCHARGER RPM LF	RF	LR	RR	NOZZLE ΔP (in. H_2O) LF	RF	LR	RR	AIR FLOW SCFM TOTAL	BARO (Corr) in hg	AIR (°F)
1									149											29.64	59.9
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

FUEL OIL DATA / DIESEL BSFC / FUEL GAS DATA / GAS BSFC / DUAL FUEL BSFC

LINE	WATER (level)	API GRAVITY AS READ @ °F	API Corrected to 60°F	LHV (Btu/lb)	LBS MEAS	TIME (sec)	lb/hr	Btu/bhp hr	(Corr) lb/bhp hr	WATER (press in hg)	LHV Btu/ft³	TO GAS METER PRESS (in) in hg	°F	CORR FACTOR	ft³ MEAS	TIME (sec)	ft³/hr (Corr)	Btu/bhp hr	PILOT Btu/bhp hr	GAS Btu/bhp hr	TOTAL Btu/bhp hr	REMARKS
1	320																					Start of maximum capability test.
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						

INJECTION IGNITION TIMING °BTDC ______ LB ______ RB

FUEL OIL SPEC

LUBE OIL SPEC

AIR FLOW NOZZLE COEFFICIENT

LF ______ RF ______

LR ______ RR ______

(FLYWHEEL END)

OPERATOR D. Ellis

ENGINEER [illegible]

WITNESS [illegible]

DATE 3/2/76

LOG NO 4 A

JOB NO 2005

DELAVAL

ENGINE AND COMPRESSOR DIVISION, OAKLAND, CALIFORNIA

POWER ENGINE FACTORY TEST LOG — LOG 4 B

CUS. L.I.L.C.O. MODEL DSR-48 TYPE SERVICE Nuclear Stan. By JOB NO. 2605 ENGINE NO. 74011

DIRECTION OF ROTATION (AS VIEWED FROM FLYWHEEL END)

EXHAUST TEMPERATURES – °F

LINE	TURBINE INLET (T - TOP, B - BOTTOM) LFTL	LFTR	LTB	RFT	RTB	LRT	LRB	RFTL	RRTR	RRB	TURBINE EXHAUST LF	RF	LR	RR	EXHAUST ELBOWS 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1															895	905	810	810	840	865	815	815	865													1
2																																				2
3																																				3
4																																				4
5																																				5
6																																				6
7																																				7
8																																				8
9																																				9
10																																				10

LINE	ENGINE WATER PSIG TO ENGINE	TO ENGINE (°F)	FROM ENGINE (°F)	TURBOCHARGER WATER OUTLET (°F) LF	RF	LR	RR	Raw AFTERCOOLER WATER INLET (°F) F	R	OUTLET (°F) F	R	FIRING PRESSURES – PSIG 1L	2L	3L	4L	5L	6L	7L	8L	9L	10L	1R	2R	3R	4R	5R	6R	7R	8R	9R	10R	AVG	LINE
1	238	153	165					64		78		1710	1700	1700	1130	1120	1120	1140	1125														1
2																																	2
3																																	3
4																																	4
5																																	5
6																																	6
7																																	7
8																																	8
9																																	9
10																																	10

LINE	LUBRICATING OIL PRESSURE – PSIG FROM PUMP	TO ENGINE	CAM HEADER	TO TURBOCHARGER LF	RF	LR	RR	LUBRICATING OIL TEMPERATURE °F TO ENGINE	FROM ENGINE	TURBOCHARGER DRAIN LF	RF	LR	RR	CRANK CASE PRESS " in H2O	REMARKS	LINE
1	550	550		26.0				160	174					.1		1
2																2
3																3
4																4
5																5
6																6
7																7
8																8
9																9
10																10

LEGEND: L, LB - LEFT BANK; F - ENGINE FRONT AT NO. 1 CYLINDER; R, RB - RIGHT BANK; R - ENGINE REAR, FLYWHEEL END; *WHEN VIEWED FROM FLYWHEEL END

TURBOCHARGER MAKE & MODEL
LF ______ RF ______
LR ______ RR ______
BB - Brown Boveri DE - Delaval EL - Elliott

OPERATOR D. Cline DATE 3/2/76
ENGINEER [illegible] LOG 4 B
WITNESS [illegible] JOB NO. 2605

Document 7

UNCONTROLLED
For Information Only

SHOREHAM I
NUCLEAR POWER STATION
STARTUP FORM 8.3

Oct. 1, 1975
REVISION 0

Preoperational Test Results Review and Approval

1. System No. R43A
2. Preoperational Test No. PT.307.004.A-2
3. System EDG 101 Qualification Preoperational Test
4. Test Engineer William J. Cook
5. Lead Startup Engineer M.W. Herlihy
6. Attached for your review are:

Preoperational Test Results and Analysis

William J Cook 4/19/84
Prepared By/Performed By

FC Clifford 4/19/84
Reviewed By

M W Herlihy 4/19/84
Reviewed By

4/23/84
Startup Manager Approval, Date

Preoperational Test Approval/Release For Performance (Startup #8.1)

System Checkout & Initial Operations Tests

Test Change Notice(s) (Startup #8.2)

7. Preoperational Test Results attached are Approved by the JTG

4/23/84
SE Site Operations Manager

William M Matejek 4/23/84
S&W Advisory Operations Engineer

4/23/84
Startup Manager

W Cheise
JTG Chairman

4/23/84
Date

A09106

APPENDIX F

ENGINE CYLINDER PRESSURE LOG

Step No.	8.8.2	
Date	4/11/84	
Time	2200	
ENGINE/CYLINDER PRESSURE (PSIG)	EDG 101	
1	1720	
2	1640	
3	1640	
4	1640	
5	1650	
6	1700	
7	1680	
8	1700	
Gen. Load (KW)	3500	
Var Loading (KVAR)	2700	

Data taken by: [signature]

JTG APPROVED NOV 8 1983

Document 8

FaAA-84-3-16
PAO 7396/PRJ-03310A

EVALUATION OF EMERGENCY DIESEL GENERATOR CRANKSHAFTS AT SHOREHAM AND GRAND GULF NUCLEAR POWER STATIONS

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The report is final, pending confirmatory reviews required by FaAA's QA operating procedures.

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Prepared for

TDI Diesel Generator Owners Groups

May 22, 1984

instance, the TDI method does not compute the phase relationship between the various orders or modes, so it is not possible to compute the true summation. The actual maximum stress is a direct result of this summation. Furthermore, the TDI method always predicts maximum stress in Crankpin No. 8, which is generally true for a single order in the first mode but not true for the combined response of all orders and modes.

The dynamic model developed used the same idealized lumped inertia and torsional spring model as the TDI analysis (Figure 2-1 and Table 2.1) with one additional spring placed between the generator and ground to represent the effect of the grid on dynamic response during synchronous operation. This spring constant was found to be 1.409×10^6 ft.-lb./radian based on generator specifications. This constant is set close to zero to represent SNPS emergency bus operation.

The first five torsional natural frequencies for the replacement crankshaft are shown in Table 3.1. The first natural frequency was found to be 2.93 Hz due to the connection to the grid. For operation on the SNPS emergency bus the first natural frequency is 0 Hz (rigid body mode). The other natural frequencies are in agreement with those computed by TDI and measured by SWEC.

When the diesel generator is running at a given speed and power level, the forced vibration problem is steady-state where both load and response repeat themselves every two revolutions of the crankshaft. To model the dynamic response, a model superposition analysis [3-1] was used with harmonic load input. The calculation of the harmonic loads will be discussed in the next section.

3.1.2 Harmonic Loading

To calculate the harmonic loading on a crankshaft it is necessary to consider gas pressure, reciprocating inertia, and frictional loads. The gas pressure loading may be obtained from pressure versus crank angle data. This pressure was measured in the SWEC test [3-2]. The pressure was measured in Cylinder No. 7 by inserting a probe through the air start valve. A top dead

center, TDC, mark for Cylinder No. 7 was simultaneously recorded by a probe on the flywheel. The pressure data at 100% load was reduced by FaAA to obtain the pressure curve shown in Figure 3-1.

The torque produced by this pressure may then be calculated as a function of crank angle. The mean value of this torque should be the torque required to produce 3500 kW divided by the mechanical efficiency. A mechanical efficiency of 1.0 was obtained, rather than the expected 0.88. The difference is probably explained by either the pressure measurements being too low or by the TDC being shifted. Peak pressures were measured in all the cylinders to ensure that all cylinders were balanced.

Normally, the excess torque above that required to run the engine at 3500 kW is dissipated by friction. In this case, because the pressure curve produced the correct power without friction, friction was not applied. The effects of pressure being too low and not applying friction are expected to largely cancel each other.

The reciprocating mass of the connecting rod and piston was found to be approximately 820 lbs. This mass causes reciprocating inertia torque on the crankshaft. The effect of this torque was combined with the gas pressure torque.

The total torque was then decomposed into its sine and cosine harmonics corresponding to each order. These torque harmonics were used in the steady-state analysis. The magnitude of the torque harmonics are normalized by dividing by the piston area and throw radius. The resulting normalized torques for the most significant orders are shown in Table 3.2.

3.1.3 Comparison of Calculated Response With Test Data

The response due to the first 24 orders and all 11 modes is calculated using modal superposition with 2.5% of critical damping for each mode. The actual value of damping used has little effect on the response since the orders are not at resonance at 450 rpm. The SWEC test report stated that the measured damping in the system was 2.6% [3-2].

Section 3 References

3-1 Timoshenko, S., D.H. Young, and W. Weaver, Jr., Vibration Problems in Engineering. Fourth edition, Wiley, 1974.

3-2 Bercel, E., and Hall, J.R., "Field Test of Emergency Diesel Generator 103," Stone & Webster Engineering Corporation, April 1984.

3-3 Peterson, R.E., Stress Concentration Factor. Wiley & Sons, New York, 1974.

3-4 "R-48 Crank Crankshaft Stress Analysis," Transamerica Delaval Inc. Report No. CR-01-1983.

3-5 Fuchs, H.O., and Stephens, R.I., Metal Fatigue in Engineering. Wiley, 1980.

3-6 Bercel, E., and Hall, J.R., "Field Test of Emergency Diesel Generator 101," Stone & Webster Engineering Corporation, October 1983.

3-7 Collins, J.A., Failure of Materials in Mechanical Design. Wiley, 1981.

3-8 Nishihara, M., and Fukui, Y., "Fatigue Properties of Full Scale Forged and Cast Steel Crankshafts," Transactions of the Institute of Marine Engineering. Series B on Component Design for Highly Pressure-Charged Diesel Engines, London, January 1976.

3-9 Burrell, N.K., "Controlled Shot Peening to Produce Residual Compressive Stress and Improved Fatigue Life," Proceedings of a Conference on Residual Stress for Designers and Metallurgists, American Society for Metals, April 1980.

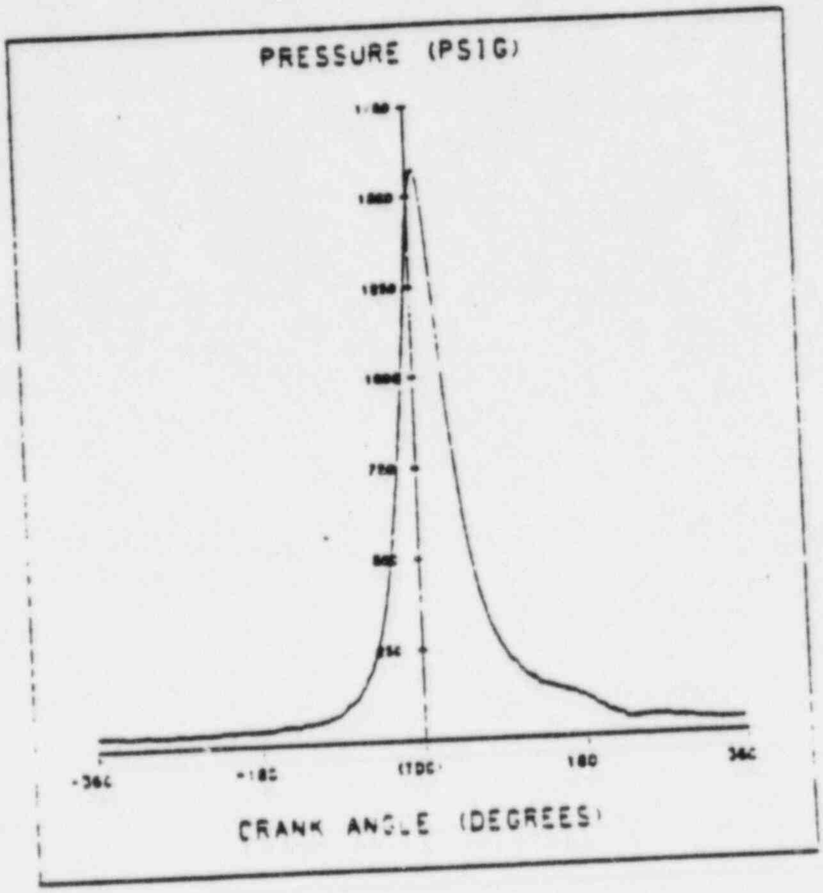

Figure 3-1. Measured pressure versus crank angle at 100% load.

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ORIGINAL

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the matter of:

TRANSAMERICA DELAVAL INCORPORATED
OWNERS GROUP MEETING

Docket No.

Location: Wading River, N. Y.   Pages: 1 - 197

Date: Thursday, March 22, 1984

TAYLOE ASSOCIATES
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that, I hope, but I think Paul has some input that would suggest that perhaps the operating conditions are not similar. And the last thing you mentioned, inspection and test, to me, that's going to be a very important aspect of all this, and I don't see inspection and test addressed in the piston skirt report. In other words, what's going to be done subsequently, to verify that these are indeed behaving satisfactorily on the basis of inspection and test.

That's a key element of the ownership program plan but it's not a matter that's identified, or addressed specifically for these piston skirts at this time.

MR. MUSELER: Well, what we certainly--with respect to the inspections, I think we mentioned that seven of the ten pistons have already been inspected after a hundred hours at full power, and roughly three hundred total hours, which is more than, much more than the cycle they're going to see, at least in the first eighteen months.

The intention there is to use the--and those inspections are, you know, are a matter of record. So our intentions, if those inspections started to show us that we were experiencing problems, might get back to this final loop that has to be closed when early inspections are done, in terms of whether it tells you something that

contradicts your original premise. With respect to the Kodiak, Alaska engine, in point of fact, that engine, we think typically runs at about 80 percent full load, and with respect to -- and so it doesn't run at a hundred percent, which is what we've beeen running Shoreham at for at least a hundred hours. But relative to the service these engines actually have to see, it's more severe service than these engines actually see in nuclear service, at least certainly for the first cycle, and probably for several cycles.

And the reason I say that is, that a, is that one of these engines, or all of these engines, if it ever had to perform its intended function, would see a high load for a very short period of time, and then would drop well below the level that the Kodiak engine runs at continuously. So while there's some--you know--there's certainly a difference between going the high load for a short period of time.

If you look at the histograms of that engine versus what these engines actually have to do, we think Kodiak is significant from that standpoint, even though it's not run at a hundred percent.

The R5 engine, on the other hand, ran, I guess, about six hundred hours at horsepower per cylinder, instead of six hundred, it runs up around nine hundred,

or something. And with respect to peak pressures--because I guess they're not always analogous--with respect to peak pressures, though, it does run at a significantly higher peak pressure. Our normal pressure is 1670, and at the overload rating, is 1750 in the Shoreham engines.

That engine, in order to run at that high horsepower, runs typically around 2000 psi. So while there aren't a lot of pistons that have experienced that, there are at least the two that we've examined, that have gone through six hundred hours at 2000 psi, and I don't know the percentages, but it's probably in the neighborhood of thirty percent higher peak pressure, peak firing pressures than our engines, and that data does give us a considerable amount of confidence. I'd rather have a hundred pistons that have seen a lot of service, but based on what we've seen so far, I think we have a high degree of confidence.

And we're not basing it--let me say again, we're not basing--and the report says that, I believe, certainly in the front--that we're basing the conclusion--our conclusion is that those pistons are unlikely to crack, and that further, you know, Dr. Wells points out in the report, that any cracks would not propagate. But we don't want them to crack, and we think that, not based on the analysis alone, but based on the information

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Transamerica Delaval

Instruction Manual

Model DSR-48 Diesel Engine
Serial Nos. 74010-2604
74011-2605
74012-2606

LONG ISLAND LIGHTING COMPANY
Shoreham Nuclear Power Station
Unit No. 1

Transamerica Delaval Inc.
Engine and Compressor Division

APPENDIX II

OPERATING PRESSURES AND TEMPERATURES

PRESSURES

The following pressures should be present for starting:

Starting Air Supply	250 psi	17.6 kg/sq cm
Starting Air Header	250 psi	17.6 kg/sq cm

While running at rated speed, the operating pressures should be as follows:

	psi	in-hg	kg/sq cm
Lubricating Oil*	50 — 55	101.8 — 112.0	3.52 — 3.87
Lubricating Oil at Turbocharger Inlet	20 — 25	40.7 — 50.9	1.41 — 1.76
Jacket Water	10 — 30	20.4 — 61.1	0.70 — 2.11
Fuel Oil	20 — 30	40.7 — 61.1	1.41 — 2.11

TEMPERATURES

While running under rated load, the outlet temperatures should be as follows:

Lubricating Oil out of Engine*	170° F — 180° F (76.6° C — 82.2° C)
Jacket Water out of Engine	170° F — 180° F (76.6° C — 82.2° C)

EXHAUST TEMPERATURES.

The exhaust temperatures shown on the "Factory Test Results" page are the average for all cylinders during factory test under *local ambient conditions*. Temperatures in the field, therefore, may exceed this average temperature. Exhaust temperatures may be considered normal if within plus or minus 50° F of the average taken for all cylinders. Temperatures, high or low, exceeding this range should be investigated (see Section 7). The exhaust temperature limits for sustained operation is 150° F between any two cylinders and 1100° F maximum.

FIRING PRESSURES.

Firing pressures may be considered normal if within plus or minus 75 psi of the average for all cylinders. High or low pressures exceeding this range should be investigated (see Section 7). The firing pressure limits for sustained operation is 200 psi between any two cylinders.

NOTES.

Operating pressures and temperatures listed are established as a guide to proper operation. Except as noted for exhaust temperatures and firing pressures, they should be held to within plus or minus 10 percent. Sudden changes in readings require immediate investigation and correction.

When making adjustments as a result of a high or low cylinder exhaust temperature, or firing pressure, both temperature and pressure readings must be taken into account when determining the proper corrective action.

*When using SAE 40 lubricating oil in engine.

FIELD TEST

OF EMERGENCY DIESEL GENERATOR 103

WITH 13 x 12 CRANKSHAFT

Prepared for

SHOREHAM NUCLEAR POWER STATION

LONG ISLAND LIGHTING COMPANY

by

E. BERCEL

J. R. HALL

APRIL 1984

Approved by: E. Bercel — Responsible Engineer, E. Bercel

J. R. Hall — Responsible Engineer, J. R. Hall

STONE & WEBSTER ENGINEERING CORPORATION

B1-1160037-1

6.2 PRINCIPAL STRESS CALCULATIONS

The synchronously averaged strain signals described in Section 6.1 were digitized into 1024 data points in the Nicolet 660 B. The digitized strain data from the three elements of each strain gage rosette were read by an HP 9826 computer. The applicable static strain component computed as discussed in 6.1 was added to each data point and the time history of the principal stresses, and the maximum shear stress, as well as the bending and torsion related stresses, were computed for the 0.4-second (1.5 strain cycle) time window of the strain samples.

6.3 OUTPUT TORQUE

The torque measurements were made by measuring the strain in the output shaft as described in Section 3.1.2. Of the two torque bridges installed, one was subject to some reduction in signal quality, but the other one (TQ9) provided excellent dynamic signals throughout the test. Using the technique described in 6.1 the torque-power relationship was determined in terms of micro-strain/kW. The torque vs output power curves are presented in Figure A-27 and A-28 in Appendix A. The obtained value was very close to the one calculated from the known material properties and geometry of the output shaft at the section where the strain gage bridges were located. The measured value for the torque-power relationship was 63.2 micro-strain per 1000 kW generated power (four-arm bridge, four times the actual strain in the shaft). Using the vendor specified figure of 96 percent for generator efficiency, the calculated torque-power relationship is 63.2 micro-strain

per 1000 kW of generated power. Since the measurement involved very low level signals the probable error is estimated at 5 to 8 percent.

The torque measurements at various selected load levels were analyzed in both the time domain and the frequency domain. Synchronous averaging was used in the time domain analysis. In the frequency domain, synchronous averaging was employed in some of the analysis to obtain phase measurements relative to the firing top-dead-center of cylinder No. 7. These measurements were obtained in the 500 Hz range which provided a 0.8 second sample. Ensemble averaging was used for general spectrum analysis to accurately display a region of resonance in the spectrum. Synchronous averaging tends to attenuate the data near a point of resonance in the spectrum as a result of the random nature of the spectrum there. The frequency range used was 50 Hz.

6.4 TORSIONAL VIBRATION

The torsional vibration data were analyzed in the time and frequency domains using the same techniques as described in 6.3. Synchronous time averaging, of the torque and torsional signals together, was also performed to display the two phenomena in relation to each other.

6.5 CYLINDER PRESSURES

Synchronous time averaging of all three cylinder pressures was performed. Frequency domain analysis was also done to measure the amplitude and phase of the 7.5 Hz and 15.0 Hz components of the cylinder pressure pulse, which

mechanical variables and output power and the results of the variable speed test are illustrated in Figures B-1 through B-11. Figures B-12 through B-78 contain the time domain data of the mechanical variables, including the calculated principal stresses and transient phenomena. The time-domain records of the electrical variables are in the third group in Figures B-79 through B-86. Finally, the frequency domain plots are presented in the fourth group in Figures B-87 through B-96 for both mechanical and electrical variables. In each group the figure numbers are arranged in ascending order with generated power to assist the reader.

7.2.1 Strain Measurements

In comparison to the dynamic strain, the static component of the measured strain was small. Since the dynamic range of the instrumentation had to accommodate the total strain, the static strain components were in the bottom 5 percent of the total measurement range. Nevertheless, the procedure described in Section 6.1 enabled the measurement of those components to a satisfactory accuracy (about +/- 5 percent). The values determined for the various load levels are given in Table B-1.

Measurements 5-3 and 7-1 represent the tensile components while 5-1 and 7-3 are the compressive strain components. The dynamic strain records are presented in the time domain only (Figures B-12 through B-18, B-24 through B-30, and B-37 through B-43). Each of those records represents 48 strain cycles averaged synchronously over a period of 12.8 seconds. To facilitate analysis, all records have been plotted to the same scale with a zero average and have been triggered at the same point in time. The time of the

TABLE 8.3.1-1

EMERGENCY DIESEL GENERATOR SYSTEM
REQUIRED LOADS AND MAXIMUM COINCIDENT DEMAND

Function	Nameplate Rating (Hp)	Total Plant Number	Number Required: Design Basis Loss of Coolant Accident, 0-10 Min	Number Required: Design Basis Loss of Coolant Accident, 10 Min on	Number Required: Loss of Offsite Power (Hot Standby)	Maximum Coincident Demand (Kilowatt) (1) (2): DG-101	DG-102	DG-103
Core Spray Pump	1250	2	1 (6)	1	-	998	998	-
Residual Heat Removal Pump	1250	4	2 (6)	1	2	999	999	1998 (4)
Service Water Pump	450	4	2	2	3 (3)	358	358	716
RBSVS and CRAC Water Chiller	292	4	2	2	2	235	235	470 (4)
RBSVS and CRAC Water Chiller Lube Oil Pump	.25	4	2	2	2	0.2	0.2	0.4 (4)
RBSVS Chiller Circ. Water Pump	75	4	2	2	2	60	60	120 (4)
RBSVS Chiller Cond. Water	20	4	2	2	2	16	16	32 (4)
RBSVS Unit Cooler	30	8	4	4	4	96	96	-
RBSVS Exhaust Fan	100	3	2	2	2	82.5	82.5	82.5
Reactor Building Exhaust Booster Fan	7.5	2	1	1	1	6	6	-
RBSVS Filter Reheat Coil	6.6 kW	2	1	1	1	6.6	6.6	-
RBCLCW Circ. Pump	100	3	2	2	2	80	80	80
Diesel Generator Air Compressor	10	6	-	-	-	12	12	12
Diesel Generator Fuel Oil Transfer Pump	.5	6	2	2	2	0.4	0.4	0.4
Diesel Generator Jacket Water Heater	36 kW	6	-	-	-	72 (1,3)	72 (1,3)	72 (1,3)
Diesel Generator Jacket Water Keep Warm Pump	2.5 kW	3	-	-	-	2.5 (1,3)	2.5 (1,3)	2.5 (1,3)
Diesel Generator Lube Oil Heater	20 kW	3	-	-	-	20 (1,3)	20 (1,3)	20 (1,3)
Diesel Generator Before & After Lube Oil Pump	5	3	-	-	-	4 (1,3)	4 (1,3)	4 (1,3)
Diesel Generator Heater	4.2 kW	3	-	-	-	4.2 (1,3)	4.2 (1,3)	4.2 (1,3)
Battery Charger (125 V)	60 kVa (1,5)	3	2	2	2	20	25	17
120 V ac Instrument Power	100 kVa DG 101 100 kVa DG 102 50 kVa DG 103	3	2	2	2	80	80	40
120 V Nonemergency Feeds	65 kVa	-	-	-	X (7)	-	-	52 (8)
Diesel Generator Room Vent Supply Fan	20	3	2	2	2	16	16	16
Battery Room Vent Supply Fan	2	3	2	2	2	1.6	1.6	1.6
Control Room Air Conditioning Unit	40	2	1	1	1	33.9	33.9	-
Control Room Vent Booster Fan	7.5	2	1	1	1	6.0	6.0	-

TABLE 8.3.1-1 (CONT'D)

Function	Nameplate Rating (Hp)	Total Plant Number	Number Required: Design Basis Loss of Coolant Accident 0-10 Min	Number Required: Design Basis Loss of Coolant Accident 10 Min on	Number Required: Loss of Offsite Power (Hot Standby)	Maximum Coincident Demand (Kilowatt) (1) (8) DG-101	DG-102	DG-103
Emergency Switchgear, Relay & Computer Rooms Air Conditioning Unit	40	2	1	1	1	33.9	33.9	-
TSC Air Conditioning Unit	40 kW	1	-	1	1	-	-	40 (3),(4)
TSC Air Cooled Condenser	30 kW	1	-	1	1	-	-	30 (3),(4)
Emergency Switchgear, Relay & Computer Rooms Exhaust Fan	10	2	1	1	1	8.0	8.0	-
RBSVS Chiller Room Exhaust Fan	3	2	1	1	1	2.4	2.4	-
Screenwell Exhaust Fan	10	2	1	1	1	8.0	8.0	-
Screenwell Interposing Relay Panel	1 kVa	1	1	1	1	-	0.8	-
MCC Room Ventilation	.75	2	1	1	1	0.5	0.5	-
LPCI M-G Set Room Ventilation	3	4	2	2	2	2.4	2.4	4.8
Unit Cooler MCC 081 Room	1.5	1	1	1	1	-	1.2	-
Spent Fuel Pool Cooling Water Pump	30	2	-	1	1	24 (8)	24 (8)	-
Loop Level Pump (CS, RHR, HPCI, RCIC)	7.5	4	4	2	4	12.0	12.0	-
Atmospheric Cont. - Hyd. Recombiner	109 kW	2	-	1	-	109 (8)	109 (8)	-
MSIV-LCS Heaters	6.6 kW	4	-	-	-	-	26.4 (8)	-
MSIV-LCS Blowers	4.4	3	-	-	-	7 (8)	3.5 (8)	-
Radiation Monitoring	1	10	-	-	-	4.8	3.2	-
Lighting (Equivalent kW)	407.2 kW	-	-	-	X (7)	180 (8)	-	227.2 (8)
Fence Security Lighting	60 kW	-	-	-	X (7)	34	-	26
Reactor Protection System M-G Set (5)	25	2	-	-	2	20 (1)(8)	20 (1)(8)	-
Reactor Protection System Backup Transformer	25 kVa	1	-	-	1	-	-	20 (8)
Battery Charger ±24 V	3 kVa	4	-	-	-	2.4 (8)	2.4 (8)	-
Uninterruptible Power (Vital Bus) (5)	37.5 kVa	1	1	1	1	-	-	30
Uninterruptible Power (Security & Communications) (5)	20 kVa	1	1	1	1	-	-	16
Battery Charger (Security and Communication)	20 kVa (1)(5)	1	-	-	-	-	-	4
Uninterruptible Power (Computer Bus) (5)	20 kVa	1	1	1	1	16	-	-
Control Rod Drive Pump (5)	250	2	-	-	1	206.1 (8)	206.1 (8)	-
Drywell Cooling System Fan (5)	25	8	-	-	4	80 (8)	80 (8)	-

TABLE 8.3.1-1 (CONT'D)

Function	Nameplate Rating (Hp)	Total Plant Number	Number Required: Design Basis Loss of Coolant Accident 0-10 Min	Number Required: Design Basis Loss of Coolant Accident 10 Min on	Number Required: Loss of Offsite Power (Hot Standby)	Maximum Coincident Demand (Kilowatt) (1) (8) DG-101	DG-102	DG-103
Primary Containment Air Cooler Subfeed	2 kVa	2	-	-	1	1.6 (8)	1.6 (8)	-
Reactor Water Cleanup Recirc. Pump (8)	60	2	-	-	1		48 (8)	48 (8)
Suppression Pool Pump Back Pump	25	1	-	-	-	20 (8)	-	-
Main Turbine Turning Gear (8)	60	1	-	-	1	-	-	48 (8)
Main Turbine Piggyback Turning Gear Drive	0.5	1	-	-	1	-	-	0.4 (8)
Main Turbine Turning Gear Oil Pump (8)	40	1	-	-	1	-	-	32 (8)
Main Turbine Bearing Lift Pump (8)	5	7	-	-	7	8 (8)	8 (8)	12 (8)
Feedwater Turbine Turning Gear (8)	1.5	2	-	-	2	1.2 (8)	1.2 (8)	-
Feedwater Turbine Turning Gear Oil Pump (8)	10	2	-	-	2	8 (8)	8 (8)	-
RFP EHC Control Transformer	1.5 kVa	2	-	-	2	1.2 (8)	1.2 (8)	
Standby Liquid Control Pump	40	2	-	-	-	32 (8)	32 (8)	-
Standby Liquid Control Main Heater (8)	10 kW	1	-	-	-	-	10 (8)	-
Standby Liquid Control Mixing Heater (8)	45 kW	1	-	-	-	45 (8)	-	-
Standby Liquid Control Heat Tracing	3 kVa	2	-	-	-	3 (8)	3 (8)	-
Heat Tracing Transformer	25 kVa	2	1	1	2	20	20	-
480 V M-G Set	200 (12)	4	2	2	2	160	160	214
Refueling Jib Crane	3.25	2	-	-	-	2.5 (8)	2.5 (8)	-
Refueling Platform Assembly	3.5	1	-	-	-	2.8 (8)	-	-
Motor Operated Valves	-	-	X (7)	-	-	19.7	18.3	0.7
Nonoperating MOV's (11)	-	-	-	-	-	95.9	75.3	-
Total Connectable Loads						4381.3	4147.8	4493.7
Minus Note 11 Loads						- 95.9	- 75.3	- 0
						4285.4	4072.5	4493.7
Minus Note 8 Loads						- 597.8	- 428.0	- 439.6
						3687.6	3644.5	4054.1
Minus Note 10 Loads						- 20.0	- 20.0	- 0
						3667.6	3624.5	4054.1
Minus Note 9 Loads						- 136.0	- 138.9	- 70.0
						3531.6	3485.6	3984.1
Minus Note 13 Loads						- 102.7	- 102.7	- 102.7
Total kW (60 seconds approx)						3428.9	3382.9	3881.4
Minus Operating MOV's						- 19.7	- 18.3	- 0.7

TABLE 8.3.1-1 (CONT'D)

Total kW (Prior to 10 minutes)	3409.2	3364.6	3880.7
Minus Note 4 Loads	- 0	- 0	-1310.2
Plus Note 14 Loads	0	0	+ 70.0
Total kW (After 10 minutes)	3409.2	3364.6	2640.5

NOTES:

<1> Maximum coincident demand shown occurs during the 0-10 minute period after a design basis loss of coolant accident (LOCA).

<2> Kilowatt loads given are from manufacturer's data for the CS, RHR, service water pumps, motor-generator sets, RBSVS chiller units, and all motors greater than 100 Hp.

<3> On loss of offsite power, it is necessary to go to a cold shutdown condition if DG-103 does not start, since the three required service water pumps will not be available. Note that only two service water pumps are required for a design basis LOCA condition. (Only one pump is connected automatically to DG-103, the other may be connected manually only.)

<4> Two units are started on DG-103. One unit is shut down when it is determined which section of the system will be used.

<5> These nonclass IE components are not required for a safe shutdown. Loading indicated for various modes of operation is desirable, although not essential. All remaining components are Class IE.

<6> Minimum safe shutdown requirements for a suction line break. Actual pump requirements depend on break location (see Section 6.3.3).

<7> X indicates load required.

<8> These loads are tripped intentionally (automatically) on a LOCA.

<9> These loads are not normally operating and receive no automatic start signal after a LOCA.

<10> These nonsafety related loads have seal-in type control circuits that drop out on a loss of offsite power prior to connecting to the diesel generators.

<11> These MOV's are connected to their respective diesel buses but do not operate upon a LOCA.

<12> The load to be carried by the M-G Sets consist of certain motor-operated valves. On Unit 103, one set operates at full load and one set operates unloaded.

<13> These loads are automatically tripped when diesel generator starts.

<14> These loads are prevented from starting until 10 minutes after a LOCA signal.

<15> Loads imposed by battery chargers are based on the dc loading of the battery chargers.