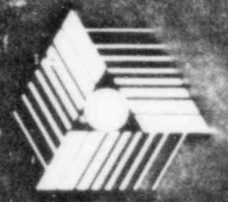

DESIGN & CONSULTING
ENGINEERING

FINAL REPORT TO
U. S. NUCLEAR REGULATORY COMMISSION
REGION I

FOR

TEST REVIEW, DATA ANALYSIS AND REVIEW OF EMERGENCY DIESEL GENERATOR OPERATIONAL/RELIABILITY PROBLEMS AT SHOREHAM NUCLEAR POWER STATION, UNIT I, SHOREHAM, NEW YORK

NRC CONTRACT NO. 05-82-249
PARAMETER CONTRACT NO. NRC-IE-82/83, TASK 38
FROM APRIL 25, 1983 TO MAY 19, 1983

PRESENTED ON JULY 12, 1983

BY

DESIGN AND CONSULTING ENGINEERING DEPARTMENT
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EVALUATION OF DIESEL ENGINE PROBLEMS AND TESTING AT SHOREHAM, NEW YORK

I. INTRODUCTION

A. Summary:

An in depth assessment of selected operational problems was conducted which included areas such as corrective maintenance, preventive maintenance and component failure. This assessment included detailed reviews of selected problems identified in Long Island Lighting Company (LILCO) Deficiency Reports, Repair/Rework Requests issued by the Start-up Group and failure reports issued by LILCO, Delaval and other vendors. In addition, observation of maintenance activities as well as a physical inspection of each emergency diesel generator unit was conducted during both standby and, when possible, running conditions.

During the review of each item, an attempt was made to determine the following:

(a) Was the work accomplished in accordance with approved procedures?

(b) Were properly calibrated tools (if applicable) used during maintenance?

(c) Were measurements, adjustments, torquing, etc. values within prescribed ranges?

(d) Were any trends detectable in readings or component failures?

(e) Were problems/failures caused by design, engine vibration, incomplete or improper workmanship?

A review of selected preoperational diesel testing was also conducted. This review included observations of in-process testing, reviews of test procedures, reviews of completed test procedures and evaluation of completed test data.

During these reviews and evaluations of the diesel generators, a number of problem areas were found to exist and are identified in the following report. In addition to specific problems/comments, which are identified, a number of recommendations and observations are also included which should be considered for corrective actions.

Although some problems are still occurring during operation/testing, the frequency at which they occur seems to be decreasing. Additional testing and corrective action is needed to provide a high level of confidence that the engines will start and operate reliably. Specific comments and recommendations are provided in various sections of this report. Section VI provides the specific recommendations for additional testing. Once these recommendations have been adopted (in conjunction with the recommendations of the LILCO Task Force), and the testing completed with no problems, this should provide the necessary assurance that the emergency diesel can accomplish their design functions.

As identified in the recommendations of NUREG/CR-0660, the training and performance of personnel (including Q/A) involved with maintenance and operation of emergency diesels contributed significantly to the reliability of the various emergency engines. This same area appears to be a problem at Shoreham. The Repair/Rework program including records was felt to need improvement.

Additional review and evaluation is also needed of various test results as identified in Section II. In addition, Section V.B provides recommendations for further investigation as a result of the turbocharger failure.

ENERGY CONSULTANTS, INC.

FOR U. S. NUCLEAR REGULATORY COMMISSION REGION I

Contract No. NRC Contract No. 05-82-249 Parameter Purchase Order No. NRC-IE-82/83, Task 38

Docket No. 50-322

License No. CPPR-95

Licensee: Long Island Lighting Company
175 East Old Country Road
Hicksville, NY

Facility Name: Shoreham Nuclear Power Station

Inspection Location: Shoreham, New York

Inspection Conducted: April 25, 1983 - May 19, 1983

Inspector: G. L. Kunkle /RJA

Gailard L. Kunkle, Senior Consultant, Energy Consultants, Inc.

B. Equipment Identification:

Manufacturer: Engine - Transamerica Delaval Company
Generator - Portec Electric Products Division

Model: DSR-48

Serial Numbers: 74010, 74011 and 74012

Ratings: 4,889 horsepower
3,500 kilowatts (continuous)
3,900 kilowatts (2 hour rating)
0.8 power factor
4,375 kilovolt amps
4,160 kilovolts
607.2 amperage

C. Background:

The three emergency diesel generators at the Shoreham Nuclear Power Station, Unit I, have experienced repeated problems during preoperational full load and endurance tests. The operational problems have included cylinder head

problems (5 heads replaced), rocker arm assembly hold-down bolt failures, turbocharger bearing failure and linear indications in engine block casting.

D. Inspection Objectives:

Provide an independent review and assessment of emergency diesel generator operability and the ability of the diesels to perform their design function, based on a comparison of design capabilities/performance ratings (as described in the Shoreham Final Safety Analysis Report, design specifications and vendor technical manuals) with actual operational data (as described in licensee preoperational test records). Witness ongoing emergency diesel generator testing, if applicable, and assess test results.

Perform an assessment of past preoperational problems, including material failures, and determine the appropriateness of corrective actions to provide assurance of future diesel operability. Review, as appropriate, licensee records of emergency diesel generator preventive and corrective maintenance actions since January 1, 1981 and the licensee's written analysis of diesel failures and corrective actions. Assess the need for independent NRC/contractor material testing and for additional licensee material testing, as may be required.

E. Persons contacted:

Long Island Lighting Company

E. Youngling
J. Rivello

Stone & Webster Engineering Corporation

R. Purcell	N. Rudikoff
T. Paulantonio	A. Stakutis
R. Lawrance	W. Dick
T. Brown	J. Kamayer
W. Cook	T. Gray

Transamerica Delaval, Inc.

L. McHugh

R. D. Jacobs and Associates

R. Jacobs

U.S. Nuclear Regulatory Commission

J. Higgins
H. Nicholas
E. McCabe
L. Bettenhausen

II. TESTING

Background:

To verify the ability of the diesels to perform their design function, the operational data in the preoperational test records were compared to the design capabilities/performance ratings described in the Shoreham Final Safety Analysis Report, design specifications and vendor technical manuals. Actual testing was witnessed where possible.

Summary:

Portions of testing on diesel engines 102 and 103 were observed over a period of two weeks. This testing was being performed in accordance with preoperational test procedures PT. 307.003 B-1 and PT. 307.005C TCN-1. In addition, the results of a completed test procedure PT. 307.005A were reviewed. (It should be noted that the results of this completed procedure have not been reviewed nor accepted by the LILCO Joint Test Group.) The comments resulting from these reviews are as follows:

Comment #1: The Nuclear Regulatory Commission Regulatory Guide 1.108 (Revision 1, August 1977) Section C.2(3) requires the emergency diesel generators to be tested at a load equivalent to the continuous rating for 22 hours and for 2 hours at the 2 hour rating. The continuous full load rating of each emergency diesel generator set is shown in Table I. Typical values of data recorded in PT. 307.005A for the full load run are shown in the last column of Table I.

TABLE I

	Continuous Full Load Rating	Test Load Values
Kilowatts (KW)	3,500	3,510
Volts (V)	4,160	4,225
Amps (A)	607.2	480
Power Factor (PF)	0.8	1.0*
Kilovolt-Amps (KVA)	4,375	3,513*

*Calculated

The low amperage (480 vs. 607.2) and calculated KVA (3,513 vs. 4,375) shows the diesel generator was not tested at its continuous full load rating considering current, power factor and KVA ratings. (Note: the higher voltage of 4,225 would only account for a 10 amp lower reading.)

Typical data for the 2 hour load run also shows the engine was not fully loaded to its 2 hour load rating on a current/power factor basis. Note: During the 2-hour full load run at the 530 amp load, the engine fuel racks were very near their full travel stops. If the amperage load were increased, the fuel racks may have reached full travel before the 110% amperage load was achieved.

Note: The lower than rated current obtained during the test did not simulate normal bus load conditions (actual bus load would probably have a lower power factor). The lower current would not result in the maximum generator I^2R heat loss. The effects that are caused by heating, therefore, were not effectively simulated.

To ensure the emergency diesels are capable of carrying their design emergency loads, additional testing should be conducted at the emergency limits (voltage, amperage & KVA) while operating at a 0.8 power factor.

Comment #2: Step 8.3.7 of PT. 307.005A states load diesel generator to full load then defines full load as 3500 $\pm$ 70 KW and 1500 $\pm$ 100 KVAR. Table I of the test procedure records KW but does not record KVAR so the data cannot be verified. In addition, Step 8.4.1 performs the 22 hour full load run, however, this step only specifies a load of 3500 + 70, - 0 KW and does not address KVAR load.

If step 8.3.7 definition of full load is correct, then the generator may not have been at full load in step 8.4.1 since only about 500 KVAR's were maintained throughout the test. This inconsistency should be investigated and resolved.

Comment #3: In evaluating the recorded data, it was found that the calculated KW (using the recorded voltage and amperage) did not always

meet the acceptance criteria unless a power factor of almost one (1) was assumed. Some examples were observed where the voltage dropped and amperage decreased by about 10% and the recorded KW went up slightly (KVAR would remain constant). These inconsistencies need further evaluation to determine if test requirements were actually met.

Comment #4: On April 27, observed that the official copy of PT. 307.005C in use for diesel testing did not contain TCN #1. (The step in progress had been changed by TCN #1. This TCN had been issued about two weeks earlier.)

Comment #5: The data sheets in test procedure PT. 307.005C were not signed by and therefore did not indicate who the data takers were.

Comment #6: Some instrumentation on the diesels being tested were not marked to indicate their calibration status as required by ANSI N45.2 and N18.7. For example, engine tachometer, cooling water thermometers, turbocharger air pressure, voltage, amperage and lube oil filter inlet and outlet pressure gages.

Comment #7: Some data had been changed/corrected by write overs making it difficult to read.

Comment #8: In test procedure PT. 307.005A&C precaution 4.7 states diesel room temperature and humidity should be frequently monitored. There was no objective evidence that this was being done.

Comment #9: Initial condition 5.5 in procedure PT. 307.005C was signed off (with no exception indicated) indicating the HVAC was in operation. However, the ventilation was not in normal operation as the ventilation damper was temporarily bypassed and failed open.

Comment #10: Step 8.4.1 of PT. 307.005A states "ensure total KVA of generator does not exceed 4375 KVA". Since there is no method provided to measure or requirement to calculate this value, it is not clear how this requirement was met.

Comment #11: The diesel generator load values in Table II of PT. 307.005A are not recorded in the correct units. The table specifies KW while values are actually recorded in MW.

Comment #12: Various steps in PT. 307.005A were designated to be witnessed by Operations Q/A. The following steps have been completed but were not signed by Operations Q/A to indicate they witnessed the steps: 8.3.9, 8.3.11, 8.5.3 and 8.6.1.

Recommendation #1: The readability of some of the test instrumentation does not seem to be accurate enough to meet the test requirements. For example, the minimum subdivision for KW on the recorder was 200 KW while the tolerance band specified in the procedure was +40 and -19 KW. Similar problems existed for amperage and voltage. Test instruments should be accurate enough to be compatible with the tolerance of the acceptance criteria in the procedure, e.g., the readability of most analog instruments is one-half the smallest scale subdivision. The high speed recorder and charts should be analyzed to verify that their accuracy will actually permit reading (interpolating) these charts to one-quarter or one-eighth of the smallest scale subdivision as necessary to assure compliance with the test requirements.

III. CORRECTIVE/PREVENTIVE MAINTENANCE AND MAINTENANCE RECORDS

Background:

Approximately eight percent of the maintenance records (including Repair/Rework Requests, Rework Supervisor Work Summaries and Quality Assurance Verification Reports) were reviewed to determine if the work was accomplished in accordance with all vendor technical requirements. This review also determined if the maintenance and maintenance records properly implemented both local and NRC requirements. In addition, problems were reviewed to determine (where possible) if the "root cause" had actually been identified and corrected.

Summary:

In many cases it was not possible to verify, based on the maintenance records identified below, that the work had been properly conducted in accordance with both technical and administrative requirements. These problems fell into the following categories:

1. Torquing - The Delaval Technical Manual, Volume I, Appendix IV provides a table of torque values to be used for various threaded fasteners. This table also stated that all torque values are based on the use of a thread lubricant consisting of a 50/50 mixture of graphite and engine oil.

   Comment A: Some maintenance records indicate incorrect torque values may have been used. For example, Repair/Rework 408 indicates the rocker arm assembly was only torqued to 120 ft lbs instead of the required 365 ft lbs; Repair/Rework 417 indicates the rocker arm assembly and sub cover were torqued to 365 ft lbs, (i.e., overtorqued) although the sub cover is only required to be torqued to 120 ft lbs. The consequences of over or under torquing should be evaluated.

Comment B: A number of maintenance records do not provide any documentation or assurance that threaded fasteners were properly torqued since no torque values are recorded in the space provided (Start-up Instruction No. 6) and since the records do not provide any reference to the use of calibrated torque wrenches (i.e., there were no Measuring and Test Equipment (M&TE) numbers and calibration due dates recorded in the space provided). The following Repair/Rework Packages are typical of this type of problem:

(1) 751 - no torque value and no M&TE number

(2) 577 - no torque value and no M&TE number

(3) 596 - no torque value and no M&TE numbers (similar work on 805 & 808 had required information)

(4) 554 - states "no torque value, vendor specs"

(5) 637 - no torque values recorded

(6) 712 - no M&TE number for torque wrench used on head studs

(7) 394 - no torque values and no M&TE numbers

(8) 423 - no torque values and no M&TE numbers

Comment C: A number of maintenance records do not provide any assurance that the required thread lubricant was used during reassembly and torquing. Some records specifically indicate "none" or "NA" in the space provided on the form. Other packages did not include a copy of this completed form to show a lubricant had been used. Start-up Instruction No. 6 provides a place for recording type of thread lubricant. Typical examples are found in the following Repair/Rework Packages:

(1) 612 and 744 - indicate lubricant was used on head studs, other studs and bolts were not addressed

(2) 712 - states "none"

(3) 670 - states "NA"

(4) There is no reference of any lubricant in packages 596, 360, 359, 511, 636, 637, 714 and 820.

Comment D: In many of the maintenance records, the Quality Assurance verification report is so brief or general it is not possible to determine what was witnessed and verified. Typical examples are found in the following Repair/Rework Packages: 612, 349, 351, 360, 670, 712, 423 and 577.

Comment E: Some maintenance records indicated repairs and/or inspections were performed but the acceptance criteria is not clear. Typical examples can be found in the following Repair/Rework Packages:

(1) 751 - A jacket water pump was disassembled and the pump impeller was "inspected and found to be satisfactory". It is not clear what this acceptance was based on since no measurements were recorded and instructions do not specify what kind of inspection to perform (i.e., visual, measurement, dye penetrant).

(2) 546 - During repairs to a jacket water pump, this package states "started lapping and blue checking bore to shaft. Attained 85% contact on blue check." No reference is made to any acceptance criteria for the required percentage of contact.

2. Maintenance Procedures - Several Repair/Rework Packages were found which indicated the repair work had been performed in accordance

with verbal directions from the Delaval service representative. The specific directions or adjustments were not normally recorded making it impossible to verify that the work was completed in accordance with the technical specifications in the Delaval service manual. One example was found where a thrust reading outside the specified tolerance was apparently accepted based on verbal direction of the vendor. Typical examples of these problems are found in the following Repair/Rework Packages:

Comment A: 590 - The work summary in this package "checked total thrust of rotor assembly - 0.007* (okay from Al Scott Delaval representative)". A Delaval letter of December 6, 1982 (attached to LDR-926) states the Elliott specifications call for a thrust of 0.008 to 0.018.

Comment B: 374 - The work summary in this package states "adjusted rocker arms accordingly as per Delaval representative".

Comment C: 546 - The work summary in this package states "installed water pump with new gasket, tighten down bolts to representative approval".

Comment D: 554 - This package documented disassembly a jacket water pump for inspection and replaced the impeller nut. The work summary states "no torque value, vendor specs".

IV. VISUAL INSPECTION OF DIESEL GENERATORS

Background:

Visual inspections of each diesel generator unit was performed. When possible, inspections were also performed while the engines were running. These inspections were performed to determine the general condition of each engine and detect possible abnormal conditions.

Summary:

While no major problems were observed on any of the engines, some conditions were noted which should be corrected to ensure future problems do not occur. Several other conditions were observed which should be evaluated to determine the need for further corrective actions. Comments resulting from these inspections are as follows:

Comment #1: Many instrumentation, control and gage lines (1/4 inch to 3/4 inch size) are inadequately braced and vibrate excessively during operation. Some lines appear to need additional brackets while others have been removed from the brackets provided and were never reinstalled. For example, the lube oil supply line to the turbocharger failed due to vibration while in its design brackets.

Comment #2: A label plate on each diesel specified required torque values. These values do not all agree with the torque values currently in the technical manual.

Comment #3: Some bolts on the air inlet elbows to the head were loose and partially unthreaded apparently due to vibration during operation. Some bolts had washers, some lock washers and others no washers. The application of washers and/or lock washers should be specified.

V. REVIEW OF COMPONENT PROBLEMS/FAILURES

A. Engine Head Cracks

Background:

LILCO Deficiency Reports 1040, 1065, 1056 and 1141, various Repair/Rework Requests and correspondence with Delaval documents the identification of cracks in three cylinder heads. The Delaval Failure Analysis Reports indicate the cracks found in the three cylinder heads occurred as a result of manufacturing defects (hot tears resulting from sand inclusions in the casting and uneven cooling). The small amount of leakage that might occur would be blown out with the exhaust. Since these cracks were self-relieving and non-propogating, Delaval stated they would not affect operability or availability in stand-by service. The Delaval reports also indicate improved casting, manufacturing and testing techniques would preclude cracks in the latest head design.

LILCO letter SNRC-873 indicates that a leak detection procedure recommended by Delaval will be implemented until the permanent corrective action can be accomplished. This permanent corrective action will install cylinder heads of the latest available design.

Summary:

LILCO's corrective action of installing the latest design heads should eliminate this problem once the work is completed. This work is currently scheduled to be completed on a non-controlling basis. The leak detection procedure recommended by Delaval would identify any future cracks should they occur.

Based on a review of the actions being taken by LILCO, additional independent NRC/contractor material testing is not recommended.

Recommendations:

(a) Since water leakage/build up into a cylinder during long idle periods could have drastic consequences in an emergency start, it is recommended that if an engine does not have the new design heads installed, then it should be barred over with the indicator cocks open on a weekly basis after reactor critical testing has started. This barring procedure, in conjunction with the barring procedures recommended by Transamerica Delaval, should assure the engines will operate satisfactorily with the existing heads.

(b) Since Delaval has indicated stricter manufacturing controls assures the new heads are a high quality product, consideration should be given to either auditing or monitoring the production of some of these new heads or performing detailed receipt inspection and testing of one or two of these new heads.

B. Turbocharger Failure

Background:

LILCO Deficiency Report #926 documents the failure of a turbocharger thrust bearing. The initial evaluation by Delaval indicated the failure occurred due to a missing guide vane on the nozzle ring. A subsequent report from the turbocharger manufacturer (United Technologies Elliott) concluded the missing blade (vane) had failed in service apparently due to mechanical fatigue. In addition, Elliott indicated that additional analysis was being conducted on the nozzle ring and that pressure and temperature readings just upstream of the turbine inlet casing during a rapid start-up cycle would be helpful.

Summary:

Based on the type of failure (mechanical fatigue), it is recommended that this not be considered an isolated occurrence until it has been determined exactly what conditions caused the fatigue failure.

Recommendation:

Consideration should be given to:

(a) Checking the other turbochargers for possible cracking

(b) Evaluating the possibility of the missing blade having been knocked back into the exhaust manifold as postulated by Elliott.

C. Engine Block Casting Indications

Background:

LILCO Deficiency Report #1224 and Repair/Rework Request numbers 867, 868, 869, 870, 871 and 880 provide the details of Stone & Webster Engineering Corporation's (S&W's) investigation and engineering evaluation of linear indications which were found in the cam galley area of the engine block casting. The investigation required the indications on each engine to be checked and mapped using non-destructive examination. A similar design engine with a substantial number of operating hours was checked by S&W engineers using nondestructive examination. Indications were found of the same approximate size with no evidence of any propagation. S&W engineers found similar indication on a new engine block casting at the factory. This shows the indications occur during manufacture and are not a result of operations. Calculations by Delaval showed the regions where the indications are located are subject to compressive stresses which would not cause the indications to propagate. Discussions with S&W lead engineers indicated Delaval is conducting tests on an operating engine in order to verify their calculations and will issue a report when this testing is completed. Based on their evaluation of these indications, S&W has concluded that this indication will present no problems to the operation and reliability of the emergency diesel generators.

Summary:

After a review of the actions taken by S&W and Delaval and discussions with the S&W engineers, who conducted the evaluation, it is felt that their actions were adequate and the conclusions correct. However, the test results should be reviewed to ensure they verify the calculations.

D. General Review of Problems

Background:

During the detailed review of various Deficiency Reports, Failure Reports and Repair/Rework Requests, a significant number of problems or errors have been identified which seem to have occurred due to errors and incomplete or improperly completed work by the manufacturer. Attachment I to this section provides examples of specific problems that fall into this category.

Summary:

A large number and variety of problems that have been experienced can be attributed to vendor workmanship. These errors, in conjunction with the problems identified during audits of Delaval's Quality Assurance Program (audits/reaudits conducted October 1975, February 1976 and June 1976), indicate a weakly implemented Quality Control Program.

Recommendation:

Although the number of problems is decreasing significantly, they have not been completely eliminated and, therefore, reliability has not been demonstrated. Based on this, strong consideration should be given to continued operation or testing until problems have been eliminated and the engines run reliably. Once the required testing has been completed and all problems corrected, at least one engine should be started and run for the design seven days at a nominal load of 3,500 KW.

The actions taken by Delaval to eliminate these quality-related problems should also be determined and evaluated. This would ensure problems with future spare parts will not occur.

To provide the confidence factor that the emergency diesel engines will operate reliably, the periodic surveillance testing should be increased to perform a four hour load test each month. If at the end of six months no failures have occurred, return to the surveillance testing specified in the technical specifications.

GENERAL REVIEW OF PROBLEMS

394 - A memo in this package from a Delaval representative indicates the casing discharge on a jacket water pump was found partially blocked by excess casting material.

442 - E&DCR-F41289 - attached to this package indicates Delaval supplied a jacket water pump with the wrong impeller.

551 - (See LDR-0832) - A memo attached to this package indicates a jacket water pump had been assembled with an extra washer behind the impeller castle nut and that the impeller had been machined to the wrong drawing which had been provided by Delaval. A second pump failed and investigation showed the impeller had been improperly installed at the factory.

577 - A Delaval Failure Analysis Report (attached to E&DCR-F43525) indicates the jacket water pump shaft failure was induced by an improperly tightened impeller hub nut. (There were no records to indicate this pump had been disassembled since it left the factory.)

LDR-816 - This deficiency report indicates incorrect springs were installed on the internal relief valves of the engine driven fuel oil pumps.

359 and 360 - (See LDR-654) - During a pre-start inspection of the gear cases, it was found that two of the engines were missing some fitted bolts required on the cam gear. Delaval drawings require drilling holes and installing and torquing these bolts after final engine timing.

701 & 702 - (See LDRs 1006 and 1024) - During inspection of the Governor Drive assembly, the following problems were found:

(a) Ccupling grid was broken due to misalignment of the governor

(b) A key of the wrong size was found installed on one engine

VI. GENERAL RECOMMENDATIONS

Background:

During the review of the Diesel Generator operations, testing and maintenance, a number of conditions were observed which did not specifically violate or deviate from requirements but which did, in the opinion of the inspector, indicate weakness or areas which could be improved. Other conditions in this category are those for which insufficient information was available to make a judgement and should be considered for further evaluation.

Summary:

The following list of observations and recommendations should be considered for further evaluation and/or possible corrective action:

Recommendation #1: Repair/Rework Requests do not reference specific repair procedures. They normally only reference the Diesel Construction specification SHI-089. This makes it difficult or impossible for either Q/A inspectors or other reviewer/auditors to determine what instructions were actually to be followed. A system that requires identifying the specific repair procedures would be a major improvement. This would allow Q/A personnel to review the specific procedure and establish hold/witness points as necessary. This could be similar to the procedure for Maintenance Work Requests.

Recommendation #2: Based on the problems identified in the 1975 audit of Delaval of the failure to have calibrated torque wrenches plus the lack of adequate documentation in maintenance records for torque value makes it impossible to ensure all components have been properly torqued. Based on the work completed to date, it is recommended that all components/ parts should have their torque values verified by analysis or tests.

Recommendation #3: As stated in other sections of this report, some problems or failures are still being experienced when an engine is run for testing. Some problems result in the engine being shutdown for

(c) A coupling half was found pinned to the coupling adapter although this pin was not shown on the Delaval Drawing.

712, 744, 408, 636, 661, 663, 670, 714, 715 and 717 - (See LDRs 1040, 1065, 1056 and 1141) - Part of the problems with the cracked cylinder heads was attributed to manufacturing defects and thin castings. The factory inspections and testing had failed to identify these deficiencies.

046 - (See LDR-0503) - Lube oil cooler tubes leaked due to improper rolling of tubes into the tube sheet which were not identified by vendor quality control.

236 - (See LDR-0560) - The lube oil pump suction line on one engine was found without a drilled passageway for the relief valve. This problem was attributed to an oversight at the factory.

351 - During a routine gear inspection, an extra loose bolt was found in the gear train. The bolt was badly beaten and chipped.

convenience to correct the problem. Other problems such as lube oil line failure and jacket water temperature pneumatic switch failure resulted in immediate engine shutdown. Testing/operation should continue until the engines all operate reliably. After all work and testing is completed, it is recommended that at least one emergency diesel generator should be started and run for seven days at about 3,500 KW. If a failure occurs, testing should continue until all three engines have demonstrated their ability to operate reliably under load for the seven-day period.

Recommendation #4: Obtain the results of audits performed on Delaval by other utilities and evaluate their findings and corrective actions (i.e., Texas Utilities, Gulf States Utilities and San Diego Gas & Electric). Based on this information, determine the need for further additional audits of Delaval.

Recommendation #5: The engine exhaust inlet and outlet elbow from the turbocharger are uninsulated and could present a fire hazard from a fuel oil or lube oil line failure. The need for insulating this area should be reconsidered or some other assurance provided that shows such a fire could not occur.

Recommendation #6: There is a substantial opening (about four (4) inches wide and several feet long) between the flywheel and the protective cage around the generator. Since this opening is on the top of the generator adjacent to the baring device, it presents a possibility of items falling into the generator causing damage or short circuits. Consideration should be given to install a protective cover over this opening.

Recommendation #7: In several of the problems/failures which Long Island Lighting Company has experienced, Delaval already had an improved/ upgraded replacement part which effectively eliminated the problem. S&W and LILCO should make a strong effort to have Delaval supply them with a list of modifications, design changes, product upgrade, etc. which have been made to this type of engine since the LILCO engines were manufactured. LILCO and S&W could then review this list and decide which of the modifications they want to implement.

Recommendation #8: During operation, a significant number of fuel oil and lube oil leaks are apparent. These leaks keep one individual busy cleaning up. During an emergency, personnel may not be available to keep these leaks cleaned up. This could result in substantial accumulations presenting a fire hazard. Action should be taken to eliminate as much of this leakage as practical.

Observation #1: Some of the LILCO Maintenance Support Division personnel have completed a diesel maintenance training program a few months ago. There was insufficient time available to determine the diesel experience or training for maintenance personnel from the construction groups who have also performed repair work on the diesels.

Observation #2: As noted in other portions of this report, there are examples that vendor field representatives operate somewhat informally at times in directing repairs. While he is assigned in the field, the Delaval representative is not clearly under the umbrella of the Delaval factory quality assurance plan. The utility (LILCO) personnel tend to accept his comments/actions since he is the "vendor expert". When a Delaval representative is performing or directing work at the site, his actions should comply with the LILCO Q/A Program just the same as any other plant worker.

Observation #3: The jacket water pumps do not have unique serial numbers making it very difficult or impossible to maintain traceability especially during multiple pump changeouts or maintenance.

Observation #4: The FSAR response to NRC question (request) 223.85 states, "As shown on Figure 9.5.7-1, a check valve prevents lubricating oil from being circulated through the turbocharger" when shutdown. However, a subsequent modification (E&DCR F-34540) has now added a small lube oil supply to the turbocharger in the shutdown condition. This response and figure should be reviewed and revised as necessary.

Observation #5: In general, it was felt that the quality assurance, engineering and testing administrative procedures that applied to

start-up activities were weakly implemented. A specific concern is the fact that most of the problems identified in this report have existed for over a year and were not identified and corrected by supervisory reviews or the audit program.