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NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

RELATED CORRESPONDENCE

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DOCKET NUMBER 50-322 OL

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

Dear Administrative Judges:

The Staff submits the following information pursuant to the Board's Memorandum and Order dated August 21, 1984.

The NRC staff's proposed witnesses are Dr. Carl Berlinger, Dr. Spencer J. Bush, Mr. Adam J. Henriksen, Dr. Walter W. Laity, and Professor Arthur Sarsten. Because of potential scheduling conflicts for Dr. Bush and Professor Sarsten, the NRC staff may seek, at the beginning of evidentiary hearings, to present the testimony of Dr. Bush and Professor Sarsten out of order.

Dr. Bush's testimony addresses metallurgical considerations related to crankshaft fabrication and shotpeening, crack initiation and propagation, and nondestructive examination.

Mr. Henriksen's testimony addresses the technical adequacy of the four components discussed in Suffolk County's contentions, excluding analytical methods for fracture mechanics and stress analysis.

Dr. Laity's and Dr. Berlinger's testimony addresses the technical assistance that the Pacific Northwest Laboratory is providing to the NRC staff in the review and evaluation of Transamerica Delaval, Inc. (TDI) emergency diesel generators.

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Professor Sarsten's testimony addresses stress analysis of diesel engine components and standards for the design of crankshafts.

The Staff's testimony is organized in the following manner: First, the technical assistance that the Pacific Northwest Laboratory (PNL) is providing to the NRC staff is discussed. This is followed by a summary of the premises on which this testimony is based. Suffolk County's contentions admitted by the Atomic Safety and Licensing Board are then addressed.

PNL has secured the services of several consultants who have extensive experience in the design, testing, operation, and maintenance of medium-speed diesel engines. The PNL project management team also calls upon experts as necessary in areas such as metallurgy, fracture mechanics, stress analysis, nondestructive testing, and heat transfer. These experts provide advice and counsel to PNL and to the NRC staff on the numerous issues that have been raised in regard to the adequacy of TDI diesel generators as emergency power sources for nuclear systems.

In the preparation of this testimony, the witnesses have reviewed the testimonies filed by Suffolk County and by Long Island Lighting Company. The witnesses have also reviewed various relevant documents submitted by the TDI Diesel Generator Owners' Group to the NRC staff, and participated in meetings of the Owners' Group with the Staff. Two of the witnesses (Henriksen and Laity) have examined key components of the TDI diesels at the Shoreham Nuclear Power Station during engine disassemblies.

The testimony of the NRC staff's witnesses can be summarized as follows:

In summary, the information available for our review from LILCO and from the TDI Diesel Generator Owner's Group did not provide an adequate basis for us to reach an unequivocal conclusion regarding the overall adequacy of the Shoreham TDI diesel generators as emergency power sources for nuclear systems. Our reservations pertain to two of the four components in contention: the crankshafts, and the cylinder blocks for the 101 and 102 engines. The following is a brief summary of our position on these components and on the other two components in contention:

o <u>Crankshafts</u>

We have concluded that at rated engine load, the torsional stresses in the crankshafts exceed the DEMA Standard Practices. Although the crankshafts may still perform satisfactorily, we believe that the information available for our review is not conclusive in this regard. One approach that would resolve our concern about the crankshafts would be to test an engine (either the 101 engine or the 102 engine to also resolve concerns about the cylinder blocks) to 10E7 cycles (about 740 hours) at rated load, with the engine operated at 110% of rated load for two hours out of every 24 hours.

On the basis of information presented in LILCO's testimony, we have concluded that neither the first shot peening nor the second shot peening of two of the crankshafts degraded their fatigue resistance. Rather, the second shot peening may have enhanced their fatigue resistance, but in our opinion the effect is not quantifiable from available information.

o Cylinder Blocks

Our reservations about the cylinder blocks stem from unresolved questions as to whether or not existing cracks in the camshaft gallery are benign. Pending a more definitive explanation of the origin of these cracks, the stresses in the area where they are located, and the predicted path of crack propagation, we do not have an adequate basis for drawing a conclusion about the suitability of these blocks for nuclear standby service.

Operating experience with the Shoreham engines and with TDI engines at other nuclear power stations suggests that ligament cracks present in the 101 and 102 blocks between the cylinder liner counterbore and the head studs will arrest. This assumes that the material in the cylinder blocks conforms to specifications for ASTM class 40 gray-iron castings. If the ligament cracks arrest, the probability of a crack initiating between studs for adjacent cylinders and propagating into the block is, in our opinion, very low because of a limited driving force. However, the blocks should be monitored for this type of cracking with a nondestructive examination technique capable of detecting subsurface cracks. It is difficult to predict the location of crack initiation, which conceiveably could start at the threads in the holes for the head studs rather than at the surface of the block.

Cylinder Heads

On the basis of known operating experience with TDI heads, we have concluded that problems in service are indicative of manufacturing defects rather than design deficiencies. Subject to nondestructive examinations of the firedecks of all cylinder heads at Shoreham, use of heads with no through-wall weld repairs of the firedeck, and surveillance after each time an engine is operated to detect coolant leaks into the cylinders, we have concluded that the heads are suitable for nuclear service through to shutdown for the first refueling.

Piston Skirts

On the basis of operating experience in the R5 test engine at TDI with piston skirts similar in design to the AE piston skirts installed in the Shoreham engines, and subject to nondestructive examination of all pistons in the area of the stud bosses, we have concluded that the AE piston skirts are suitable for nuclear service through to the shutdown for the first refueling.

Based on the testimony summarized above, the NRC staff believes that these components may be qualified for nuclear standby service at Shoreham if: (1) an engine (either the #101 or #102) is tested at its rated load (either the current FSAR value or a new lower value), (2) the engine block is inspected using non-destructive techniques before and after the test to characterize the cracks in the block, and other key engine components are inspected after the test, (3) the engine block is instrumented during the test with strain gages, (4) the applicant provides additional information to resolve outstanding staff questions concerning the crankshafts and engine blocks, and (5) the applicant performs limited destructive examinations of the old #103 engine block to resolve outstanding staff questions concerning cracks in the blocks. The successful completion of these actions is considered to be confirmatory in nature as they are expected to provide a basis for concluding that these components are satisfactory for their intended service.

The professional qualifications of the NRC Staff's proposed witnesses are enclosed.

Sincerely,

Richard J. Goddard
Counsel for NRC Staff

Enclosure: As Stated

cc: (w/enclosure)

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

August 13, 1984

Docket Nos.: 50-322/416-417/206/312/458-459/400-401/413-414/440-441
50-438-439/445-446/424-425/329-330/460

Mr. J. B. George, Chairman
Transamerica Delaval, Inc.
Owners Group
Texas Utilities Generating Company
Post Office Box 1002
Glen Rose, Texas 76043

Dear Mr. George:

SUBJECT: SAFETY EVALUATION REPORT, TRANSAMERICA DELAVAL, INC.
DIESEL GENERATOR OWNERS GROUP PROGRAM PLAN

Enclosed is the staff's evaluation of the Transamerica Delaval, Inc. Owners Group Program Plan submitted on March 2, 1984. The evaluation addresses the resolution of known problems and the design review/quality revalidation program, Phases 1 and 2 respectively of the program plan. Additionally, it addresses engine testing and inspections, maintenance and surveillance, and administrative controls that are deemed necessary to assure diesel engine reliability. The SER also sets forth requirements to ensure diesel engine reliability for owners seeking to operate their plants prior to completion of the Owners Group Program Plan and staff review of that plan.

Any future findings and recommendations from the Owners Group will be evaluated in subsequent Safety Evaluation Reports. The staff will continue to issue plant-specific Safety Evaluation Reports regarding the reliability of the TDI diesels.

Sincerely,

Darrell G. Eisenhut, Director
Division of Licensing

Enclosure:
As stated

cc w/enclosure:
C. Ray, TDI
W. Coleman, TDI

SAFETY EVALUATION REPORT

TRANSAMERICA DELAVAL, INC.

DIESEL GENERATOR OWNERS GROUP PROGRAM PLAN

1.0 INTRODUCTION

Thirteen nuclear utilities that own diesel generators manufactured by Transamerica Delaval, Inc. (TDI) have established an Owners Group to address questions raised concerning their reliability, operability and quality assurance. On March 2, 1984, the Owners Group submitted a plan to the U. S. Nuclear Regulatory Commission (NRC) (Ref. 1) which, through a combination of design reviews, quality revalidations, engine tests and component inspections, is intended to provide an in-depth assessment of the adequacy of the respective utilities' TDI engines to perform their safety related function.

This Safety Evaluation Report (SER) is a review of the proposed Owners Group Program Plan (OGPP), and presents the staff's evaluation and conclusions on the requirements for interim and full-term licensing of TDI diesel generators.

2.0 BACKGROUND

Concerns regarding the reliability of large bore, medium speed diesel generators manufactured by TDI for application at domestic nuclear plants were first prompted by a crankshaft failure at Shoreham in August 1983. However, a broad pattern of deficiencies in critical engine components have since become evident at Shoreham and at other nuclear and non-nuclear facilities employing TDI diesel generators. These deficiencies stem from inadequacies in design, manufacture and QA/QC by TDI.

In response to these problems, eleven (now thirteen) U. S. nuclear utility owners formed a TDI Diesel Generator Owners Group to address operational and regulatory issues relative to diesel generator sets used for standby emergency power. The Owners Group program was initiated on October 25, 1983 at a technical information exchange meeting held in Atlanta, Georgia. This information exchange meeting involved 59 industry representatives, including personnel from 26 utilities as well as the Institute of Nuclear Power Operations, NRC and Nuclear Safety Analysis Center/Electric Power Research Institute. The organization of the Owners Group is outlined in a Project Interface Document (Ref. 2)

3.0 OWNERS GROUP PROGRAM DESCRIPTION

The Owners Group program embodies three major efforts as follows:

1. Phase I: Resolution of 16 known generic problem areas intended by the Owners Group to serve as a basis for the licensing of plants during the period prior to completion and implementation of the Owners Group program.

2. Phase II: A design review/quality revalidation (DR/QR) of a larger set of important engine components to assure that their design and manufacture; including specifications, quality control and quality assurance and operational surveillance and maintenance, are adequate.

3. Identification of any needed additional engine testing or inspections; based on findings stemming from the Phase I and II programs.

3.1 Phase I - Resolution of Known Generic Problems

On the basis of a review of accumulated data on TDI diesel generator operating experience from industry sources (nuclear, marine, stationary), the Owner's Group has identified 16 components with problems that have potential generic applicability. The components are as follows: Air Start Valve Capscrews, Connecting Rods, Connecting Rod Bearing Shells, Crankshaft, Cylinder Block, Cylinder Heads, Cylinder Head Studs, Cylinder Liner, Engine Base and Bearing Caps, Engine Mounted Electrical Cable, High Pressure Fuel Oil Tubing, Jacket Water Pumps, Piston Skirts, Push Rods, Rocker Arm Capscrews and Turbochargers.

Included in the OGPP is a task description for the design review of each of these components, and a summary of the analysis, testing, and inspection planned for each component in the lead engine. Under the lead engine concept the design would be verified through analyses, testing, and inspection of one engine (the "lead" engine) and the verification would be considered applicable to other engines equipped with the same components and operated under the same conditions (the "following" engines) which would, therefore, require only limited confirmatory verification.

As stated in the Plan, the Owners Group recommends that these known generic problems be resolved before placing the engines in service to support full-power operation of a nuclear plant. However, exceptions are considered permissible by the Owners' Group to the extent that interim operation prior to problem resolution may be justified by any owner.

3.2 Phase II - Design Review/Quality Revalidation

The second element of the OGPP, Design Review/Quality Revalidation, entails a review of components other than those already identified as known problems (Section 3.1, above). Through a process that considers the function of each component, its role in the overall operation of the engine, known performance data, and the engineering judgment of the Owners Group Component Selection Committee, components are selected for design review and/or quality revalidation to assure that they have been adequately designed and fabricated.

According to guidelines established by the Owners Group, a component is normally selected for DR/QR if its failure would result in engine shutdown ("Type A" component). The Component Selection Committee determines whether or not DR/QR is required for a component if its failure could result in reduced engine capacity ("Type B"). DR/QR is generally not required for a component if its failure would have little effect on engine performance ("Type C").

3.3 Engine Testing and Inspection

The OGPP addresses engine testing in two sections. First, the "Testing Program Summary" of the Plan states that technical staff will use results of component evaluations to establish testing/inspection requirements for "lead" engines, and that these results will dictate the need for tests and inspections of "following" engines. The specific test plans will result from NRC/owner interactions. Second, for the known problem resolution tests, a test inspection plan is provided for engines at eleven nuclear stations in the series of tables in Section III and Appendix 6 of the Plan (Reference 1). Testing of the 16 components with known problems would be for 100 hours at 100% power but in some cases components would be tested on more than one lead engine and could be tested to 300 hours. Additionally, some number of starts would be part of the confirmatory tests on the lead engine. "Following" engines would only have to go through preoperational testing specified by TDI and NRC if all components in the engine could be verified as being similar to components already tested in lead engines. (It is the staff's understanding that this test program has evolved somewhat since Appendix 6 of the plan was written. The staff notes, however, that plant-specific submittals will identify tests and inspections actually performed.)

4.0 NRC STAFF EVALUATION

Enclosure 1 to this SER is a Technical Evaluation Report (TER) entitled, "Review and Evaluation of TDI Diesel Generator Owners Group Program Plan," (PNL-5161) of March 2, 1984. This TER was prepared by Pacific Northwest Laboratory (PNL), which is under contract to the NRC to perform technical evaluations of the TDI Owners Group generic program, in addition to plant-specific evaluations relating to the reliability of TDI diesels. PNL has retained the services of several expert diesel consultants as part of its review staff.

The NRC staff has reviewed the OGPP and the enclosed TER by PNL. The Safety Evaluation herein addresses the scope and strategy of the OGPP for purposes of achieving a resolution of the existing concerns relating to the reliability of diesel generators manufactured by TDI. Specific findings and recommendations from the Owners Group Program review will be evaluated in subsequent Safety Evaluation Reports by the staff.

Based on its review, it is the staff's overall finding that the OGPP incorporates the essential elements needed to resolve the outstanding concerns relating to the reliability of the TDI diesel generators for nuclear service, and to ensure that the TDI diesel engines comply with GDC 1 and GDC 17. These essential elements include (1) resolution of known generic problems (Phase I), (2) systematic design review and quality revalidation of all components important to reliability and operability of the engines (Phase II), (3) appropriate engine inspections and testing as identified by the results of Phase I and II, and (4) appropriate maintenance and surveillance programs as indicated by the results of Phase I and II.

Certain plants will be requesting a full power operating license prior to completing implementation of the Owners Group Program. Section 4.6 provides the staff's evaluation of considerations which must be addressed by individual utility owners to ensure the reliability of the TDI engines for an interim period pending staff review and approval of findings from the Owners Group Program and of owner specific actions to resolve the TDI engine issues.

4.1 <u>Phase I - Resolution of Known Problems</u>

As stated by the Owners Group and PNL, the staff agrees that resolution of known problems is a major element of the effort necessary to establish the reliability of the TDI engines.

The Owners Group to date has identified 16 components with known generic problems which it considers to be of most significance and deserving of priority attention as a basis for licensing. In addition to components included among these 16, PNL has identified the engine gears as another engine component which is of particular importance to the reliability and operability of the engines and which also warrants careful attention. The staff notes, however, the gears will be included within the scope of the Phase II program for each plant. In the absence of reported engine failures attributable to gears, the staff concludes that gears need not be folded into the Owners Group Phase I program for priority attention. However, the condition of the gears should be inspected prior to the licensing of each facility (see Section 4.6, "Interim Bases for Licensing").

The Owners Group has submitted reports addressing each of the 16 problem areas currently identified as part of Phase I. However, as noted in Section 2.1.2 of the enclosed TER, some reports have lacked information regarding fundamental aspects of the identification and resolution of problems. As guidance, key considerations which should be addressed as part of the Owners Group resolution of these issues are identified on page 7 of the enclosed TER. To complete its reviews, the staff has requested the information necessary for PNL and the staff to complete its review. Upon completion, the staff will issue safety evaluations of the proposed Owners Group resolution of each of the Phase I issues.

The staff concludes that in view of the critical importance of many of the Phase I components to the operability and reliability of the diesel engines, the TDI engine owners must satisfactorily address these known problem areas as a condition for licensing (See Section 4.6).

4.2 Phase II - Design Review and Quality Revalidation

The NRC staff concurs that in view of concerns regarding design manufacturing and QA deficiencies by TDI, the DR/QR program is needed to ascertain the design and quality of key engine components, beyond those specifically being addressed as part of Phase I. PNL will perform an audit review of the final Phase II submittals consisting of an independent review of 10 to 20 key components. The results of this audit review will be reviewed by the NRC staff. The staff's review of PNLs audit review will form the basis of the staff findings regarding the adequacy of the DR/QR program and, depending upon the outcome of the audit review, whether the scope of the review should be expanded. The staff has concluded that the audit review strategy proposed by PNL will be adequate to ensure that the DR/QRs are adequately thorough and complete and that Owners Group recommendations stemming from the DR/QR tasks are appropriate.

Because known problem areas will be well addressed by all owners prior to licensing (see section below, "Interim Basis for Licensing), the staff has concluded that staff review and approval of the Phase II results should not be a requirement for licensing of near term operating license applicants. However, the staff will condition the operating licenses to require staff review and approval of the plant-specific Phase II programs prior to restart from the first refueling outage.

4.3 Engine Testing and Inspections

Based on the current status of reviews being conducted by PNL on the Phase I reports submitted by the Owners Group, calculated design margins for some key engine components do not provide sufficient confidence by themselves to ensure the adequacy of the component design. This is particularly true since the analyses submitted by the Owners Group to date are intended to support engine operation at 100% of full rated load.

In the enclosed TER, PNL has recommended testing of a "lead engine" for 10^7 cycles to verify design adequacy. The staff agrees that operating experience is a key ingredient for verifying design adequacy of key components, especially in cases where supporting analyses indicate relatively small design margins, or in cases where significant uncertainties exist. However, the staff concludes that the need for additional testing for each of the key engine components must consider the analyses performed, the uncertainties in the analyses, and relevant operating experience.

The staff notes that for many plants, the maximum emergency service load requirements for worst case loss of off-site power or loss of off-site power and Loss of Coolant Accidents are significantly less than the engine name plate rating. Realistic consideration of the maximum engine load requirements in the conservative supporting analyses would reveal enhanced design margin relative to the margins which exist at 100% of rated load. Furthermore, it may be possible to establish that these maximum load requirements fall within the envelope of relevant operating experience for engines where key components of the same design have operated successfully for extended periods (i.e., beyond 10^7 operating cycles). Thus, for plants where the engine load requirements are less than the load rating of the engine, it may be possible to demonstrate adequate assurance of component reliability at a "qualified load" exceeding the maximum emergency service load requirements without having to rely on additional testing of a "lead engine." Where the "qualified" load is less than the full rated load of the engines, however, it would be necessary for applicants to propose changes to the engine operating procedures and to the Technical Specifications to ensure that the engines are not unnecessarily loaded above the "qualified load" during emergency service and surveillance testing.

The staff will incorporate the results of the Phase I program into its evaluation of the need for additional testing and inspection during Phase II. In the interim, test and inspection considerations pertinent to plant licensing are addressed in Section 4.6.

4.4 Maintenance and Surveillance Program

A comprehensive maintenance and surveillance program is a key aspect to ensuring the continued reliability and operability of the diesel generators for the life of the plant. Surveillance and maintenance requirements are addressed in the DR/QR report to the owners for the components considered in a particular engine. The owner is expected to consult with the manufacturer, the engine manual, in addition to the surveillance and maintenance schedules in the DR/QR report, to develop his plant-specific surveillance and maintenance program. The staff will review the maintenance and surveillance programs as part of its review of the Phase II reports for the individual plants. Pending the staffs review and approval of these programs, the staff will require implementation of an augmented program as part of an interim basis for licensing (See section 4.6 below).

4.5 Administrative Controls

In the enclosed TER, PNL has made a number of comments pertaining to administrative control aspects of the Owners Group Program.

1. Provisions for addressing new problems that arise during the program should be addressed.

2. Formal criteria [illegible] disseminating corrective actions to all members of the Owners Group should be established.

3. Formal criteria should be established by the Owners Group to assure corrective actions have been implemented for all applicable engines.

4. The Owners Group Program Director should personally ensure that technical reports address all pertinent issues, including those identified by PNL on page 7 of the TER, and is complete within itself.

With regard to comment No. 1, the NRC staff notes that there is a procedure established by the Owners Group in a Project Interface Document, Attachment 5 "Policy for Communicating Plant Specific Concerns/Recommendations Having Generic Implications" (Reference 2) which the staff concludes adequately addresses the PNL comment. Specifically, the "Project Interface Document" establishes a formal procedure for ensuring that new concerns of a potential generic concern are brought to the attention of the Owners Group. Upon receipt, the Owners Group will evaluate what, if any, Owners Group actions are warranted. The Owners Group will notify the owners of the new concern and identify the actions taken.

With regard to item 2, the staff finds that issuance of the Phase I and II reports by the Owners Group will ensure that recommended corrective actions are disseminated to all members of the Owners Group.

With regard to item 3, the staff notes that it is the responsibility of the utility to implement the Owners Group recommendations as the utility deems appropriate. The staff will require that the utilities document their actions relative to the Owners Group recommendations. The staff will review the acceptability of the utility actions and issue plant-specific SERs.

With regard to item 4, the staff feels the Owners Group Technical Program Director should sign all reports to the NRC to signify that he has personally verified that all pertinent issues have been addressed and that the report is complete unless otherwise indicated. As previously discussed, PNL and the staff have found that some of the early Owners Group submittals have been inadequate in some respects. This has been communicated to the Owner's Group. To facilitate the PNL and staff review of these reports, it is clearly to the benefit of the Owners that the reports address all pertinent topics. PNL and the staff will make final conclusions concerning the technical issues only after all pertinent issues have been satisfactorily addressed by the Owners Group.

4.6 Interim Basis for Licensing

Based on the staff and PNL review of the Owners Group Program Plan and of the status of the Owners Group efforts to resolve significant known problems (i.e. Phase I), the staff concludes that it should generally be possible for individual owners to ensure the reliability of their TDI engines for an interim period pending staff review and approval of findings from the Owners Group program and of owner specific actions to resolve TDI engine issues. The interim basis for licensing shall include the following elements:

1. For engines where emergency service load requirements involve a BMEP greater than 185 psig, the utility shall provide information demonstrating that crankshafts, pistons and other key engine components (as identified below) which are of the same design as those in the subject engines have operated successfully for at least

10^7 loading cycles under loading conditions which meet or exceed the severity of the maximum emergency service load requirements for the subject engines. For purposes of this SER, this load level (i.e., the load level above a load corresponding to 185 psig BMEP enveloped by successful operating experience) will be referred to as the "qualified load" for the subject engine. Where appropriate operating experience does not already exist relative to this qualified load, a test of an engine with the same designs of these key components for 10^7 cycles will be required to establish an adequate "qualified load" for the subject engines.

The staff will consider excepting engines from this requirement on a case-by-case basis where the 185 psig BMEP criterion is exceeded only for brief periods of time.

In addition to pistons and crankshafts, the subject 185 psig BMEP criterion may also be made applicable to other components (e.g. connecting rods and engine block) as determined through interaction between the utility and the NRC. Pertinent considerations for this determination include predicted component design margins, analysis uncertainties, and the capability for periodic and effective component surveillance.

The 185 psig BMEP criterion above reflects existing PNL and staff concerns regarding the limited design margin available to certain key engine components, particularly the piston skirts and crankshaft, while the engine is operated at full rated load. With regard to the piston skirts, however, AE piston skirts have accummulated in excess of

6000 hours without failure. A substantial portion of this load has been accummulated at loads corresponding to 185 psig BMEP. PNL has also concluded that pending the evaluation of crankshaft stresses at higher loads, 185 psig BMEP is considered to be conservative.

The staff and PNL have not yet made conclusions regarding the applicability of the R-5 engine experience with AE piston. However, even if the staff finds that the R-5 experience verifies the adequacy of AE piston skirts at full rated load, the 185 psig BMEP criterion above would remain operative in view of concerns regarding other key components, particularly the crankshaft.

2. For engines with non-AE piston skirts, the utility shall provide information that piston skirts of the same design have operated successfully for at least 10^7 cycles under loading conditions which meet or exceed the maximum emergency service load requirements for the subject engines. Where appropriate operating experience does not exist, a test of an engine with the same piston design for 10^7 cycles will be required to establish an acceptable qualified load for the subject pistons. The staff will consider excepting engines from this requirement where utilities can satisfactorily demonstrate to the NRC acceptable design margin for the pistons for the maximum emergency service load requirements.

3. Appropriate changes to engine operating procedures should be implemented to ensure that the engines are not loaded unneccessarily above 185 psig BMEP, or above "qualified load" (see items 1 and 2 above) as justified on the basis of analysis of critical component operational data.

4. The plant Technical Specifications should be revised to limit testing of the engines to 185 psig BMEP, or "qualified load" as appropriate to preclude operating the engines unnecessarily at more highly stressed conditions.

5. Following preoperational testing, the engine with the most operational hours on critical internal engine components shall be subjected to an engine disassembly and inspection. Action to be taken on the other engine(s) of a plant will be contingent upon the results of the inspection conducted on the subject engine, and the owner's ability to demonstrate through a review of the manufacturers QA records, that the engines have similar "as-manufactured" quality.

   The inspections should include as a minimum all components currently being considered as part of the Owners Group Phase I program, plus the engine gears and wrist pin bushings. Other components should be included in this inspection, as approriate, based on any adverse operating experience. The types of inspections to be performed should include those recommended by the Owners Group (e.g., dye penetrant, eddy current, ultrasonic, radiographic, etc) for these components as appropriate based on the types of problems (e.g., cracks, abnormal wear or other distress, inadequate assembly or torqueing, etc.)

which have previously have experienced on these components at Shoreham, Grand Gulf, and other TDI engines. All parts found with unacceptable defects shall be replaced prior to declaring the engine operable. The engine block and engine base may be excepted if indications are non-critical. Non-critical indications are defined as not causing oil or water leakage, not propagating, and not adversely affecting the ability of the block to support the cylinder liners and stud preload.

A description of the inspections performed and the results should be submitted for NRC staff review and approval prior to plant operation above 5% power. This report should address all indications found and the engineering basis for acceptance or rejection of the subject components. Where the type of inspections or acceptance criteria deviate from Owners Group recommendations, this should be specifically identified and justification provided.

6. Following engine reassembly, "hot" and "cold" crankshaft deflection measurements shall be taken to verify that the crankshaft alignment is within manufacturer's recommendations. The hot deflection measurements should begin within 15 to 20 minutes of engine shutdown. In addition, a torsiograph test should be performed. To the extent not already included as part of the manufacturers recommendations or plant Technical Specification requirements, the following engine tests shall be performed to demonstrate operability of the engine:

- 10 modified starts to 40% load

- 2 fast starts to a load greater than or equal to the maximum emergency service load but not to exceed a load corresponding to 185 psig BMEP or "qualified" load.
- 1 24-hour run at a load greater than or equal to the maximum emergency service load but not to exceed a load corresponding to 185 psig BMEP or "qualified load."

A modified start is defined as a start including a prelube period as recommended by the manufacturer and a 3- to 5-minute loading to the specified load level, with operation at the level for a minimum of 1 hour. A fast start is one conducted from the control room on simulation of an Engineered Safety Feature (ESF) signal with the engine on ready standby status. The engine should be run for 4 hours for each fast-start test. The 24-hour run is recommended to detect abnormal temperatures, pressures, and/or temperature excursions that might indicate abnormal engine behavior. Either a modified or a fast start may be utilized.

7. The engine maintenance and surveillance program to be implemented during the (interim) period prior to final resolution of the TDI engine concerns shall be submitted for NRC staff review and approval. Appendix A provides an example of a program which was recently approved for Grand Gulf.

Proposed exceptions or modifications to the above interim bases will be considered by the staff where adequate justification is provided. The staff will review owner actions relative to the above bases for interim operation and issue a safety evaluation prior to authorizing plant operation.

5.0 CONCLUSIONS

Based on its review of the Owners Group Program Plan (OGPP) and of PNL's evaluation of the plan, the staff concludes that the OGPP incorporates the essential elements needed to resolve outstanding concerns relative to the reliability of the TDI engines for nuclear service, and to ensure that the TDI engines comply with GDC 1 and GDC 17. Specific findings and recommendations stemming from the Owners Group Program will be evaluated in subsequent Safety Evaluation Reports by the staff.

A number of owners are seeking operating licenses and/or authorization to operate their plants prior to the completion of the Owners Group Program and the staffs review of that program. The staff has concluded that sufficient progress has been made by the Owners Group to resolve known problems with TDI engines such that the NRC can proceed with licensing of these plants for at least one operating cycle subject to the conditions identified in Section 4.6 of this SER. Operation beyond the first refueling cycle will be subject to license conditions requiring staff reviews and approval of licensee actions to verify and enhance the reliability of the TDI engines.

7.0 REFERENCES

1. TDI Diesel Generator Owners Group Program Plan, March 2, 1984.

2. Letter C. L. Ray, Jr. (Duke Power) to H. R. Denton (NRR) OG TP-82, June 20, 1984, Re: TDI Diesel Generator Owners Group Technical Program Management Project Interface Document.

3. Transcript of TDI Diesel Generator Owners Group meeting held July 11, 1984, page 110, lines 5-25; page 111, line 1.

APPENDIX A

AUGMENTED MAINTENANCE - SURVEILLANCE PROGRAM

The following maintenance and surveillance actions are provided as guidance to augment the maintenance program recommended by TDI. Alternate actions may be justified on the basis of plant-specific maintenance practices, design and experience. The overall goal of the augmented maintenance program should be to stagger the testing and surveillance to prevent both diesels from being out of service at the same time, and ensure reliability of the diesels while minimizing their unavailability.

Action	Frequency
1. Air-roll Engine (Cylinder Heads)	At 4hr and 24hr after each shutdown and prior to planned start.
2. Visually inspect external engine block and base for oil and water leakage. 3. Sample lubricating oil at lube oil filter inlet when engine is running - chemical analysis by qualified laboratory.	Monthly, or after every 24hr of engine operation, whichever comes first.
4. Routinely sample lubricating oil - chemical analysis by qualified laboratory and sump water check. 5. Record lube oil filter differential pressure.	Monthly
6. Visually inspect all connecting rods and check for preload relaxation.	After 200 hours of engine operation or 9 calendar months, whichever comes first, and prior to power levels above 5%.
7. Check 25% of cylinder head studs and 100% of air-start valve capscrews for preload relaxation. 8. Visually check cams, tappets and pushrods. 9. Check hot and cold crankshaft deflections. 10. Check rotor float for one turbocharger and inspect stationary nozzle ring bolts.	After 270hr of engine operation or each refueling outage, whichever comes first.

Action	Frequency
11. Record engine operating parameters: a. engine inlet lube oil pressure b. turbo L.O. R.F. pressure c. turbo L.O. L.F. pressure d. fuel oil pressure e. fuel oil filter differential pressure f. air manifold pressure L.B. g. air manifold pressure R.B. h. lube oil filter differential pressure i. jacket water pressure (inlet and (outlet) j. crankcase vacuum k. all cylinder exhaust temperatures l. stack temperatures at turbine inlet m. lube oil temperature (inlet and (outlet) n. jacket water temperature (inlet and outlet) o. tachometer p. hourmeter q. engine load	During surveillance test, record parameters hourly, unless more frequent recording is recommended by manufacturer.
12. Clean and inspect "Y" strainers in starting air system.	Quarterly
13. Flush jacket water system	Three to four years.

ENCLOSURE 1

PNL-5161

Review and Evaluation of TDI Diesel Generator Owners' Group Program Plan

June 1984

Prepared for
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June 1984

Prepared for
Division of Licensing
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
under Contract DE-AC06-76RLO 1830
NRC FIN B2952

Project Title: Assessment of Diesel Engine Reliability/Operability

NRC Lead Engineer: C. H. Berlinger

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PACIFIC NORTHWEST LABORATORY

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The above consultants concurred on an unedited version of this report.

ABSTRACT

This report documents a review, performed by the Pacific Northwest Laboratory (PNL), of the Transamerica Delaval, Inc. (TDI) Diesel Generator Owners' Group Program Plan. This report was prepared as part of the technical support PNL is providing to the U.S. Nuclear Regulatory Commission (NRC), Division of Licensing, on matters pertaining to the reliability of TDI diesel generators as emergency power sources for safety-related nuclear systems. Dr. Carl H. Berlinger is NRC's TDI Project Group Leader.

The report presents the comments and conclusions reached by PNL, with the advice and counsel of five diesel engine consultants, on the principal elements of the Owners' Group Plan: Generic Problem Resolution, Design Review/Quality Revalidation, and Engine Testing and Inspection. Also included are PNL's comments on the related issues of Surveillance and Maintenance, and Administrative Controls. The conclusions drawn from PNL's evaluation of these issues form the basis for two additional topics addressed in the report: Critical Elements Required to Establish Diesel Engine Operability and Reliability, and Considerations for Interim Licensing.

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REVIEW AND EVALUATION OF
TDI DIESEL GENERATOR OWNERS' GROUP PROGRAM PLAN

1.0 INTRODUCTION

Eleven nuclear utilities that own diesel generators manufactured by Transamerica Delaval, Inc. (TDI) have established an Owners' Group to address questions raised by a major failure in one TDI diesel (at the Shoreham Nuclear Power Station in August 1983), and other problems in TDI diesels. On March 2, 1984, the Owners' Group submitted a plan to the U.S. Nuclear Regulatory Commission (NRC) for "...a comprehensive program which, through a combination of design reviews, quality revalidations, engine tests and component inspections, will provide an in-depth assessment of the adequacy of the respective utilities' TDI engines to perform their intended safety related functions."

At the request of NRC, Pacific Northwest Laboratory (PNL) undertook a project to provide support to NRC staff in addressing questions of TDI diesel generator reliability, operability, and quality assurance. A primary task of the project is PNL's assessment of the TDI Diesel Generator Owners' Group Program Plan.

Summarized in this report are the comments and conclusions reached by PNL, with the advice and counsel of five diesel engine consultants, after our review and evaluation of the Owners' Group Program Plan. We focused our attention on three aspects of the Plan:

- adequacy of the overall approach for identifying and correcting significant problems with TDI diesels, and for verifying the suitability of these engines as power sources for safety-related nuclear systems
- thoroughness of the planned effort for addressing all aspects of TDI diesel operability and reliability that should be covered
- critical elements that should be considered in interim licensing decisions (i.e., licensing prior to completion of the implementation of the Plan).

This report reflects the advice of four PNL consultants in diesel engine technology who met at PNL on May 2 and 3, 1984, to discuss their initial review and evaluation of the Owners' Group Plan, and on June 28, 1984, to discuss this report in its final form. Comments received from NRC on a draft version of this report were considered in the preparation of the final version. The consultants who participated in these meetings are as follows:

- Mr. A. J. Henriksen, private consultant
- Mr. B. J. Kirkwood, Covenant Engineering
- Mr. P. J. Louzecky, Engineered Applications Corporation
- Dr. A. Sarsten, Norwegian Institute of Technology.

Mr. J. A. Webber of Ricardo Consulting Engineers PLC, West Sussex, England, participated in a meeting at PNL on April 2 and 3, 1984, to develop an approach for evaluating the Owners' Group Program Plan. Key issues discussed in that meeting that pertain to PNL's review of the Plan are also incorporated in this report.

Members of the PNL project team who participated in the above-mentioned meetings are:

- W. W. Laity, Project Manager
- J. M. Alzheimer
- M. Clement
- S. D. Dahlgren
- D. A. Dingee
- R. E. Dodge
- J. F. Nesbitt
- J. C. Spanner
- F. R. Zaloudek.

S. H. Bush, a retired PNL staff member currently serving as a consultant to the project, also participated in these meetings on a part-time basis.

2.0 REVIEW OF OWNERS' GROUP PROGRAM PLAN

The Owners' Group Program Plan encompasses three major elements for establishing the adequacy of TDI diesel engines to serve as emergency power sources for safety-related nuclear systems. These elements, and a summary of the action planned by the Owners' Group on each, are as follows:

- Generic Problem Resolution - Evaluate and resolve significant problems with potentially generic applicability that have been identified in 16 components, and prepare reports on these components that will provide a basis for near-term licensing decisions involving TDI diesels.
- Design Review/Quality Revalidation - Through reviews of the Parts Manuals supplied by TDI, identify the critical components of TDI engines in addition to the 16 referred to above and assure that these components are properly designed and fabricated. A comprehensive Component Data Base of parts will be generated for each power plant, and the parts classified into one of three categories, depending on their importance for engine operation.
- Engine Testing and Inspection - Establish special or expanded engine tests and component inspections as appropriate to verify the adequacy of the engines and components to perform their intended functions.

These three elements are illustrated schematically in Figure 1 as part of an overall approach for establishing diesel engine operability and reliability. Included in Figure 1 are factors that warrant attention, according to PNL's consultants, in the action planned to correct deficiencies, verify the adequacy of the corrective action, and apply the lessons learned to all engines of the same class. Many of these factors are included explicitly or implicitly in the Owners' Group Program Plan. These factors and related issues identified in PNL's review of the Plan are discussed under the five subheadings that follow:

- Known Problem Resolution
- Design Review/Quality Revalidation
- Engine Testing and Inspection
- Surveillance and Maintenance
- Administrative Controls.

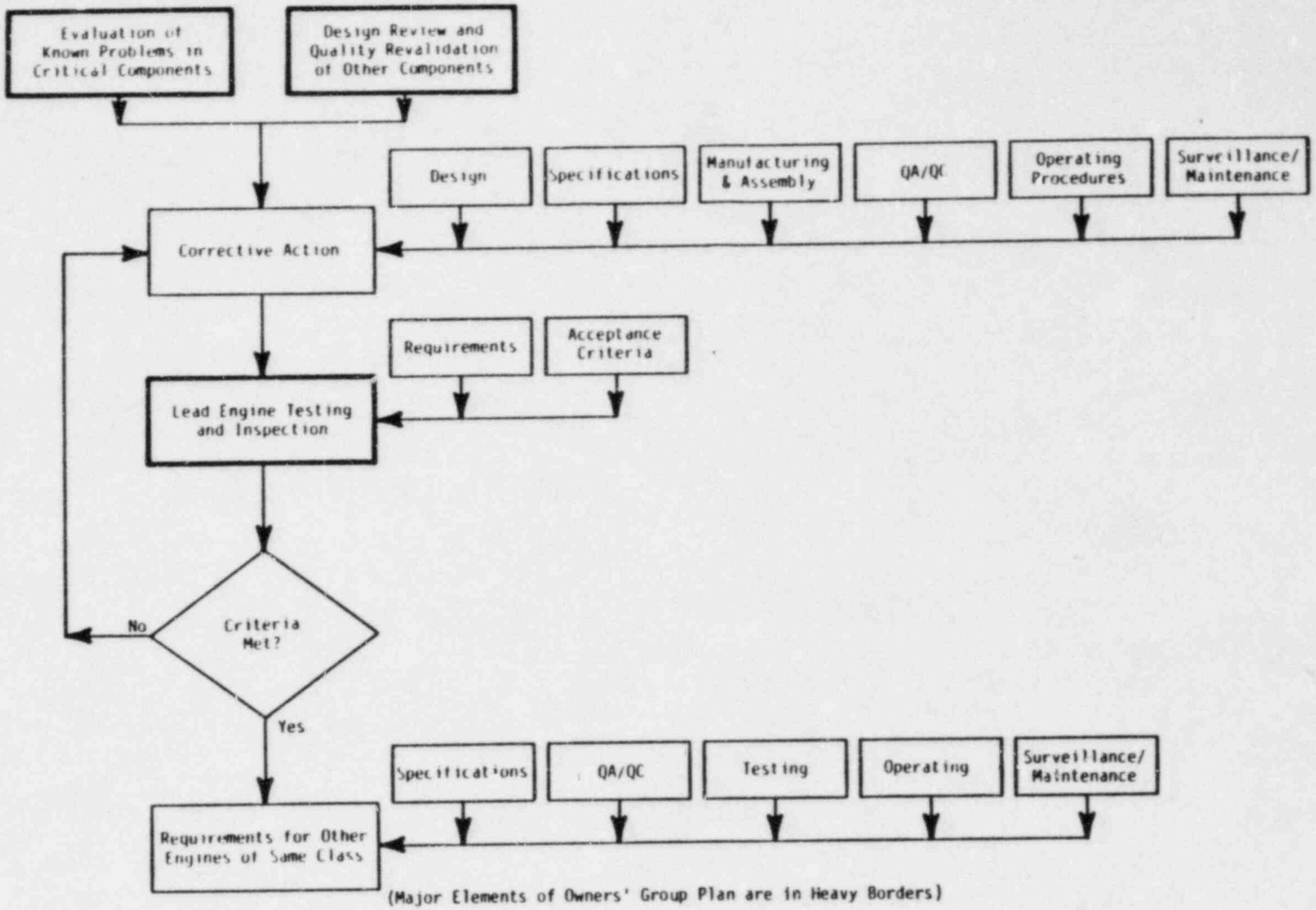

FIGURE 1. Approach for Establishing Diesel Engine Reliability/Operability

2.1 KNOWN PROBLEM RESOLUTION

2.1.1 Owners' Group Plan

On the basis of a review of accumulated data on TDI diesel generator operating experiences from industry sources (nuclear, marine, stationary), the Owners' Group has identified 16 components with problems that have potentially generic applicability. These components are listed in Table 1, together with PNL's estimate of the anticipated complexity in resolving the known problems in each.

Included in the Owners' Group Plan is a task description for the design review of each of these components, and a summary of the analysis, testing, and inspection planned for each component in the lead engine[(a)] of a given model[(b)] and for other engines of the same model. As stated in the Plan, the Owners' Group recommends that these problems be resolved before placing the engines in service to support full-power operation of a nuclear plant. However, exceptions are considered permissible by the Owners' Group to the extent that interim operation prior to problem resolution may be justified by any owner.

2.1.2 PNL Comments

Pacific Northwest Laboratory concurs with the Owners' Group that resolution of known problems is a major element of the effort necessary to establish the operability and reliability of TDI engines. This element takes on added importance if, as stated in the Owners' Group Plan, the reports on these problems "...will provide the bases for the licensing of the early TDI plants...".

(a) Under the lead engine concept, design changes would be verified through testing in one engine (the "lead" engine) and the verification would be considered applicable to other engines equipped with the same components and operated under the same conditions (the "following" engines). Recognizing that corrective actions are not yet identified for all components with known problems, and that components of different design may be used in engines of the same model (e.g., AN piston skirts at Catawba and AE skirts at Grand Gulf), there may be more than one "lead" engine of the same model.

(b) The word "model" as used in this report refers to the manufacturer's designation for a particular engine design (e.g., the DSRV-16 engine).

TABLE 1. Components with Known Problems Identified by Owners' Group

Components with Known Problems	Complexity of Resolution (Anticipated by PNL) Straight-Forward	Intermediate	Complex
1. Piston skirts			X
2. Connecting rod bearing shells		X	
3. Rocker arm cap screws	X		
4. Air-start valve cap screws	X		
5. Cylinder head studs	X		
6. Push rods	X		
7. HP fuel oil tubing	X		
8. Crankshaft			X
9. Turbocharger			X
10. Connecting rods			X
11. Engine base and bearing caps		X	
12. Cylinder heads			X
13. Cylinder liner	X		
14. Cylinder block			X
15. Engine-mounted electrical cable	X		
16. Jacket water pumps	X		

Key considerations that warrant particular attention in the Known Problem Resolution program element include:

- identification of root cause(s)
- corrective action - As illustrated in Figure 1, factors that should be considered as appropriate include design, specifications, manufacturing and assembly, quality control/quality assurance, operating procedures, and surveillance and maintenance.
- basis for corrective action - Design changes should be supported by analysis.
- verification of corrective action - Testing may be a key aspect; it is addressed as a separate element of the Owners' Group Program Plan and is discussed in Section 2.3 of this report.
- TDI engines for which corrective action is applicable - Considerations include engine classification (e.g., R-48), engines in which the component in question is used, rated engine load, and the engine-flywheel-generator assembly for components that transmit shaft power. For example, action to correct a crankshaft problem will apply only to engines of the same type that are rated for the same load, and that are equipped with generators and flywheels with the same torsional vibration characteristics.
- implementation of corrective action for all engines to which it is applicable, and verification of implementation - Formal criteria should be established by the Owners' Group for this process.
- life-cycle performance - Action to assure continued satisfactory performance of the lead engine and other engines of the same class should be identified. A key aspect of this action should be a long-term surveillance and maintenance program appropriate for diesel engines in nuclear service.

The PNL team and consultants reviewed those sections of the Owners' Group Plan pertaining to this program element, as well as reports submitted by the

Owners' Group through May on known problems. We noted the following items, which, in our opinion, warrant additional attention:

- content of reports on known problems - Reports received from the Owners' Group generally lack information on one or more of the fundamental aspects (e.g., those listed above) of the identification and resolution of problems and/or malfunctions. PNL's views on this issue are documented in letters to NRC dated April 18 and June 4, 1984, and were discussed with the Owners' Group during a meeting on April 26. Matters that require clarification or elaboration as identified in letters documenting PNL's reviews of the reports should be addressed by the Owners' Group in written responses, or the reports should be reissued with these responses.

- provision for addressing new problems - According to Section 1[illegible].A, paragraph 4, of the Owners' Group Plan, "...the results of ongoing Owners Group design reviews or owners testing/inspection results as part of the DR/QR efforts may result in revision to this listing" (of known problems). The Owners' Group should make formal provisions for addressing additional, potentially generic problems with TDI engines that may be identified through testing, inspection, expert opinion, and/or operating experience in nuclear or non-nuclear (e.g., stationary) applications. An example of a potential problem that has been identified by PNL consultants is the apparent cracking in wrist pin bushings (both new and used) of TDI engines at the Shoreham Nuclear Power Station.

- critical components - Certain components are particularly important for the reliability and operability of a diesel engine. Potential consequences of failure of these components include immediate shutdown of the engine, possibly severe engine damage, extensive outage for repairs, and, depending on the circumstances, a potentially severe hazard to operating personnel in the vicinity of the engine. Accordingly, any problems identified with these components warrant particularly careful attention relative to the "key considerations" summarized earlier in this section. Components in this category include:

--crankshaft

--connecting rods

--connecting rod bearings

--wrist pin bushings[a]

--cylinder heads

--turbocharger

--pistons

--gears.[a]

2.2 DESIGN REVIEW/QUALITY REVALIDATION

2.2.1 Owners' Group Plan

The second element of the Owners' Group Plan, Design Review/Quality Revalidation, entails a review of components other than those already identified as having known problems (Section 2.1, above). Through a process that considers the function of each component, its role in the overall operation of the engine, known performance data, and the engineering judgment of the Owners' Group Component Selection Committee, components are selected for design review and/or quality revalidation to assure that they are adequately designed and fabricated.

According to guidelines established by the Owners' Group, a component is normally selected for DR/QR if its failure would result in engine shutdown ("Type A" component). The Component Selection Committee determines whether or not DR/QR is required for a component if its failure could result in reduced engine capacity ("Type B"). DR/QR is generally not required for a component if its failure would have little effect on engine performance ("Type C").

(a) These components were not included on the list of 16 components with known problems identified by the Owners' Group Plan (Appendix 5). However, wrist pin bushings are addressed by the Owners' Group in Design Review of Connecting Rods of Transamerica Delaval Inline DSR-48 Emergency Diesel Generators, FaAA-84-3-13 (Failure Analysis Associates, April 1984).

2.2.2 PNL Comments

In light of the deficiencies in TDI's quality assurance program identified by the NRC vendor inspection program, PNL concurs that action is necessary to establish the adequacy of the design and quality of key engine components. PNL also concurs that the DR/QR of components other than those for which known problems have been identified need not be a prerequisite for near-term licensing of nuclear power plants with TDI engines, provided that the considerations discussed in Section 4 of this report are addressed.

Any new, potentially significant problems identified in the DR/QR process should be added to the list of known problems discussed in Section 2.1 of this report. The manner in which the Owners' Group plans to do this is not clear.

The DR/QR of components should also include aspects other than design and fabrication. For example, several reports submitted by the Owners' Group on components with known problems have identified assembly and installation procedures as critical to satisfactory operation (e.g., bolt preload). Accordingly, these procedures should also be evaluated as part of the DR/QR process.

To verify the adequacy of the DR/QR performed by the Owners' Group, PNL plans to audit the reports as follows:

- Several (three or four) of PNL's diesel engine consultants will identify 10 to 20 key components. This selection will be independent of the selection made by the Owners' Group, and will include components that our consultants classify as "Type A" and "Type B."
- The consultants will then review the appropriateness of the DR/QR for each of these components, the level of the review performed, and the DR/QR action taken on each.
- The results of the audit will form the basis for any additional action that may be necessary. If there is a concensus among PNL's consultants that the components audited have received an adequate DR/QR by the Owners' Group, no further action may be needed. If significant differences exist between the DR/QR considered

appropriate by the consultants and the DR/QR performed by the Owners' Group, it will be necessary to establish a course of action for resolving the differences.

2.3 ENGINE TESTING AND INSPECTION

2.3.1 Owners' Group Plan

The Owners' Group Plan addresses engine testing in two sections. First, the "Testing Program Summary" of the Plan states that technical staff will use results of component evaluations to establish testing/inspection requirements for "lead" engines, and that these results will dictate the need for tests and inspections of "following" engines. The specific test plans will result from NRC/owner interactions. Second, for the known problem resolution tests, a test/inspection plan is provided for engines at eleven nuclear stations in the series of tables in Section III and Appendix 6 of the Plan.

2.3.2 PNL Comments

The PNL project team and consultants view this program element as the key for tying together corrective actions described in the other major program elements and verifying the adequacy of design changes. However, the tests outlined in the "Testing Program Summary" and in Appendix 6 of the Owners' Group Plan are not sufficient, in our opinion, to demonstrate the adequacy of solutions to known problems.

PNL recommends that the elements summarized below be included in the testing program. The recommended tests are in addition to those already called for in NRC Regulatory Guide 1.108, "Periodic Testing of Diesel Generator Units Used as Onsite Power Systems at Nuclear Power Plants."

Because of the plant-specific nature of engine installations at nuclear power stations, detailed plans for engine tests and inspections should be prepared by individual owners. Key engine data (e.g., temperatures and pressures) should be defined in the test plans, together with requirements for how these data are to be logged. Acceptance criteria for the tests and inspections should also be included in the plans. The plans should reflect recommendations of the Owners' Group and the engine manufacturer, and should be submitted to NRC before the tests are conducted.

Engine tests and inspections discussed in this section may be monitored by NRC representatives.

2.3.2.1 Pretest Inspections

Prior to conducting the operational tests of an engine (either "lead" or "following"), the owner should verify that the key engine components (e.g., those listed in Table 1) are sound and are consistent with the latest recommendations of the Owners' Group for part model and acceptance criteria. If the engine is in a nuclear power station that is a candidate for a license before the Owners' Group Plan is fully implemented, this verification should be accomplished through engine disassembly sufficient for inspection of all key components. The crankshaft need not be removed for this inspection, unless evidence is found during the inspection that it should be.

Appropriate nondestructive tests should be performed, defective parts should be replaced, and design improvements that have been recommended by the Owners' Group and/or the engine manufacturer should be implemented. A possible exception may be made for the engine block and engine base, which may be placed in service if flaws found through nondestructive tests are noncritical, i.e., the flaws are not a pathway for oil or water leakage, are not propagating, and do not otherwise affect the structural integrity of the engine. Any exceptions for these components should be evaluated on a case-by-case basis.

For TDI engines in nuclear power stations that will apply for operating licenses after the Owners' Group Plan is fully implemented, the verification described above may be accomplished through a review of QA/QC records, if the quality control system and the records are adequate. Included in these records should be documentation of key engine components by "design" (e.g., "AE" piston skirts). In the absence of adequate records, this verification should be accomplished through engine disassembly and inspection as discussed above. Even with adequate records it would be desirable to open the engine if it were in storage for more than a few months, and spot-check components for any degradation that may have occurred during storage.

As part of pretest inspections, crankshaft deflection should be measured under both "hot" and "cold" conditions to verify that crankshaft alignment is within manufacturer's recommendations. The "hot" measurements should be completed within 15 to 20 minutes of engine shutdown. For "following" engines only, the "hot" measurements (but not the "cold" measurements) may be waived prior to the preoperational tests unless otherwise recommended by the manufacturer, but they should be taken at the completion of the 24-hour, preoperational run described in NRC Regulatory Guide 1.108.

2.3.2.2 "Lead" Engines

For key engine components subject to fatigue stresses (e.g., the crankshaft), operation at "qualified" load to 10^7 cycles (about 750 hours at 450 rpm) is recommended to verify design adequacy. "Qualified" load may be taken as 1) the maximum postulated Engineered Safety Feature (ESF) load that the engine may be required to carry, 2) the continuous rating ("nameplate" load) of the diesel generator, or 3) the load specified by the owner in the purchase specifications for the engine. If the engine is qualified at the maximum postulated ESF load and if that load is increased at some later date (due, for example, to a change in the emergency electrical system), the first qualification test may not be applicable. Similarly, a test at a given load may not be applicable to other engines if they are expected to operate at higher loads.

The test to 10^7 cycles does not have to be continuous. For example, it may be necessary to shut down the engine periodically to perform surveillance and maintenance of key engine components (e.g., articulated connecting rods in V-engines) in accordance with recommendations of the Owners' Group and/or the engine manufacturer.

This test is not, by itself, sufficient to prove design adequacy. Rather, it is intended to verify the analysis on which the design of a component is based, by demonstrating that the component will meet load and service requirements without evidence of distress under conditions that could induce high-cycle fatigue. On the basis of common industry practice, a test to at least

10^7 cycles is necessary for this verification. Together with the analysis, satisfactory completion of this test will provide reasonable assurance of design adequacy.

Following this test, crankshaft deflection should be remeasured under both "hot" and "cold" conditions to determine changes, if any, from pretest measurements. The deflection data are needed to establish the stability of crankshaft alignment.

The engine should then be disassembled to the extent necessary for inspection of all key engine components, and the nondestructive tests discussed in Section 2.3.2.1 should be repeated. Results of all inspections should be recorded, and compared with corresponding information from pretest inspections. All parts found to be defective should be replaced, with the possible exceptions noted in Section 2.3.2.1. If a key component fails the test, the root cause should be identified, corrective action taken, and the component retested to the full 10^7 cycles. Retesting should be performed in either the "lead" engine, or in another engine where the component will be subject to equal or greater loads.

Following assembly, "hot" and "cold" crankshaft deflection should be remeasured to verify proper alignment. Preoperational testing should also be performed to confirm that the engine is operable. This testing should include the manufacturer's preoperational test recommendations and the following elements, if they are not already included in the manufacturer's recommendations:

- ten modified starts to at least 40% of "qualified" load
- two fast starts to "qualified" load
- one 24-hour run at "qualified" load.

A modified start is defined as a start including a prelube period as recommended by the manufacturer and a 3- to 5-minute loading to the specified load level, with operation at the level for a minimum of 1 hour. A fast start is one conducted from the control room on simulation of an Engineered Safety Feature (ESF) signal with the engine on ready standby status. The engine should be loaded to "qualified" load and run for 4 hours at that load on each fast-start test. The 24-hour run is recommended to detect abnormal temperatures, pressures, and/or temperature excursions that might indicate abnormal engine behavior. Either a modified or a fast start may be utilized.

2.3.2.3 "Following" Engines

To be considered a "following" engine, the maximum operating load of that engine should be no greater than the "qualified" load at which the "lead" engine has been tested, and the engine should meet the definition summarized in the footnote on page 5 of this report. "Following" engines should receive preoperational testing recommended by the manufacturer and/or NRC Regulatory Guides. These tests are considered sufficient to verify proper engine assembly and operation.

At the completion of these preoperational tests, crankshaft deflection should be measured under both "hot" and "cold" conditions for comparison with pretest measurements (described in Section 2.3.2.1). If engine operating conditions (e.g., temperatures and pressures) remain within normal limits and show no abnormal excursions, additional post-test engine disassembly and inspection need not be performed except as recommended by the manufacturer and/or the Owners' Group (e.g., periodic inspections of bolted joints on articulated connecting rods), or as may be required by NRC on the basis of information that may come to light during implementation of the Owners' Group Plan. However, the engine should be barred-over 4 to 8 hours after shutdown to detect any leakage of cooling water through the cylinder heads into the cylinders, and this check should be repeated at intervals established in the engine surveillance and maintenance procedures.

2.4 SURVEILLANCE AND MAINTENANCE

2.4.1 Owners' Group Plan

The Owners' Group Plan does not specifically address surveillance and maintenance activities.

2.4.2 PNL Comments

PNL views a comprehensive surveillance and maintenance program as a key aspect of the overall effort for establishing TDI diesel engine operability and reliability. Such a program contributes to continued satisfactory engine performance and facilitates the timely identification of potential engine problems. Recommendations for a definitive surveillance and maintenance program should be developed by the Owners' Group in consultation with the engine manufacturer, and detailed plans based on these recommendations should be developed for each engine installation by individual owners. The plans should be provided to NRC.

2.5 ADMINISTRATIVE CONTROLS

2.5.1 Owners' Group Plan

The Owners' Group Plan provides a charter and organization for carrying out the program. The Plan also provides bar-chart scheduling plans. Specific provisions are made for approvals in conjunction with the component selection for the DR/QR elements of the Plan.

2.5.2 PNL Comments

Certain aspects of administrative controls established by the Owners' Group are not evident from the Program Plan. Those pertaining to resolution of known problems, identification of new problems, and implementation of corrective action are of particular importance for establishing the reliability of TDI engines. Formal procedures should be established for:

- identifying new, potentially significant problems and adding them to the list of those already being addressed by the Owners' Group
- disseminating corrective actions to all members of the Owners' Group
- reviewing reports on known problems for the content discussed in Section 2.1.2, above - The Owners' Group Technical Program Director should certify by his signature that the review addresses all pertinent issues and is complete within itself.

3.0 CRITICAL ELEMENTS REQUIRED TO ESTABLISH TDI ENGINE OPERABILITY AND RELIABILITY

The program logic of Figure 1 forms a basis for identifying the critical elements needed to establish TDI engine operability and reliability for nuclear service (i.e., program elements that should be accomplished prior to licensing action). The evaluation of the Owners' Group Plan in Section 2.0 reflects these elements, which are:

- For key engine components (e.g., those listed on page 9) necessary actions include the following: 1) the Owners' Group should assure NRC that all significant problems (e.g., those that can lead to immediate or early engine shutdown or capacity limitation) with TDI engines have been identified; 2) the causes of each identified problem should be determined to the satisfaction of NRC (viz. design and specifications, materials and fabrication, QA/QC, installation, maintenance, or operations); and 3) a program for resolving these problems should be established and submitted to NRC. Standards of performance in these areas have been suggested to NRC in a letter from PNL dated April 18, 1984.
- The corrective action should be implemented and the individual owners should confirm that the intended action has been taken (e.g., design changes, materials changes, and changes to operation and maintenance procedures). This would include, as appropriate, testing and inspection described below.
- Lead-engine testing and inspection of any new or changed component should be completed. This should include the testing elements identified in Section 2.3.2. A plan for these tests should be submitted to NRC by the Owners' Group in advance of the tests. These tests and inspections may be monitored by NRC representatives.
- Each "lead" and "following" engine should undergo preoperational testing as described in Section 2.3.2.

- A plan to assure continued satisfactory performance of engines in service should be established by the Owners' Group and provided to NRC. The principal element of the plan is the surveillance and maintenance program.
- A procedure should be established to communicate future industry problems and disseminate corrective actions to all nuclear industry owners of TDI engines.

4.0 CONSIDERATIONS FOR INTERIM LICENSING

Certain plants may be candidates for near-term operating licenses prior to completion of the implementation of the Owners' Group Plan. Because of the plant-specific aspects of these licenses, they will need to be treated on a case-by-case basis. Summarized in this section are factors that PNL recommends for consideration in this process.

The lead-engine tests and inspections discussed in Section 2.3.2 of this report should be a prerequisite for a license to operate a reactor at power levels that would require a diesel generator to carry an emergency load corresponding to engine Brake Mean Effective Pressure (BMEP) greater than 185 psig. If the BMEP would not exceed 185 psig under emergency conditions, and if the engine is equipped with AE piston skirts, the tests and inspections could be performed in parallel with operation of the reactor under an interim license. This BMEP limit as a condition for an interim license is based on the following considerations:

- Most of the operating experience with AE piston skirts of which PNL is aware has been at Kodiak, Alaska, where a TDI engine reportedly has accumulated in excess of 6,000 hours without piston-skirt failure.[a] A substantial portion of this operation reportedly has been at a power level that corresponds to a maximum cylinder pressure of about 1,200 psig. At the recommended BMEP limit of 185 psig, the maximum cylinder pressure is also approximately 1,200 psig. The operating experience at Kodiak establishes a reasonable basis for confidence that AE piston skirts will operate satisfactorily at this load level.
- Pending the evaluation and approval of reports from the Owners' Group that address crankshaft stress levels at higher loads, the load corresponding to 185 BMEP is considered to be reasonably conservative for the crankshaft.

(a) A discussion of this operating experience is documented in the transcript of the TDI Owners' Group meeting held on March 22, 1984 (page 91 ff.).

- Because of certain open items in the implementation of the Owners' Group Plan, an adequate basis does not yet exist to provide reasonable assurance that TDI diesel engines would operate reliably in nuclear service at power levels higher than those corresponding to a BMEP of 185 psig. Open items include resolution of comments and questions raised by PNL in reviews of reports submitted by the Owners' Group on known problems, verification of corrective actions through engine tests, completion of action items on component task descriptions prepared by the Owners' Group, and design review/quality revalidation of key components. Key engine components of particular concern in this regard include the piston skirts and the crankshaft, because their condition cannot be monitored without significant engine disassembly.

If the criteria are met for power plant operation under an interim license, one of the TDI engines at the power plant could be designated the "lead" engine for the tests and inspections, or the tests and inspections could be performed on a "lead" engine at another power plant. However, the TDI engines at the power plant with the interim license should undergo the preoperational inspections discussed in Section 2.3.2 of this report, preoperational testing in accordance with manufacturer's recommendations and applicable NRC Regulatory Guides, and the additional preoperational tests discussed in Section 2.3.2. Furthermore, they should receive enhanced surveillance analogous to the surveillance recommended by PNL for the Grand Gulf Nuclear Power Station in a letter dated April 16, 1984 to NRC.

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Enclosures

ATTACHMENT 1

Professional Qualifications

Spencer H. Bush

Review and Synthesis Associates
630 Cedar
Richland, Washington 99352

Education

B.S.	Metallurgical Engineering, University of Michigan	1948
B.S.	Chemical Engineering, University of Michigan	1948
M.S.	Metallurgical Engineering, University of Michigan	1950
Ph.D.	Metallurgy, University of Michigan	1953

Employment

1940-42	Assistant Chemist, Dow Chemical Company
1942-46	U. S. Army (1944-46: Manhattan Project)
1951-53	Instructor, Dental Materials, U. of Michigan
1953-54	Senior Scientist, General Electric Company Hanford Atomic Products Operation (HAPO)
1954-57	Supervisor, Physical Metallurgy, General Electric HAPO
1957-60	Supervisor, Fuels Fabrication Development, GE/HAPO
1960-63	Metallurgical Specialist, General Electric HAPO
1963-65	Consulting Metallurqist, General Electric HAPO
1965-70	Consultant to the Director, Battelle-Pacific Northwest Laboratories
1970-83	Senior Staff Consultant, Battelle-Pacific Northwest Laboratories
1983-	President, Review and Synthesis Associates, Richland, WA
1968-	Affiliate-Adjunct Professor, Metallurgical Engineering--Joint Center for Graduate Study, University of Washington, Washington State University, Oregon State University
1973-74	Regents Professor, University of California, Berkeley

Affiliations (active only)

U.S. Nuclear Regulatory Commission Advisory Committee on Reactor Safeguards (Member 1966-1977, Consultant 1978-)
Executive Committee, Welding Research Council Pressure Vessel Research Committee
Member, ASME Section XI Subcommittee on Nuclear Inservice Inspection
Executive Board, ASME NDE Engineering Subdivision
U. S. Representative, OECD PISC-II Managing Group
Chairman, Washington State Board of Boiler Rules
Sigma Xi
Tau Beta Pi
Phi Kappa Phi

Society Memberships

Fellow, American Nuclear Society
Fellow, American Society for Metals
Member, American Institute of Mining, Metallurgical and Petroleum Engineers
Fellow, American Society of Mechanical Engineers
Member, National Academy of Engineering

Awards and Honors

National Academy of Engineering Award 1970
Regents Professor, University of California, Berkeley 1973-74
ASTM Gillett Lecturer 1975
ASNT Mehl Lecturer 1981
ASME Certificate, Boiler and Pressure Vessel Code
ASME Bernard F. Langer Award 1983

Licenses

Registered Professional Engineer, Metallurgical Engineering-267 and Nuclear Engineering-292, State of California

Author or co-author of one book, 16 chapters in books, 30 journal articles and numerous other documents and technical papers.

Summary of Current Areas of Expertise

Consultant on materials and safety with particular emphasis on environmental effects such as stress corrosion and radiation damage as they affect material properties and component design in nuclear reactors. Scientific contributions have been primarily in the physical and mechanical metallurgy of nuclear materials. Specific experimental work has been in temper embrittlement of steels. Work in reactor materials included kinetics studies of oxidation in zirconium alloys, effect of fabrication variables on properties of zirconium alloys, irradiation effects in uranium alloys and reactor structural materials, and stress corrosion. Substantial work has been done in reactor safety, particularly on failure mechanisms in pressurized systems.

A major role has been in the synthesis of available information to develop a coherent picture of the relative roles of materials, fabrication and nondestructive examination on the reliability of nuclear components. Based on such a synthesis of data generated throughout the world, it is possible to suggest changes leading to an improvement in reliability with a comparable improvement in system safety. Consulting on special assignments has become increasingly significant since 1978 for both government and private organizations. Typical activities have been in the areas of component reliability, seismic design of pressure boundary components, seismic fragility values, reactor system reliability under faulted conditions, turbine reliability and valve performance.

ATTACHMENT 2

Professional Qualifications

Adam J. Henriksen

Adam J. Henriksen, Inc.
Diesel Consultants
7731 N. Fairchild Road
Fox Point, Wisconsin 53217

Education

Horten High School, Horten, Norway
Graduated in 1934

Royal Norwegian Naval Academy, Engineering Branch
Graduated in 1940

American Management Association (four weeks)
General Management Course 1968-1969

Service Record

Royal Norwegian Navy
Midshipman Engineer 1937-1940
Engineering Officer (Lieutenant S.G. at time of discharge) 1940-1946

Societies and Registrations

The American Society of Mechanical Engineers, Member
Registered Professional Engineer in the State of Wisconsin

Publications

A.S.M.E. Paper Number 60-WA-185, "Supercharging of a Large Two-Cycle, Loop-Scavenged Diesel Engine"

Experience

May 1980 to Date	Consulting Engineer, Diesel Engines
March 1975 - May 1980	Rexnord Inc. Nordberg Machinery Group, Process Machinery Division Milwaukee, Wisconsin

March 1975 - May 1980 — Manager, Service Department

Responsible to Division Customer Service Manager for all phases of installing and servicing the Company's product lines of crushers, screens, mills and hoists. Further responsible for all administration of up to 24 authorized repair facilities.

November 1953 - March 1975 — Rexnord Inc. Nordberg Machinery Group, Power Machinery Division
Milwaukee, Wisconsin

September 1966 - March 1975 — Manager, Test and Service Department

Responsible to Division General Manager for all phases, inclusive financial and contracting, involved in testing, installing and servicing the company's line of diesel engines and gas turbines. The department consisted of five subsections.

September 1965 - September 1966 — Chief Field Engineer

Responsible to Manager, Test and Service Department for all field testing, including field R/D work on the company's line of diesel engines. Further responsible for solving problems arising in the field, and for reducing no-charge costs resulting from problems occurring in the field as well as in the factory.

February 1964 - September 1965 — Assistant Chief Engineer

Responsible to the Chief Engineer for Administrative and Technical leadership of the Engineering Department's R/D and Application groups. Further served as head of a group consisting of shop, service, and engineering personnel for the purpose of solving problems and reduce no-charge costs.

May 1963 - February 1964 — Head, Application Engineering

Responsible to the Chief Engineering for the Administrative and Technical leadership of the Engineering Department's Application group. This entailed stationary, marine, electrical, and automatic control application engineering.

1961 - 1963 — Head, R/D Department

Responsible to the Chief Engineer for the Administrative and Technical leadership of the Engineering Department's R/D group. During this period the group was heavily engaged in R/D work required to upgrade the company's line of four-cycle diesel engines including conducting tests on heavy fuel on these engines.

1955 - 1961 — Senior R/D Engineer

Project Engineer in charge of supercharging the company's line of two-cycle diesel, duafuel and spark-fired engines. The commercial rating of the entire product line increased by over thirty percent.

1953 - 1955	Marine Project Engineer Marine Project Engineer, planning and drawing in connection with marine installations. Calculating and specifying auxiliary equipment pertaining to above installations.
1952 - 1953	Yarrows, Ltd., Shipbuilders & Engineers, Victoria, B. C. Canada Position and duties as for above.
1950 - 1952	Messrs. Zetlitz-Nilsson, Ziegler and Bang, Marine Consulting Engineers, Oslo, Norway Marine Superintendent Engineer, planning of new vessels, examination of building specifications and drawings, charge of supervision of ships in service, examination of engineering reports, etc., prepare detailed specifications for tenders in connection with repairs and class surveys of ships.
1947 - 1950	Messrs. Harland & Wolff, Ltd., Shipbuilders and Engineers, Glasgow, Scotland Test and Guarantee Engineer, testing marine propulsion and auxiliary diesel engines in the manufacturer's plant, supervising marine machinery installations and sea trials at home and abroad. Guarantee Engineer aboard three vessels for a total of twenty months.
1946 - 1947	Fred Olsen, Ship Owner, Oslo, Norway First Assistant Engineer aboard S/S EK.
1937 - 1946	Please refer to service record
1936 - 1937	Wilhelm Wilhelmsen Lines, Ship Owner, Oslo, Norway Apprenticeship required for entrance to the Royal Norwegian Naval Academy. Shipboard duties.
1934 - 1936	Horten Naval Yard, Horten, Norway Apprenticeship required for entrance to the Royal Norwegian Naval Academy. Machine Shop practice.

ATTACHMENT 3

Professional Qualifications

Walter W. Laity

PNL Project Manager
Diesel Engine Operability/Reliability Project
Battelle, Pacific Northwest Laboratory

Education

B. S. Mechanical Engineering, University of Washington
M. S. Mechanical Engineering, Oregon State University
Ph.D. Mechanical Engineering, Oregon State University

Experience

Dr. Laity joined the staff of Battelle-Northwest in November 1974. His academic background and experience are primarily in the fields of the thermal sciences, transport phenomena, and advanced energy conversion systems.

Dr. Laity served a 5-year tour of duty (1962-1967) as a Naval officer in the headquarters organization of the Naval Nuclear Power Program, where he was involved in the engineering of machinery for Naval nuclear propulsion plants. Machinery for which he was responsible included propulsion and auxiliary turbines, reduction gears, condensers, heat exchangers, propeller shaft bearings, pumps, blowers, air conditioners, and distilling plants. During the last 3 years of that assignment, he was a technical leader For the design, manufacture, testing, and installation of steam plant components tor a new design Naval nuclear plant.

Dr. Laity has gained significant additional experience at Battelle as a technical contributor, project manager, and manager of an R&D section of 38 people. His attention has been focused on fundamental and applications-oriented research in the fluid and thermal sciences, and the application of these disciplines to the evaluation and development of energy systems for both well-established and new technologies.

Professional Registration

Registered Professional Engineer, Oregon, No. 7440.

Professional Registration

American Society of mechanical Engineers
Accrediation Board for Engineering and Techynolgy (ASME Visitor)
Sigma Xi

Professional Qualifications of

Carl H. Berlinger

Division of Licensing

Office of Nuclear Reactor Regulation

United States Nuclear Regulatory Commission

My name is Carl H. Berlinger, I am the Group Manager of the TDI Project Group. In this position I manage the activities of the Project Group staff and coordinate the efforts of NRR and other offices, interface with industry and licensees and as appropriate keep the ACRS, hearing boards and the Commission informed regarding the status and resolution of this issue. I have held this position since January 16, 1984.

I received a Ph.D in Mechnical Engineering from the University of Connecticut in 1971, and a Bachelor of Science and a Master of Science degrees in Mechanical Engineering from Clarkson College of Technology in 1960 and 1962, respectively.

September 1981 to January 1984

UNITED STATES NUCLEAR REGULATORY COMMISSION

Division of Systems Integration - Core Performance Branch

Branch Chief -

Duties included:

1. Management of the activities of a branch engaged in the review, analysis and evaluation of calculational methods used by applicants for the licensing of nuclear power plants in the fuel and core design areas of reactor plant engineering.

2. Responsible for development and application, in conjunction with consultants, of independent calculational methods including complex computer codes for the analysis of fuel and reactor core performance during steady-state, transient, and accident conditions.

3. Participates as a technical specialist on various NRC committees, subcommittees, panels, task force assignments, and on technical, industrial and professional society committees.

4. Represents the Commission in dealings with other governmental departments and agencies, national laboratories, industry and industry organizations in discussion of complex technical matters in the areas of new or proposed reactor systems.

November 1980 to September 1981

USNRC

Division of Licensing - Systematic Evaluation Program Branch

Section Leader - Systems Engineering

Duties included:

1. Supervised senior technical staff in the Systems Engineering section.

2. Responsible for the analysis, evaluation and safety reviews in the areas of thermal hydraulics, physics, site hazards, and safety analyses aspects of the reactor core, primary and secondary plant systems, electrical and auxiliary systems.

January 1980 to November 1980

USNRC

Division of Licensing - Operating Experience Evaluation Branch

Branch Chief -

Duties included:

1. Organized newly formed branch; formulated goals and objectives.

2. Established procedures and significance criteria for systematic screening and technical review of domestic and foreign licensee event reports and operating experience reports, respectively.

3. Initiated staff reviews of significant licensee events.

4. Developed licensee event reporting requirements.

5. Managed and participated in the investigation of plant operating problems and identified generic reactor operating problems.

April 1976 to January 1980

USNRC

Division of Operating Reactors - Reactor Safety Branch

Section Leader -

Duties included:

1. Provided technical supervision and review of senior technical staff in the Reactor Safety Branch.

2. Planned, coordinated and reviewed safety design evaluations of reactor cores, reactor systems, and engineerined safety features, and in accident analysis evaluations.

3. Acted as contract coordinator.

4. Served on the initial on-site response team sent to TMI.

5. Served as the team leader of the on-site response team sent to Oyster Creek following the 1979 plant transient.

6. Served as a reactor systems expert detailed to the Office of the Executive Director.

September 1973 to April 1976

USNRC (AEC)

Division of Operating Reactors - Reactor Systems Branch

Senior Nuclear Engineer - Reactor Systems Section

Duties included:

1. Served as a senior reactor systems specialist.

2. Responsible for analyzing and evaluating proposed nuclear reactor designs in the areas of thermal hydraulics, nuclear and reactor system performance.

3. Represented the AEC before ACRS, licensee and industry meetings.

4. Responsible for making technical recommendations and formulating technical positions regarding standards, regulatory guides and codes as related to reactor safety.

August 1970 to September 1973

COMBUSTION ENGINEERING CORPORATION

Nuclear Power Division - Accident Analysis Department

Principal Safety Engineer -

Duties included:

1. Responsible for the development of analytical tools for analysis of LMFBR maximum hypothetical accidents.

2. Performed quality assurance of complex computer codes and plant safety analysis (including LOCA and plant transients).

3. Presented testimony before ACRS regarding the San Onofre Units 2 and 3 plants.

4. Developed a transient steam generator/superheater model for the once through steam generator with integral economizer.

February 1969 to August 1970

UNIVERSITY OF CONNECTICUT

Mechanical Engineering Department

Graduate Teaching Assistant -

Duties included:

1. Taught undergraduate heat transfer course.

2. Designed, procurred, constructed and operated all equipment and instrumentation required for Ph.D dissertation.

3. Administered a research budget of $20,000.

August 1961 to February 1969

PRATT AND WHITNEY AIRCRAFT

Advanced Power Systems

Senior Analytical Engineer -

Duties included:

1. Planning and coordinating research and development of advance engineering products.

2. Analyzed heat transfer, thermodynamic and aerodynamic problems.

3. Supervised the design, manufacture, testing and evaluation of new design concepts.

ATTACHMENT 5

Professional Qualifications

Arthur Sarsten

Professor of Internal Combustion Engines
The Norwegian Institute of Technology (NTH)
7034 Trondheim, Norway

at

Division of Combustion Engines and
Marine Engineering, Marine Technology Center
Department of Marine Technology
Hakon Hakonsons gt34
N-7000 Trondheim, Norway

Practical Training

1942 - 1945 Apprentice, A/S Wichmann, Rubbestadneset, Norway. Machine shop work in engine factory in various lathes, drill presses, shaping etc. One year in diesel engine assembly work.

Education

- 1939 N.Y. Public Schools + 1 Year High School

1940 - 1945 Voss off. Landsgymnas, Voss, Norway

1949 - 1953 The Norwegian Institute of Technology, Trondheim, Norway. B.Sc. in Mechanical Engineering, diploma thesis in I.C. Engines.

1958 - 1960 Renesselaer Polytechnic Institute, Troy, N.Y. Post graduate work evenings, later full time. M.Sc. in ME 1960.

1960 - 1963 R.P.I., Troy, N.Y. full time. Thesis in field of nonlinear vibrations D.Sc. 1963.

Memberships

Society of Automotive Engineers
American Society of Mechanical Engineers
The Institute of Marine Engineers
The Royal Norwegian Society of Sciences and Letters
The Norwegian Academy of Technical Sciences

1954 - 1959 Wichmann Motorfabrikk A/L, Rubbestadneset, Norway (Manufacturer of two-stroke marine diesel engines up to ca. 2500 bhp.) Position would correspond to project engineer for

AC type (280 x 420 mm). Design, calculation and follow-up to production stage of this type of loop-scavenged engine and hydraulic c.p. propeller units. Supervision of 1-2 detail draftsmen.

1958 - 1960 ALCO Products Inc., then at Schenectady, N.Y. Calculation of stress and vibrations in engine components. Cam design and dynamics. R&D work accumulator fuel injection.

1963 - 1964 Gebr. SULZER, Winterthur, Switzerland. Mainly 2-stroke diesel engines. Design calculator rotating through various departments. Design of cams and related computer programming, FORTRAN II for IBM 1620. Balancing and torsional vibration calculation, some test bed work.

1964 - 1978 Professor of Internal Combustion Engines, The Norwegian Institute of Technology, Trondheim, Norway, and head, Division of I.C. Engines (Institutt for forbrenningsmotorer) staff ca. 20. Also research and consultant work, mainly for foreign engine firms. Engaged in computer work FORTRAN IV, UNIVAC 1107-1108. We have been active in engine dynamics, valve dynamics, torsional vibrations, thermal loading problems, use of finite element technique for temperature and stress field calculations, sale of TESTRAN FEM-package to various engine and component firms. Lab does radioactive wear tests, bearing work, consumer tests and research on outboard engines. Headed Norwegian Large Bore Research Project 1965 - 1968 ($200 000,-) for research on thermal damage on certain crosshead engines. Awarded (with 3 co-authors) The Herbert Ackroyd Stuart Award 1968'9 from The Institute of Marine Engineers for paper reporting results of this research.

1971 - 1973 Dean, Department of Mechanical Engineering, Norwegian Institute of Technology. 14 Divisions, ca. 600-700 students.

1974 Prof. invité, Département de génie mécanique, Université de Sherbrooke, Canada.

1978 - present Professor of Internal Combustion Engines, Division of Combustion Engines and Marine Engineering, at the new Marine Technology Center. Staff approx. 40. Head of Division 1978 - 1980, (rotates).

1983 - 1984 Visiting professor at Lawrence Berkeley Laboratory, One Cyclotron Road, Berkeley, CA 94720.

Partial List of Relevant Publications

Sarsten, A. "A Computer Programme for Damped Torsional Vibrations Using a Complex Holzer Tabulation", European Shipbuilding No. 6. 1962. Vol. XI, p. 138-146.

Sarsten, A., Valland, H. "Computer-aided Design of Valve Cams." Int. Comb. Engines Conf., Bucharest 1967, Paper 11-19, p. 761-786.

Fiskaa, G., Iversen P., Sarsten, A. "Computer calculation of stresses in axi-symmetric thermally loaded components." Inst. of Mech. Engineers Symposium Computers in I.C. Engine Design, Manchester. April 1968, Proc. 1967-68, Vol. 182, Part 3L, p. 152-168.

Sarsten, A., Hansen, A, Langballe, M., Martens, O. "Thermal Loading and Operating Conditions for Large Marine Diesel Engines." IMAS69 Conference, London, Sect. 4, p. 38-49. Given Herbert Ackroyd Stuart Award 1968'9 by The Institute of Marine Engineers.

Hansen, A., Rasmussen, M., Sarsten, A. "Thermal Loading of Diesel Engine Components and Its Prediction." Paper A30, 9th Intern'l Congress on Combustion Engines (CIMAC) Stockholm, Sweden 1971, 25 pp.

Wacker, E., Strecker, E., Sarsten, A., Haaland, E. "Finite Element-Programme zur Berechnung von Brennraum-Bauteilen", Motortechnische Zeitschrift (MTZ) 32. Nr. 8, Aug. 1971, p. 267-279.

Sarsten, A., Holth, T., Øvbrebo, A. "A Method for Direct Solution of Steady-State Forced Vibration of Linear Systems." ASME paper 13-DGP-12, presented at Diesel and Gas Engine Power Conf. Washington, D.C. April 1973.

Sarsten, A. "Massekrefter og massemomenter ved stempelmaskiner. (Inertia forces and moments in piston engines). 176 pp., Tapir Forlag, Trondheim, 1968.

Sarsten, A. "A Direct Method for Calculating the Steady-State Vibration of Marine Shafting Systems." Report IF/R15, Div. of I.C. Engines, NTH, Trondheim, 1974.

Valland, H., Sarsten, A. "Application of the direct solution method to engine vibration problems," Norwegian MARITIME RESEARCH No. 1, 1980, Vol. 8, pp. 39-50.

Sarsten, A. "A reduction method for calculation of the forced vibration of large, free systems with multiple branch points." Report IFMM 81, Div. of Comb. Eng. and Mar. Engrg., 35 pp.

Chen, T., Sarsten, A. "Combustion simulation of medium speed diesel engines and result analysis." 2nd Congress of IMAEM, Trieste, Sept. 21-26, 1981.

Einang, P. M., Koren, S., Kvamsdal, R., Hansen, T. and Sarsten, A. "High-Pressure, Digitally-Controlled Injection of Gaseous Fuel in a Diesel Engine, with Special Reference to Boil-Off from LNG Tankers," Paper, CIMAC '83 Conference, Paris, June 1983.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

CERTIFICATE OF SERVICE

I hereby certify that copies of SAFETY EVALUATION REPORT, TRANSAMERICA DELAVAL, INC. DIESEL GENERATOR OWNERS GROUP PROGRAM PLAN and the Professional Qualifications of Spencer H. Bush, Adam J. Henriksen, Walter W. Laity, Carl H. Berlinger, and Arthur Sarsten in the above-captioned proceeding have been served on the following by deposit in the United States mail, first class, or, as indicated by an asterisk, through deposit in the Nuclear Regulatory Commission's internal mail system, or, as indicated by a double asterisk, by hand-delivery, this 24th day of August, 1984:

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Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

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Administrative Judge
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