40. Surveillance and reporting programs in place at VEGP, including those established pursuant to 10 C.F.R. Part 21 and § 50.55(e), will continue to identify, monitor, and resolve any future problems with the TDI diesel generators. Id., ¶¶ 12-14.

Respectfully submitted,

By: ______________________________
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Attorneys for Applicants

DATED: July 31, 1985

July 24, 1985

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

DOCKETED
USNRC

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OFFICE OF SECRETARY
DOCKETING & SERVICE
BRANCH

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| GEORGIA POWER COMPANY, ET AL. | ) | Docket Nos. 50-424 |
| | ) | 50-425 |
| (Vogtle Electric Generating Plant | ) | |
| Units 1 and 2) | ) | |

AFFIDAVIT OF JOHN C. KAMMEYER

| | | |
|---|---|---|
| STATE OF NEW YORK | ) | |
| | ) | ss. |
| COUNTY OF SUFFOLK | ) | |

I, John C. Kammeyer, being duly sworn, state as follows:

1. I am employed by Stone & Webster Engineering Corporation ("SWEC") as Head of the Site Engineering Office at Shoreham Nuclear Power Station ("Shoreham") and as the SWEC Senior Site Representative. My business address is Shoreham Nuclear Power Station, P.O. Box 604, Wading River, New York 11792. I have personal knowledge of each of the matters set forth herein and believe them to be true and correct.

2. Prior to my present position, I was employed by SWEC as Program Manager for the Transamerica Delaval, Inc. ("TDI") Owners Group Design Review and Quality Revalidation ("DR/QR")

Program. I acted as Program Manager for nearly one year, from April of 1984 to March of 1985. As Program Manager, I had the overall responsibility for implementation of the DR/QR Program. I was responsible for directing engineers and quality inspectors in the resolution of TDI diesel engine problems, and the design review/quality revalidation of selected engine components at twelve nuclear power plants, including the Vogtle Electric Generating Plant ("VEGP").

3. Prior to acting as Program Manager for the Owners Group, I was employed by SWEC as the Assistant Head of the Site Engineering Office at Shoreham. During the construction and start-up testing phase of the Shoreham plant, I was responsible for directing engineers and designers in the resolution of problems involving fluid system and related components, such as piping, valves, mechanical equipment, and equipment erection. I also provided engineering and managerial support to Long Island Lighting Company for Shoreham's original DR/QR program and the plant's licensing effort. During the plant's pre-operational phase, my responsibilities included assisting in the development of the station modification programs and engineering the specific modification packages necessary for upgrading mechanical systems and equipment. My responsibilities specific to the TDI diesel generators installed at Shoreham included the following: a) June, 1980 to October,

1980, principle engineer assigned to the "Plant Maintainability Study," which included a review of all major diesel engine and auxiliary components for the purpose of assuring their accessibility and proper physical arrangement in order to meet maintenance requirements; b) April, 1981 to June, 1984, principle engineer assigned to the resolution of all problems and technical issues involving the TDI diesel generators during final erection of equipment and the start-up testing phase of the Shoreham plant; these responsibilities included:

(1) Resolution of non-conformances identified on engine and auxiliary components;

(2) Evaluation and implementation of all product improvements and design upgrades, including:

(a) Redesigned jacket water pumps,

(b) Modified turbocharger supports,

(c) Upgraded pistons,

(d) New crankshafts,

(e) New cylinder heads,

(f) Turbocharger prelubrication modification,

(g) New pushrods,

(h) Upgraded new subcover,

(i) New cylinder block;

(3) Development of procurement requirements for replacement and spare parts;

(4) Working with TDI in the general revision and upgrade of the diesel engine operation and instruction manuals;

(5) Directing engineers and designers in the development of detailed procedures for disassembly and rebuilding of the diesel engines;

(6) Development of an engine vibration qualification program;

(7) Participation in a diesel generator "Operational Review Program," to assess the significance of diesel generator modifications, non-conformances, etc., on the operational capability and reliability of the diesel generators; and presentation of the results and conclusions of this program to the Nuclear Regulatory Commission ("NRC");

c) November, 1983 to April, 1984, special assignment to the Shoreham DR/QR program, which evolved into the TDI Diesel Generator Owners Group DR/QR Program; areas of responsibility included the following:

(1) Assisted in the development of the Shoreham DR/QR program, including its conception, development of procedures, and structuring of the basic organization;

(2) Participated in the development of a computerized database chronicalling experiences with diesel engine components in both nuclear and non-nuclear applications;

(3) Participated in the identification of components to be subjected to a design review and/or quality revalidation;

(4) Expanded the Shoreham-specific DR/QR program to cover TDI engines installed at eleven other nuclear power plants;

(5) Participated in site-specific engine inspections to review the results of quality inspections at a number of plants;

(6) Participated in the review of all Phase I design review reports, generated as a result of the Owners Group Program.1/

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1/ As more fully described beginning at ¶ 10.

My present responsibilities at Shoreham include management of the SWEC Site Engineering Office. As SWEC Senior Site Representative, I am also responsible for project policy interpretation and personnel matters on-site. As SWEC's contact to the Owners Group Executive Committee, I am responsible for SWEC's continuing support to the owners in the following areas: a) engine startup consulting and support activities; b) special testing (including engine vibration monitoring); c) maintenance program development and support; d) implementation of modifications or development of alternatives; and e) development of responses to NRC Staff information requests.

4. I am a graduate of Ohio State University, from which I obtained a Bachelor of Science degree in mechanical engineering. Prior to attending college, I spent six years in the U.S. Navy's Nuclear Power Program. My final three years in the service were spent as a reactor operator aboard a nuclear submarine. I am a member of the American Society of Mechanical Engineers. A statement of my professional qualifications is attached hereto as Exhibit 1.

## I. THE TDI DIESEL GENERATOR OWNERS GROUP PROGRAM PLAN

### A. Background

5. TDI has been a major supplier of large diesel engines for marine propulsion, gas compression, and non-nuclear electric power generation for years. The engine known as the "Enterprise engine" of the Enterprise Engine and Machinery Company (which was acquired by TDI in 1960), underwent a major redesign in the late 1960s to transform it for the current ratings for electric power generation offered by TDI. The first engine of the revised design was sold in May of 1969, and operated at 400 rpm. The first engine of the four-valve design for 450 rpm operation (similar to the VEGP engines) was ordered in 1972.2/ By mid-1976, orders for over 160 R-4 engines had been placed with TDI, including over seventy V-16 engines. When Georgia Power Company placed its orders for four TDI DSRV-16-4 emergency standby diesel generators in 1976 for VEGP, orders for 42 emergency standby diesel generators at twelve other nuclear sites had already been placed with TDI.

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2/ The DSRV-16-4 diesel generators at VEGP are TDI R-4 (four valve) engines of the 16-cylinder, four-cycle, V-type design. Other TDI engines in nuclear service include the DSR-48 design, an in-line, 8-cylinder engine, and the DSRV-20 engine, a V-type design, but with 20 cylinders.

6. On October 25, 1983, as a result of a number of diesel generator operating experiences involving various nuclear power plant utility owners and various diesel engine types and manufacturers, a technical information exchange meeting hosted by Mississippi Power & Light was held in Atlanta, Georgia. As a result of discussions at this meeting, twelve U.S. utility owners, including Georgia Power Company, formed the TDI Diesel Generator Owners Group to address operational and regulatory issues relating to TDI diesel generator sets used as sources of back-up power in U.S. nuclear power plants.

7. The structure of the TDI Diesel Generator Owners Group was formalized and approved at an executive meeting held in Atlanta, Georgia on December 21, 1983. It consisted of an Executive Committee consisting of company officers from each participating utility and a technical program director. Reporting to the technical program director were the project engineer, the DR/QR program manager, and the DR/QR report review manager, each of whom was responsible for a different aspect of the program. Details of the organization of the Owners Group are presented in the "TDI Diesel Generator Owners Group Program Plan," which was submitted to the NRC on March 2, 1984.

8. The Program Plan established by the Owners Group provided an in-depth assessment of the adequacy of the respective utilities' TDI diesel generators to perform their intended

safety-related function through a combination of design reviews, quality revalidations, engine tests and component inspections. High quality technical resources were used in the implementation of the Program. Organizations and individuals with expert knowledge in the various areas requiring investigation, inspection and analysis were employed to ensure that the evaluations of the individual TDI diesel generators would be thorough and meaningful. The major technical resources utilized in this comprehensive Program, and their function were:

| | Organization | Role in Owners Group Program |
|---|---|---|
| a. | Stone & Webster Engineering Corporation (SWEC) | Management of quality revalidation and design review effort; |
| | | Performance of design review tasks; |
| | | Provision of licensing and logistical support. |
| b. | Failure Analysis Associates (FaAA) | Analysis of known problems; |
| | | Performance of design review tasks. |
| c. | FEV (German Diesel Consulting Firm) | Technical evaluation of known problems. |
| d. | Transamerica Delaval (TDI) | Provision of technical and experience data; |
| | | Review of design review and quality revalidation results. |
| e. | Owners Group | Provision of plant-specific technical and experience data; |

| Organization | Role in Owners Group Program |
|---|---|
| | Provision of working level engineers familiar with diesel generator plant-specific applications; |
| | Provision of overall program management. |
| f. Impell | Performance of design review tasks. |
| g. Subvendors | Provision of technical expertise on unique components; |
| | Provision of support for investigations and site-specific disassembly/reassembly of engines. |

9. The NRC Staff's evaluation of the Owners Group Program Plan was presented in "Safety Evaluation Report-Transamerica Delaval, Inc. Diesel Generator Owners Group Program Plan," dated August 13, 1984. This safety evaluation report ("SER") included a review of the technical evaluation report ("TER"), "Review and Evaluation of TDI Diesel Generator Owners' Group Program Plan," (PNL-5161) of June, 1984, which was prepared by Pacific Northwest Laboratory ("PNL").3/ Based on its review, the NRC Staff's overall finding was that the Owners

3/ PNL 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.

Group Program Plan incorporated 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 included: (1) resolution of known generic problems (Phase I); (2) systematic design review and quality revalidation of all components important to reliability and operability of each owner's 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 Phase II.

B. Phase I - Resolution of Generic Problems

10. In Phase I of the Owners Group Program, one of the first activities undertaken was the assemblage of experience data pertinent to TDI engines. Using input from various nuclear data sources4/ (i.e., INPO, SOERs, LERs, 10 C.F.R § 50.55(e)'s, and 10 C.F.R. Part 21's, etc.) as well as non-nuclear sources (both marine and stationary), supplemented by data obtained as a result of feedback from the utilities' own inspection and testing results (conducted as part of the Owners Group Program), TDI engine/component operational experiences

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4/ More fully described at ¶ 76.

were documented. A review of the accumulated data resulted in a conclusion by the Owners Group technical staff (i.e., SWEC, FaAA, FEV, etc.) that a limited number of components warranted consideration as significant known problems with potentially generic applicability to TDI diesel generators. Accordingly, sixteen components received priority attention within the Owners Group design review group. The sixteen components were as follows:

a. Turbocharger,
b. Base and bearing caps,
c. Crankshaft,
d. Cylinder block,
e. Cylinder head studs,
f. Connecting rods,
g. Connecting rod bearing shells,
h. Pistons,
i. Airstart valve capscrews,
j. Cylinder heads,
k. Fuel oil injection tubing,
l. Main and connecting pushrods,
m. Rocker arm capscrews,
n. Jacket water pump,
o. Wiring and termination,
p. Cylinder liner.

11. A detailed design review of each of these components was conducted by the Owners Group consultants to establish the adequacy of their design. Specific design and/or manufacturing concerns were identified and resolved through analyses, testing and documentation reviews. Establishment of maintenance requirements and the preparation of inspection plans for these components also formed part of the Phase I effort.

12. While TDI drawings and certain TDI information were used as input to both the Phase I and Phase II (DR/QR) programs, the actual technical evaluations were performed independently of TDI, thereby providing an independent verification of the critical design aspects of each component. Independent design verification was achieved as follows:

a. The attributes of the component to be verified by design review were determined by a thorough investigation of the component's service history and identification of likely failure modes.

b. Methodology for verification of the critical attributes was established, and significant engine components (i.e., components designed by TDI), were evaluated by the Owners Group, not by review of TDI analysis.

13. The Owners Group Program achieved independence from TDI's quality assurance ("QA") program by inspection and testing of the diesel generator equipment at each of the nuclear plant sites, including VEGP. These inspections were performed by both Owners Group personnel and by VEGP personnel. Examples of inspections performed by Owners Group personnel included field walkdowns of pipe, tubing and electrical conduit, safety-related wiring, and generator control equipment. In addition, eddy current examinations were performed on components such as the crankshaft and connecting rods, and material comparator and hardness readings were taken on various components. The Owners Group recommended inspections are a specific means of verifying critical aspects of each component, and as this method verifies the suitability of the components actually installed, independence from TDI's QA program is achieved.

14. Review findings and final recommendations on the Phase I components were outlined in thirty-six separate reports.5/ These reports contain recommendations for maintenance, testing and inspection, and recommendations concerning operating procedures and procurement specification

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5/ Thirty-six reports (fifteen subject reports plus supplements) were required to address the sixteen components due to differences between types of engines (i.e., the DSR-48 and DSRV-16-4). All of the sixteen components were addressed in separate reports except for the cylinder block and cylinder liner which were evaluated together.

requirements. As these reports were completed, they were sent to the NRC Staff for review and comment. The testing and analysis in support of these thirty-six Phase I reports represent a significant effort, spanning over a year's time and involving more than a hundred engineers and technicians. The following discussion addresses each of the sixteen Phase I components, providing an overview of the problems associated with them in the past and the methodology, and conclusions of the Owners Group review.

15. Rocker Arm Capscrew. The rocker arm capscrews in TDI diesel engines transmit resultant loads from the valve springs, valve opening pressure, pushrods, and rocker arm assemblies to the subcover and cylinder heads. The rocker arm capscrews were included among the sixteen Phase I components due to isolated failures which were attributed to insufficient preload application.6/ Two rocker arm capscrew designs were evaluated by the Owners Group, the original "straight shank" type capscrew and a modified "necked shank" design.7/ The VEGP capscrews are of

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6/ Joint Intervenors identified "[e]ngine rocker arm shaft bolt failure" as a problem experienced with the TDI diesels. See "CPG/GANE's Response to Applicants' First Set of Interrogatories and Request for Production of Documents," December 5, 1984, Answer to Interrogatories 14-1, 14-2. This refers to a failure of a rocker arm capscrew.

7/ A detailed discussion of the analysis performed is included in SWEC, "Emergency Diesel Generator Rocker Arm Capscrew Stress Analysis," March, 1984 and its Supplement, April, 1984, both prepared for the Owners Group.

the "necked shank" design. See "Affidavit of Steve A. Phillips" ("Phillips Affidavit"), Ex. 2.

16. Based on the results of its analyses, the Owners Group concluded that both the original and the modified designs were adequate for nuclear service. The modified "necked shank" design was found to be somewhat more resistant to fatigue failure and less likely to lose its preload due to its lower cyclic load. The threads utilized for both designs were determined to adequately resist distortion during preload application and the material utilized for the modified rocker arm capscrew design was determined to meet or exceed the requirements of the American Society for Testing Materials ("ASTM") Standard A193. The Owners Group recommended a quality revalidation review (material verification) on a sample basis to confirm capscrew material properties. The Owners Group further recommended that all materials used in the "straight shank" design, if not AISI 4140,8/ have a minimum proof strength of 90,000 psi. The Owners Group recommended that the capscrew torque be checked at every outage after initial engine operation.9/

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8/ AISI 4140 and ASTM-A193 are comparable in their requirements for chemical composition. AISI 4140 is a standard of the American Iron and Steel Institute.

9/ See Phillips Affidavit, Ex. 2, for a discussion of testing and inspections already performed at VEGP.

17. Fuel Oil Injection Tubing. The fuel oil injection tubing on the TDI standby diesel engines transfers high pressure fuel from the individual cylinder fuel pumps to the injection nozzles. The fuel oil injection tubing was included among the Phase I components due to leaks that developed in tubing installed on TDI diesels at two nuclear sites.

18. Both shrouded and unshrouded tubing designs were analyzed by the Owners Group.10/ The Owners Group also reviewed the TDI endurance test procedures and test results.11/ The test report from the fuel pump supplier (Bendix) was also reviewed. This report included tests demonstrating that cavitation and erosion were not a problem at the flow levels required in the TDI engines. In addition to these manufacturers' tests, several utility engines with TDI tubing, have accumulated more than 750 hours ($10^7$ cycles) of operation. This provides confirmation that the fatigue failures of the fuel oil injection tubing were isolated occurrences (manufacturing flaws) and not a generic problem.

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10/ Shrouded tubing is scheduled to be installed on the VEGP diesel generators, as recommended by the Owners Group. See Phillips Affidavit, ¶ 7.

11/ A detailed discussion of the Owners Group review of this component is contained in: "Emergency Diesel Generator Fuel Oil Injector Tubing," April, 1984, prepared by SWEC.

19. Based on its analyses, the Owners Group determined that the fuel oil injection tubing meets the stress criteria of ASME III Class 2 piping design. The fracture mechanics analysis concluded that a 0.0048 inch deep maximum flaw size could be contained on the inner surface of the tube and not propagate. The testing method (eddy current) used to detect cracks will assure that any flaw which might occur in the tubing does not exceed 0.004 inch deep. The compression fittings used to connect the tubing to the pump and injector were considered satisfactory given their testing and in-service performance.

20. The Owners Group recommended inspection of the inner surface of the high pressure tubing using eddy current techniques. Maintenance instructions recommend that the tubing and fittings be checked visually each month for fuel oil leaks while the engines are operating. Also, the tubing supports should be checked at each outage to assure that the elastomer inserts are functional and to check for any excessive fuel oil line vibration and deflection. Performance of the Owners Group recommended inspections and maintenance will ensure the suitability of the engines' fuel oil injection tubing.

21. Main Bearing Saddle, Bearing Caps and Fasteners. The main bearing saddle, bearing caps, and the fastener assembly support the engine crankshaft in the TDI standby diesel generators. The cylinder firing pressure exerts a load on the engine

piston which is transmitted to the main bearing saddle assembly through the connecting rod and the crankshaft. Therefore, the entire load on the piston is supported by the saddle-bearing cap assembly.

22. The saddle-bearing cap assembly was included among the generic concerns due to cracks observed in the bearing pedestals of DSR-4 inline engines, a nut pocket failure in a DSRV-16-4 engine, and through-bolt failures on a DSR-46 engine.12/

23. The Owners Group performed a stress analysis for both the bearing saddle and bearing caps.13/ The Owners Group concluded that the saddle-bearing cap assembly is adequate for nuclear service. The safety factors calculated by conservative analysis were adequate to conclude that the saddle-bearing cap assembly has infinite life against fatigue failure.

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12/ Joint Intervenors identified "[c]racked bedplates in area of main journal bearings" as a problem experienced with the TDI diesels. See "CPG/GANE's Response to Applicants' First Set of Interrogatories and Request for Production of Documents," December 5, 1984, Answer to Interrogatories 14-1, 14-2. This refers to problems experienced with the main bearing saddle, caps, and fastener assembly supporting the crankshaft.

13/ A detailed discussion of analyses performed is included in "Design Review of Engine Base and Bearing Caps for Transamerica Delaval DSRV-16 Diesel Engines," prepared by FaAA for the Owners Group.

24. To increase the factor of safety between the saddle and the bearing cap, the Owners Group recommended that the mating surfaces of the base and cap be thoroughly cleaned with solvent before first assembly and upon any reassembly as a precautionary measure to improve the frictional force resisting cap movement. The mating surfaces of the base and cap were cleaned with solvent at VEGP, as recommended. See Phillips Affidavit, Ex. 2.

25. Connecting Rod Bearing Shell. The babbitt-overlayed cast aluminum connecting rod bearing shells in the TDI standby diesel generator engines provide the oscillating/sliding surface between the crankpin and the connecting rod through formation of a hydrodynamic film. The cylinder firing pressure is transmitted through the connecting rod bearing shells to the crankpin. The force is thus converted into engine torque.

26. The connecting rod bearing shells were included among the Phase I components due to cracks found in several connecting rod upper shells in the Shoreham DSR-48 engines. These cracks were identified in the bearing shells after about 250 hours of full-load operation and were due to the combined effects of the Shoreham-unique design (1/4" x 45 degree) chamfer on the connecting rod bearing caps and voids in the bearing material resulting from the manufacturing process.

27. The Owners Group analysis concluded that the connecting rod bearing shells used on DSRV-16-4 engines, such as VEGP's, with 13-inch x 13-inch crankshafts and connecting rod bores with 1/16" x 45 degrees chamfer (which fully support the bearing shell) have a fatigue life of 38,000 hours of full-load engine operation.14/ This conclusion is verified by the operating history of the engines.15/

28. Based on the results of its analyses, the Owners Group concluded that the babbitt-overlayed cast aluminum connecting rod bearing shells were suitable for their intended purpose. The Owners Group analysis resulted in a recommendation that the size of the voids in the casting in the critical area of the bearing not exceed 0.050 inch. In the non-critical areas of the bearing shell, and in the lightly-loaded lower bearing shell, the void size can be as large as 0.250 inch. To assure compliance with the acceptance criterion, the Owners Group recommended inspection of the bearing shells by radiography. This inspection has been performed at VEGP and some shells rejected. See Phillips Affidavit, Ex. 2. The shells

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14/ A detailed discussion of the Owners Group analysis is included in the FaAA report, "Design Review of Connecting Rod Bearing Shells for Transamerica Delaval Enterprise Engines," March, 1984.

15/ For example, no failure of bearing shells was observed after 1200 hours of operation of a Grand Gulf DSRV-16-4 engine.

will be replaced by shells meeting the Owners Group acceptance criteria prior to preoperational testing. Id.

29. Emergency Diesel Generator Engine and Auxiliary Module Wiring and Termination Qualification to IEEE-383-1974. The TDI diesel generator engine and auxiliary module wiring and termination are interconnected by instrument, control, and power circuits on the diesel generator itself and within the control panels. The wiring and termination was included among the sixteen Phase I components because of a Service Information Memorandum ("SIM") and a 10 C.F.R. Part 21 notice issued by TDI informing utilities of two potentially defective engine-mounted cables that did not meet IEEE-383-1974 standards.

30. The Owners Group analysis included a review of the circuit requirements. Included in this analysis was a determination of the wire insulation rating, type and rating of termination, voltage, maximum temperature, current flame retardancy requirements (IEEE-383-1974), and routing.16/ Based on the results of its analysis, the Owners Group cncluded that the wiring and termination were satisfactory, provided that the modification referenced in TDI's SIM is implemented. VEGP will

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16/ A detailed discussion of this analysis is included in SWEC, "Emergency Diesel Generator Auxiliary Module Control Wiring & Termination Qualification Review," July 1984, prepared for the Owners Group.

be replacing its cables with 90°C IEEE-qualified cable, as required. See Phillips Affidavit, ¶ 14.

31. Satisfactory performance of the wiring and termination has been demonstrated in several utility engines with more than 750 hours of operation and over 100 starts each. This operating history confirms the reliability of the TDI-generic wiring and termination.

32. Cylinder Head Stud. The cylinder head studs in the TDI standby diesel generators transmit cylinder firing pressure forces from the cylinder heads to the engine block and assure the required preload on the cylinder head gasket for combustion gas and water sealing. The cyinder head studs were included among the Phase I components due to isolated failures resulting from insufficient preload in some non-nuclear applications. Two distinct head stud designs were evaluated by the Owners Group, the original, "straight" shank design, and a modified, "necked" shank type. The VEGP engines have the "necked" shank design. See Phillips Affidavit, Ex. 2.

33. A stress analysis was performed by the Owners Group on both head stud designs17/ The analysis included a

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17/ A detailed discussion of the analysis is included in SWEC, "Emergency Diesel Generator Cylinder Head Stud Stress Analysis," April, 1984 and its Supplement, May, 1984, both prepared for the Owners Group.

determination of the applied stresses, the endurance limits, a fatigue life analysis, a thread distortion analysis, and a thermal stress evaluation of both stud designs. Based on its analysis, the Owners Group concluded that both the "straight" and "necked" studs were satisfactory for nuclear service. The "necked" shank design (used at VEGP) is somewhat more resistant to fatigue failure and less likely to lose its preload. The "necked" design top thread in the block is lower than that on the "straight" stud, which means that the "necked" design will produce lower stress levels near the liner landing area than the "straight" stud. The Owners Group recommended a quality revalidation review (material verification) on a sample basis to confirm that the cylinder head stud meets the requirements of AISI 4140. This materials verification has been performed at VEGP. See Phillips Affidavit, Ex. 2.

34. Air Start Valve Capscrew. The air start valve capscrews in the TDI standby diesel generators provide the clamping force to hold the air start valves in place on the cylinder heads. The air start valve capscrews were included among the Phase I components because cylinder heads were found with insufficiently drilled-out air start valve capscrew holes which could prevent the air start valve from being properly seated. This was discovered during an inspection prompted by a SIM issued by TDI which recommended that users measure the

length of their engine air start valve capscrews because some were too long. TDI recommended that the capscrews be shortened. VEGP has replaced the original 3-inch long capscrews supplied with its engines with the 2-3/4 inch length. See Phillips Affidavit, ¶ 14, Ex. 2.

35. A stress and dimensional analysis was performed by the Owners Group for the air start valve capscrew in order to verify TDI's recommended modification to a shorter length.18/ The analysis included a determination of minimum possible capscrew clearance (given the specified tolerances of the capscrew and its clamped parts), the applied stresses, a fatigue analysis and an analysis of stresses during tightening. Satisfactory fatigue and operational life has been demonstrated by several utility engines which have accumulated more than 750 hours ($10^7$ cycles) of operation and over 100 starts. This operating history verifies that capscrew fatigue and operational failures will not be a problem.

36. Based on analysis and operating experience, the Owners Group concluded that the air start valve capscrew was satisfactory for nuclear service. The design provides adequate

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18/ A detailed discussion of this analysis is included in the SWEC report, "Emergency Diesel Generator Air Start Valve Capscrew Dimensions and Stress Analysis," March 1984, prepared for the Owners Group.

safety factors against fatigue failure and failure while tightening. The capscrew will not fail due to loss of preload.

37. The Owners Group recommended retorquing at eight-hour intervals during initial engine operation, as specified by TDI, until no further movement is detected. This retorquing procedure will assure retention of a tight seal as the copper gasket "sets". VEGP will perform this retorquing, as recommended. See Phillips Affidavit, Ex. 2.

38. Pushrods. The intake and exhaust main pushrods and the exhaust connecting (intermediate) pushrods were among the sixteen Phase I components. The primary function of the pushrod is to provide a portion of the linkage that transmits camshaft lobe motion to the intake and exhaust valves, thereby controlling the valve opening and closing cycle. Three basic designs are in use. These are: 1) forged head; 2) ball end; and 3) friction-welded end.

39. The forged head design consists of a tubular steel shaft fitted with hardened steel end pieces attached to the tube with four plug welds near the end of the tube. Cracking in the tube wall adjacent to the plug welds has been found in the forged head design.

40. The ball end design consists of a tubular steel shaft fillet-welded to a carbon steel ball at each end. The ball end

design has exhibited cracking at the interface of the pushrod tube and ball end fitting. These cracks have developed in the heat-affected zone of the high carbon chrome steel ball. Complete separation between the tubular steel shaft and the pushrod ball has occurred upon disassembly. Failures of the forged head and ball end designs have not affected engine operability because the valve train lash has never been sufficient to allow the pushrod end to escape from the tube.

41. The friction-welded design (the design used at VEGP, see Phillips Affidavit, Ex. 2), consists of a tubular steel shaft friction-welded to a solid steel plug on each end. No failures have been reported for the friction-welded pushrods.

42. The Owners Group investigation of the pushrods consisted of a metallurgical analysis of the fillet-welded ball end design, fatigue analyses and an analysis of the buckling stability and wear resistance of the forged head and friction-welded designs.19/ In addition, the Owners Group performed experimental evaluation, including fatigue tests of forged-head and friction-welded pushrods. The fatigue tests were performed at loads in excess of those expected in service to a life of $10^7$ cycles. From the analysis and testing performed, the

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19/ A description of the Owners Group review is contained in, "Design Review of Push Rods for Transamerica Delaval Diesel Generators", April, 1984, prepared by FaAA.

Owners Group concluded that the friction-welded design is the most reliable of the three pushrod designs.

43. The Owners Group recommended an inspection and sampling plan for the pushrods as follows:

a) Verify that the main end connector pushrods are friction-welded.

b) Perform a liquid penetrant or magnetic particle test on all main and connector pushrods. If these inspections cannot be performed, a visual inspection is acceptable if the surface is thoroughly cleaned to remove any coatings or deposits.

All pushrods for the Unit 1 A-train engine have been liquid penetrant tested, with satisfactory results. See Phillips Affidavit, Ex. 2. The B-train pushrods will be liquid penetrant tested prior to preoperational testing of the engine. Id. The pushrods on the Unit 2 engines have also been liquid penetrant tested, with satisfactory results. Id.

44. Cylinder Heads. The cylinder heads in the TDI standby diesel generators provide a pressure-tight cap for the engine cylinders and provide passages and sealing for cooling water, lube oil, starting air, intake, and exhaust gases. The

cylinder heads were included among the sixteen Phase I components because of head defects consisting of cracks in locations such as the fire deck, the exhaust and intake bridges, exhaust valve seats, and induction port.

45. A metallurgical analysis was performed by the Owners Group which included: 1) examination of casting shrinkage indications found in a cylinder head taken from a Comanche Peak engine; 2) examination of a pre-existing shrinkage void and of a crack in a stellite weld deposit, each found in a Grand Gulf head; and 3) the examination of a crack across the wall of the fuel injector port in a head from an engine at the Catawba Nuclear Power Station.20/

46. Based on metallurgical evaluations of different generations of TDI cylinder heads, limited analysis of the fire deck area, and review of the service history, the Owners Group reached the following conclusions and made the following recommendations:

a. Past problems with cylinder heads (i.e., leaks) are attributable to the manufacturing process.

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20/ A detailed discussion of the analyses performed is included in FaAA report "Evaluation of Cylinder Heads of Transamerica Delaval, Inc. Series R-4 Diesel Engines," May 1984, prepared for the Owners Group.

b. Cylinder heads cast before September, 1980 are subject to core shift, inadequate control of solidification, and inadequate control of the stellite valve seat weld deposition process. Heads cast before October, 1978 were not stress-relieved and are therefore subject to fatigue crack growth in thin sections and/or from fabrication-induced defects.

c. The potential for pre-existing flaws in heads manufactured after September, 1980 is significantly less than for heads manufactured earlier.

d. The heads are adequate for their intended service, provided the Owners Group recommended inspections and maintenance activities are followed.

47. The cylinder heads in the VEGP diesels were manufactured after September, 1980. See Phillips Affidavit, Ex. 2. VEGP has performed the inspections recommended by the Owners Group. Id. Visual inspection, liquid penetrant tests, magnetic particle tests, and ultrasonic tests were performed on all of the Unit 1 and Unit 2 heads. Id. One cylinder head from Unit 1 was rejected and replaced. Id. Two heads were rejected from the Unit 2 engines and replaced. Id. VEGP has committed to implement Owners Group recommended maintenance and surveillance, see id. ¶ 11, which includes barring-over of the engines.

48. Piston Skirt. The piston skirt in the TDI diesel generators transmits the cylinder gas pressure force on the piston crown to the connecting rod. Also, the piston skirt supports the piston crown and guides the connecting rod into the engine's cylinder. The side thrust developed due to the obliquity of the rod is transferred to the piston skirt. The piston skirt provides a sliding friction surface against the stationary cylinder liner. In the TDI diesel generators, the piston crown is bolted to the piston skirt.

49. The piston skirts were included among the sixteen Phase I components due to cracks in the skirt-to-crown stud attachment bosses in 23 out of 24 pistons in a DSR-48 engine at Shoreham. Each of the cracked piston skirts were of the AF design.

50. The Owners Group performed a detailed analysis of the AF and AE type piston skirts. Basically, the AF and AE piston skirts are similar in design with identical loading and functional attributes. The major difference between the two designs is in their fabrication thermal history and the configuration of the stud bosses inside the skirt where the washers on the crown attachment stud meet the skirt.

51. In the Owners Group analysis, a non-destructive dye-penetrant test was performed on a cracked AF piston.21/ The

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21/ A discussion of the analysis performed by FaAA for the Owners Group is contained in "Investigation of Types AF and AE Piston Skirts," May 23, 1984.

analysis found that all of the cracks were similarly located and oriented on the spot-faced boss. A destructive examination was conducted and the cracks were opened up. Examination of the fractured surfaces indicated that they were fatigue cracks. This was confirmed by examination in a scanning electron microscope.

52. The Owners Group experimental and analytical evaluations showed that the peak stresses in the AE skirts (the design utilized at VEGP, see Phillips Affidavit, ¶ 14, Ex. 2), are generally lower than the corresponding AF values. This fact, coupled with the positive operating history of the AE skirt on both nuclear and non-nuclear TDI diesel engines, led the Owners Group to conclude that the AE piston skirts are adequate for unlimited life under full load conditions.

53. Cylinder Block and Liner. The cylinder block in the TDI standby diesel generators makes up the central framework for the engine. The cylinder block was included among the Phase I components because of block top cracking exhibited in blocks in the Shoreham engines and other TDI engines in nuclear and non-nuclear applications. Four types of cracks were identified in the Shoreham engine blocks: 1) ligament (from cylinder liner counterbore to head stud counterbore); 2) stud-to-stud; 3) stud-to-end of block; and 4) circumferential cracks at the liner counterbore.22/ All of these cracks connected with

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22/ Owners Group analysis of circumferential cracking showed these cracks to be the result of loads applied to the cylinder

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the block-top surface and could be detected by surface inspection. At Shoreham, one block (from Emergency Diesel Generator ("EDG") 103) was found to have a Widmanstaetten graphite microstructure. This block also had stud-to-stud and stud-to-end cracks. No instance has been reported where cylinder block cracks have resulted in failure of an R-4 or RV-4 engine.

54. The Shoreham engine blocks analyzed by the Owners Group had operated a significant amount of time at or above the nameplate rating of 3500 kW.23/ As part of its engine requalification testing, Shoreham operated each engine 100 hours at or above the design load. During engine disassembly and inspection, ligament cracks were found. After inspection, unit EDG102 was operated through 100 starts to loads greater than 50% nameplate load and was then reinspected. Eddy current examination showed no discernable extension of ligament cracks. In general, cracks were detected and measured using visual, liquid penetrant, and eddy-current inspection techniques.

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liner landing. Liner landing pressure is primarily controlled by the interference of the liner collar (proudness) above the block top. The VEGP blocks have been reworked to reduce this interference to current TDI specifications. See Phillips Affidavit, Ex. 2. Liner crush has been maintained. Id.

23/ A detailed discussion of the analysis performed is contained in the Owners Group report, "Design Review of TDI R-4 and RV-4 Series Emergency Diesel Generator Cylinder Blocks and Liners," prepared by FaAA.

55. A cylinder block strain gage test was conducted by the Owners Group on unit EDG103 following a 100-hour full power endurance test. A metallurgical analysis was also conducted. The analysis consisted of an investigation of the microstructure, composition and mechanical properties of four TDI R-4 cylinder blocks from three engines at Shoreham. The four cylinder blocks investigated were EDG101, EDG102, EDG103 (original) and EDG103 (replacement). It was established that the microstructure of EDG101, EDG102, and EDG103 (replacement) was normal for grey cast iron but the EDG103 (original) block was characterized by an abnormal graphite distribution (degenerant Widmanstaetten graphite). It is generally accepted that the mechanical properties of grey cast iron with the Widmanstaetten ferrite are lower than normal. Higher than normal amounts of the tramp elements (lead and antimony), were present in the EDG103 (original) block. The study described in the Owners Group report clearly showed that the original, cracked EDG103 cylinder block was characterized by an abnormal microstructure and that the mechanical properties of that material were substandard.

56. The Owners Group fracture and fatigue life evaluation produced a cumulative damage analysis which takes into account a cumulative Fatigue Damage Index ("FDI"). This index accounts for hours of operation at each power level and the

corresponding mean stress and cyclic stress driving the crack at each power level. The index quantifies the effect of differing fatigue crack growth rates of different materials. This allows comparison of the test period experience on the original Shoreham EDG103 block, with its documented degraded fatigue resistance, to the expected behavior of other type cylinder blocks having the fatigue resistance characteristic of typical grey cast iron under required test and postulated Loss of Offsite Power/Loss of Coolant Accident ("LOOP/LOCA") conditions. Application of the cumulative damage analysis can be used to set future engine operation limits. Safe operation can be assured during a LOOP/LOCA based on Shoreham benchmark operations in combination with past operation of the engine provided proper procedures are followed as referred to in the Owners Group report.

57. Based on the stress analysis, the Owners Group made the following recommendations:

- Periodic inspections are necessary to demonstrate that each cylinder head block is capable of performing its intended function as a component in a diesel generator in nuclear standby service.
- All blocks should be metallurgically evaluated to verify that the microstructure is characteristic of typical grey cast iron.
- Cylinder blocks that are inspected and found to be free of ligament cracks can operate without additional inspections for combinations of load and time that produce less than the excess cumulative damage index that has been demonstrated by its operation at the

time of the latest block top inspection. Blocks of engines that have operated without block top inspection or for a time beyond the last inspection in excess of the allowable fatigue damage index should conservatively be assumed to have cracked ligaments.

- For blocks with known or assumed ligament crac! ., absence of detectable stud-to-stud or stud-to-end cracks between the heads should be established before returning the engine to emergency standby after any operation in excess of 50% nameplate load. Any stud-to-stud or stud-to-end crack indications must be evaluated with detailed inspection to assure that they extend less than 1.5 inches from the block top before returning the engine to emergency standby after any operation in excess of 50% nameplate load. It is necessary to evaluate the microstructure to ensure typical cast iron.

The above recommendations are being implemented at VEGP. See, e.g., Phillips Affidavit, Ex. 2.

58. Turbocharger. The turbochargers on the TDI standby diesel generators utilize exhaust gas energy to drive the turbine which drives a compressor on a common shaft to pressurize the engine intake manifold. This forces more air into the combustion chamber, permitting more fuel to be introduced which results in higher combustion pressures and higher net engine output than that possible with natural aspiration.

59. The turbochargers were included among the Phase I components because of thrust bearing, nozzle vane, nozzle ring capscrew and washer, and nozzle ring failures on TDI nuclear and non-nuclear standby diesel engines.24/

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24/ A detailed discussion is included in the FaAA report "Design Review of Elliott Model 90G Turbocharger Used on

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60. The Owners Group performed inspections of thrust bearings from nuclear engines that had experienced a series of starts and some operating time. The thrust bearings from an engine that used only the drip pre-lubrication system experienced measurable wear with a low number of operating hours and engine starts. The thrust bearing from an engine with a before and after (b & a) lubrication system, activated manually for two minutes prior to start, experienced no measurable wear.25/

61. The Owners Group concluded from its analyses that the thrust bearing would provide adequate service if a prelubrication system operated with a drip provision for fast starts was installed and used during non-emergency starts. The Owners Group found that the thrust bearings were of adequate design, given proper lubrication, to operate at the loads introduced by the exhaust and induction air gases during transient, normal operating and overload conditions. The Owners Group recommended that the thrust bearing be inspected at each 5-year overhaul interval.

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Transamerica Delaval DSR-48 and DSRV-16 Emergency Diesel Generator Sets", prepared for the Owners Group.

25/ The VEGP turbochargers' drip pre-lubrication systems are being modified so that lube oil can be manually-added. See Phillips Affidavit, Ex. 2.

62. The Owners Group found no problems with regard to the dynamic performance of the rotor assembly. The Owners Group also reported on the nozzle ring capscrew, washer and vane failures, after investigating the failures of these components at several nuclear power plants. The analysis concluded that the nozzle vane failures were due to high cycle fatigue introduced by engine vibration or exhaust gas pulsations. The report concluded that while isolated vane failures may occur, they have not resulted in any degradation in diesel generator performance or a shutdown among the nuclear engines investigated.26/ No cause for the cracked washer was found.27/ The failure of the capscrews is attributed to improper preload. The single nozzle ring failure is attributed to probable impact from a broken vane. Recommendations were made that all turbochargers be inspected for nozzle vane damage and that all capscrews be properly torqued to the 18 to 22 lbf-ft specified by Elliott. This has been done at VEGP. See Phillips Affidavit, Ex. 2. In addition, it was recommended that the exhaust temperatures be monitored and corrective actions taken if they exceed the values recommended by TDI. VEGP will be monitoring exhaust temperatures. Id. Based on the results of the

26/ Maintenance performed during every outage would permit identification of loose or missing vanes or capscrews.

27/ Failure of a washer would not cause any degradation of diesel generator performance.

analysis and the recommendations made for this component, the Owners Group concluded that the Elliott Model 90G turbochargers will perform satisfactorily.

63. Jacket Water Pump. The jacket water pump, taking suction from the jacket standpipe, delivers coolant (treated water) at the required pressure and flow rate to the engine jacket water header. The pump provides the coolant circulation needed to cool the engine cylinder assemblies, exhaust manifold, turbocharger, intercooler, and engine lube oil cooler.

64. The particular water pump design used on the DRSV-16-4 engine (such as the ones at VEGP) does not have a history of failures. However, the jacket water pump used on the TDI standby generators equipped with the in-line diesel engine, model DSR-48, has a history of shaft failures in nuclear and non-nuclear service.

65. The Owners Group report for the DSRV-4 pump reflects the use of two different impeller diameters - either 12.1 inches or 10.75 inches.28/ This variability is due to differences in plant specification and the consequential coolant flow requirement for the standby generators. In addressing the

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28/ A detailed discussion of the analysis is included in SWEC, "Emergency Diesel Generator Engine Drive Jacket Water Pump Design Review," April 1983, and its supplement, June 1984.

impact of the difference in diesel impeller diameter on the review, the Owners Group used a conservative approach - one based on analyzing the system with the larger impeller. This situation represented "the worst case" in terms of shaft and coupling loading. The Owners Group concluded that the DSRV-4 and the modified DSR-4 pump designs were adequate for nuclear service.

66. Crankshaft. The crankshaft in TDI standby diesel generator engines converts reciprocating motion, component inertial forces and gas pressure piston forces to rotary motion and torque at the output flange. The 13" x 13" DSRV-16-4 engine crankshaft was included among the Phase I components due to three crankshaft failures in non-nuclear applications. The non-nuclear failures were attributed to torsional fatigue cracks initiated in the oil holes of main journal numbers 6 or 8. There have been no failures of 13" x 13" crankshafts on DSRV-4 engines in nuclear service. The only failure of a crankshaft in a TDI diesel engine in nuclear service was on the smaller 11" x 13" crankshafts on the three Shoreham DSR-48 engines.

67. The Owners Group performed a dynamic torsional analysis of the crankshaft to determine the true range of torque at each crankthrow. A torsional model of the crankshaft was developed to supplement TDI's conventional forced vibration

calculations. In order to compute the true summation of the stresses due to various orders, the model included computations for phase relationships between the various orders. The first three natural frequencies of the VEGP crankshaft were calculated. The natural frequencies were found to be in agreement with those computed by TDI.

68. Further analysis considered the harmonic loading on the crankshaft. Gas pressure, inertial forces and frictional loading were considered for the harmonic loading calculations. The dynamics of a V-16 engine are such that the 4th order load components from the left and right banks almost cancel. In practice, however, due to various reasons such as manufacturing tolerances and individual cylinder timing, the balance is not complete. To simulate the unbalance the Owners Group applied one degree delay in the right bank cylinder. In the absence of torsiographic test data, the calculated amplitudes are not compared with the measured amplitudes. The model was used to calculate the range of torques at each crankthrow. The stress level was found to be highest between cylinders 3 and 4, 5 and 6, 7 and 8. The highest nominal shear stress amplitude of 5335 psi was found to be lower than the 7000 psi allowable by the Diesel Engine Manufacturers Association ("DEMA"). The Owners Group performed calculations to determine the amplitude of free-end vibration and the associated nominal shear stress at

7000 kW power and at a crankshaft critical speed of 438.4 rpm. The highest nominal shear stress amplitude of 5128.8 psi was found to be lower than the 7000 psi allowable by DEMA.

69. The Owners Group analysis concluded that the TDI calculations were appropriate and show that the crankshaft stresses are below DEMA recommendations for a single order. The torsiograph tests performed on DSRV-16-4 diesel engines at a number of nuclear stations also show that the peak-to-peak crankshaft stresses are within the DEMA recommendations. The Owners Group concluded that the VEGP crankshafts are adequate for their intended service provided all of the Owners Group recommendations are followed. A torsiograph test should be performed and the results compared with both the Owners Group analysis and TDI's calculations.29/ The results of the torsiograph test should demonstrate that the crankshaft stresses meet DEMA standards and that they are close to the TDI and Owners Group values. Individual cylinder timing should be adjusted to accomplish engine balance and bring the stress values in line with those of TDI and the Owners Group.

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29/ Torsiograph testing will be conducted at VEGP to confirm the adequacy of the crankshafts. See Phillips Affidavit, ¶ 22. Cylinder imbalance testing will also be conducted at the time of torsiograph testing. Id.

70. Connecting Rods. The connecting rods used in the TDI standby diesel generators transmit engine cylinder firing forces from the pistons to the crankshaft such that the reciprocating motion of the pistons induces shaft rotation and output torque. By virtue of the V-cylinder configuration, the mechanism required to perform this function consists of two connecting rods arranged in a master-articulated manner. This arrangement requires more sophistication in bearing design and assembly methodology than that found with in-line type engines. Such complexity makes the design analysis more involved and requires that there be substantial operating experience and/or experimental data to confirm the design integrity.

71. Initially, the connecting rod assembly was produced with 1-7/8 inch diameter bolts to secure the main assembly joint (master rod box to link rod box). Operating experience in non-nuclear applications indicated that the design was vulnerable to failure by one of two mechanisms -- either by loss of bolt preload resulting in bolt failure or by the fatigue failure of the master rod box with cracks initiating at the thread roots. To compensate for the loss of bolt preload, the installation torque specification for the joint bolts was increased. Corrective action for the fatigue of the master rod box resulted in a design revision with 1-1/2 inch diameter bolts, torqued to 1700 lbf-ft to provide the same clamping

force obtained with the 1-7/8 inch bolt configuration torqued to 2600 lbf-ft. This change in bolt diameter provided a greater material section and consequently reduced the stress levels in the master rod box. The VEGP connecting rods are supplied with the revised 1-1/2 inch diameter bolt. See Phillips Affidavit, Ex. 2.

72. The analysis conducted by the Owners Group indicated that both rod assembly designs were acceptable for nuclear service.30/ The results, however, showed that the 1-1/2 inch design was not vulnerable to fatigue failure under the same engine load conditions as in the case of the 1-7/8 inch design.

73. For both designs, the Owners Group recommended that each rod assembly be inspected with nondestructive techniques to confirm the absence of flaws. In the case of the 1-7/8 inch bolt system, the inspection should be performed at intervals of 200 engine hours. For the 1-1/2 inch bolt system, the inspection need only be done initially to confirm the absence of pre-existing flaws. Beyond these inspections, the rod assemblies need only be checked for proper bolt torque at installation. VEGP is implementing these Owners Group recommendations. See, e.g., Phillips Affidavit, Ex. 2.

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30/ A detailed description of this analysis is included in FaAA report "Design Review of Connecting Rods for Transamerica Delaval DSRV-4 Series Diesel Generators," August 1984, prepared for the Owners Group.

74. The Owners Group concluded that the rod assemblies are suitable for their intended application provided the following maintenance recommendations are observed: 1) the bolt holes be initially inspected to verify the absence of pre-existing flaws, 2) the procedure for torquing the rod bolts reflect the importance of cleaning the threaded surfaces and using a thread lubricant as specified in the TDI instruction manual, and 3) a comprehensive inspection of the connecting rods be conducted at each engine overhaul interval.

### C. Phase II - Design Review/Quality Revalidation of Selected Engine Components

75. Phase II of the Program (design review and quality revalidation), examined the components of each owner's particular engines, not evaluated in Phase I, from the standpoint of both design and quality attributes, to assess their ability to reliably perform their intended function. These components did not have a history of problems. A Component Selection Committee composed of a component selection chairperson, SWEC representative, FaAA representative, TDI representative, diesel generator specialist, and an owner's representative, formally reviewed each owner's engine components. Based on the specific component's function and role in the overall operation of the engine, applicable site and industry experience, and the engineering judgment and experience of the Committee, certain

components were then selected for a detailed design review and/or quality revalidation.

76. The first step in component selection, review of engine experience, encompassed three areas of review: (1) nuclear industry experience; (2) non-nuclear industry experience; and (3) utility site-specific experience. Nuclear industry experience associated with each component was gathered and entered into the component database (a computer summary of the selected diesel generator components compiled using the "TDI Parts Manual"). Sources of information included:

a. Licensee Event Reports (LERs);

b. Significant Event Reports (SERs);

c. Institute for Nuclear Power Operation ("INPO") Significant Operating Event Reports (SOERs);

d. 10 C.F.R. § 50.55(e) reports;

e. 10 C.F.R. Part 21 reports;

f. INPO Nuclear Plant Reliability Data System entries (NPRDS);

g. Electric Power Research Institute reports;

h. Inspection and Enforcement (I&E) bulletins, notices, and circulars;

i. TDI Service Information Memos (SIMs).

The non-nuclear industry experience of the component was gathered on engines manufactured by TDI. Sources of information included:

a. Stationary/marine engine experience;

b. Correspondence between TDI and purchasers;

c. Ships' logs; and

d. Engine inspection reports.

Each utility in the Owners Group, including GPC, gathered site-specific component experience which was entered into the database. Sources of information included:

a. Design change documents;

b. Repair/rework documentation;

c. Deficiency reports;

d. Inspection reports;

e. Maintenance logs.

All of the information in this database contributed to the Committee's selection of components.

77. During the component selection process, engine components were classified as either Type A, Type B, or Type C. These classifications were based on the effect the component's failure would have on diesel generator performance. A description of each of these classifications follows:

a. Type A Component - a component, based on the judgment and experience of the Component Selection Committee, whose failure would result in immediate diesel generator shut-down, or prevent start-up under emergency conditions.

b. Type B Component - a component, based on the judgment and experience of the Component Selection Committee, whose failure would result in reduced capacity of the diesel generator, or the eventual failure of a Type A Component, if not detected.

c. Type C Component - a component, based on the judgment and experience of the Component Selection Committee, whose failure would have little bearing on the effective use or operation of the diesel generator.

Examples of Type A, Type B, and Type C components follow:

a. <u>Type A</u>

Turbocharger
Crankshaft
Cylinder Block
Connecting Rods

b. <u>Type B</u>

Intercooler
Jacket Water Standpipe: pipe, fittings, gaskets
Base and Bearing Caps-Base Assembly
Cam Bearing

c. <u>Type C</u>

Turbo Tools
Pyrometer Wire
Turbo Charger Air Inlet Adapter
Crankcase Vacuum Fan

Examples of components which did not require classification were items such as nameplates and maintenance tools.

78. The Component Selection Committee chose the components to be subjected to a design review and/or quality revalidation on the foregoing bases (i.e., component classification as to criticality, past industry and other site-specific experience, etc. as inputted to the component database, as well as the engineering judgment and experience of the Component Selection Committee). Absence of adverse operating experience did not necessarily exclude a component from the DR/QR process. The following illustrates the general guidelines for selection:

a. Type A Components - design review and/or quality revalidation normally required.

b. Type B Components - Component Selection Committee would determine if design review and/or quality revalidation was required.

c. Type C Components - design review and/or quality revalidation normally not required.

79. Engine components selected for design review and/or quality revalidation were then subjected to reviews, inspections, testing, etc., as required by the Component Selection Committee. The nature of a specific component determined if a Design Review alone was required, Quality Revalidation alone was required, or both were required. The critical attributes of a given component, and how best to verify that attribute

(i.e., analysis, inspection or both), dictated the nature of the required review.

80. An example of a Design Review-only component is the flywheel. It was determined that the only attribute required for review was the flywheel's effect on the crankshaft torsional system. Only design review was required to determine, for each plant, what differences, if any, existed between the site-specific flywheel and the lead engine, and to evaluate any differences.

81. An example of a Quality Revalidation-only component is the control panel assembly terminal boards/switches/wiring. It was determined that the only review of attributes required was a visual inspection of the control panel for cleanliness and a verification that the wire was purchased to environmental qualification requirements.

82. Design review and/or quality revalidation requirements were reflected in specific task descriptions ("Component Revalidation Checklists") prepared for each component by the Owners Group Design Review Group and Quality Revalidation Group.31/ Task descriptions included any requirements

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31/ The Design Review Group consisted of consultants from SWEC, FEV, Impell, and FaAA. SWEC was responsible for small bore piping and tubing equipment. Impell was responsible for

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specified in the selection process, as well as more detailed descriptions of procedures, standards, or design review approaches to be applied.32/ The individual task descriptions were then implemented by the Owners Group technical staff, in the case of design reviews, and by the individual owner's quality revalidation group, as discussed in the Phillips Affidavit, in the case of quality reviews.

83. The Owners Group Program is based on a lead engine and follow-on engine concept. The lead DSR-48 engines, at Shoreham, and lead DSRV-16-4 engines, at Comanche Peak, were extensively evaluated over an eight-month period. A full review was conducted on all the required components during this period, utilizing over a hundred engineers, designers and

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large bore piping. FaAA and FEV were responsible for engine components. Each component was assigned a task leader from the various organizations. This task leader would develop a task description which was reviewed and approved by the Design Review Chairman and the Program Manager.

The Quality Revalidation Group consisted of SWEC engineers, quality assurance engineers, and inspectors. Based upon the inspection and review requirements, as specified by the Component Selection Committee and the Design Review Group, they would develop specific task descriptions for each component.

32/ The task description for each component reviewed in Phase II of the Program is contained in or referenced in each owner's final DR/QR report, prepared by the Owners Group. The DR/QR Report prepared for VEGP, Unit 1, incorporates the information contained in the 12-volume VEGP report on its engine inspection effort. See also Phillips Affidavit, ¶ 6.

technicians. For each of the follow-on engines, including those at VEGP, each component requiring a design and/or quality review was evaluated by the Design Review Group Task Leader to determine if the lead engine review was applicable. This evaluation involved identifying differences in design, loading, or application and evaluating any significant differences.

84. The gears provide a typical design task description for a VEGP Type A component based on the lead engine review. The design review checklist called for a comparison between the gear design for VEGP and the lead engines. To accomplish this, a review of the TDI parts list and applicable drawings was performed. This showed that the design at VEGP was the same as Comanche Peak and Grand Gulf. Gear loads were calculated by utilizing the lead engines. Gear analysis was conducted with input from the specific VEGP crankshaft torsional vibration analysis. The VEGP gear tooth loads were compared to the Comanche Peak and Grand Gulf loads to ensure that the VEGP loads were bounded. The calculations performed on the Comanche Peak and Grand Gulf gears showed that the TDI design was adequate to meet its intended function. Since VEGP's load was bounded by Comanche's and Grand Gulf's, the gear train installed in the VEGP engines was considered acceptable.

85. 171 components were reviewed for the VEGP engines. 153 of these components were the same as those selected for

DR/QR on the lead engines. Each component report in the VEGP DR/QR Report contains a general description of the component, the objective of the review, the methodology used, results and conclusions (and includes references to the lead engines' reports as required). A total of twelve reports (some of which address multiple components) were prepared for components unique to the VEGP engines. Exhibit 2 contains examples of two VEGP-unique reports (for the cylinder block and starting air manifold tubing supports) and two reports (for the connecting rod bearing shells and rocker shaft assemblies) which rely on the previously-prepared lead engine reports (which are also included).

86. Upon completion of the DR/QR effort, inspection results, document packages, design review findings, and calculation results, were reviewed and approved by the Owners Group technical staff. Where results of these reviews and/or inspections indicated the need for additional action (i.e., component replacement, maintenance recommendations, etc.), follow-up activities were initiated.

87. Follow-up activities, if any, were generally a recommendation for increased maintenance, a one-time quality inspection, or, in some cases, a modification to the equipment. In the case of the gear train review discussed above, the following recommendations were made to ensure component reliability:

a. Visual inspections are to be performed during scheduled refueling outages for signs of progressive pitting.

b. Mating surfaces between idler gear and hub are to be thoroughly cleaned prior to assembly.

c. Hub nuts are to be properly torqued to the recommended torque range and relocked.

D. Engine Maintenance and Surveillance, Testing and Inspection

88. The final elements of the Owners Group Program involve enhanced engine maintenance and an engine testing program, coupled with specific inspections of both Phase I and Phase II components.33/ The Owners Group technical staff, in evaluating specific engine components, provided technical recommendations to the owners regarding special or expanded engine tests and component inspections which would be appropriate to ensure the adequacy of the engines and components to perform their intended safety-related functions. These recommendations, together with maintenance and surveillance requirements, were conveyed in each plant's DR/QR report and will be performed at VEGP. See Phillips Affidavit, ¶¶ 11, 22.

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33/ A discussion of VEGP's maintenance and surveillance program and engine testing is contained in the Phillips Affidavit.

## II. CONCLUSION

89. At the completion of each owner's DR/QR effort, a final report was issued by the Owners Group summarizing and transmitting results of the DR/QR reviews, identifying any corrective actions or recommendations, and providing conclusions regarding the adequacy of the diesel generators to perform their intended safety-related service.

90. The Owners Group completed its review and issued the final DR/QR report on the DSRV-16-4 diesel engines at VEGP Unit 1 in December of 1984.34/ Both the scope, and the comprehensiveness of this review represents a significant effort by the Owners Group technical staff and Georgia Power Company personnel. The results of this review, as presented in the VEGP DR/QR Report, establish that the important components of the TDI diesel generators at VEGP have been assessed to be adequate for their intended safety-related function.

91. Nuclear standby diesel generator reliability has been a major concern of both the industry and the NRC. Although previous programs have been sponsored by the NRC, EPRI, and other industry groups to quantify and improve diesel generator reliability, the Owners Group Program was unprecedented in its

34/ A separate DR/QR report will not be prepared for VEGP Unit 2.

approach and analytical detail. Many of the components reviewed were analyzed using techniques exceeding the detailed engineering effort which originally went into their design. The TDI Diesel Generator Owners Group Program has provided assurance of the reliability of the TDI diesel generators by establishing the reliability and acceptability of their critical engine components. Recommendations made by the Owners Group, when implemented, will further improve component reliability, thereby improving the overall reliability of the TDI diesel generators. The Owners Group effort has provided a sound basis for concluding that the TDI diesel generators at VEGP are fully capable of reliably performing their intended safety-related functions.

State of New York
County of Suffolk

John C. Kammeyer

Subscribed and sworn to before me this 30 day of July, 1985.

Connie-Maria Pardo
Notary Public

My commission expires on March 30, 1987.

Exhibit 1

July 1985

KAMMEYER, JOHN C.

ENGINEER
POWER DIVISION

## EDUCATION

Ohio State University - Bachelor of Science, Mechanical Engineering, 1979

Various U.S. Navy Electronic Technician and Nuclear Power Courses

Various Stone & Webster Engineering Corporation ("SWEC") Career Development and Continuing Education Courses

## EXPERIENCE SUMMARY

Mr. Kammeyer has six years of experience on nuclear power plant projects and six years experience on U.S. Navy Nuclear Submarines. Currently, as an Engineer, he is assigned as the Head of the Site Engineering Office ("SEO") and the SWEC Senior Site Representative at the Shoreham Nuclear Power Station. Mr. Kammeyer is responsible for on-site SWEC support at the Shoreham plant.

Since joining SWEC in June 1979, he has also been assigned to the Transamerica Delaval, Inc. ("TDI") Owners Group, as the Design Review and Quality Revalidation Program Manager. In addition, he has completed the Career Development Program, including assignments to the 850 MWe boiling water reactor Shoreham Nuclear Power Station as a Site Engineer and as a Systems Engineer, and to the 938 MWe pressurized water reactor North Anna Power Station project as a Systems Engineer.

Prior to college, Mr. Kammeyer spent six years in the Navy's Nuclear Power Program; the final three years were spent as a Reactor Operator aboard a nuclear submarine.

## PROFESSIONAL AFFILIATIONS

American Society of Mechanical Engineers - Associate Member

**DETAILED EXPERIENCE RECORD**
**KAMMEYER, JOHN C. 47182**

**STONE & WEBSTER ENGINEERING CORPORATION, BOSTON, MA**
**(June 1979 to Present)**

Appointments:

Engineer, Power Division - Feb 1981
Career Development Engineer, Power Division - June 1979

**Shoreham Nuclear Power Station, Long Island Lighting Company**
**(Nov 1979 to Present)**

As **ENGINEER (Jul 1985 to Present)** assigned to the Site Engineering Office ("SEO") in the capacity of Head-SEO and SWEC Senior Site Representative. Responsible, under direction of the Project Engineer, for management of personnel and activities at the site in support of initial plant startup and power testing.

As **ENGINEER (Mar 1985 - Jun 1985)** reassigned to the SEO in the capacity of Power Engineer and Assistant Head-SEO.

As **ENGINEER (Apr 1984 to Feb 1985)** on special assignment to the Transamerica Delaval, Inc. ("TDI") Owners Group in the capacity of Program Manager of the Design Review and Quality Revalidation effort for TDI diesel generators utilized at 12 different nuclear power plants. Responsible for directing engineers and quality inspectors in the resolution of generic TDI diesel engine problems, and the design review/quality revalidation of selected engine components and participating in meetings with the Nuclear Regulatory Commission and its technical staff to present the overall program and provide briefings on problem component analyses.

As **ENGINEER (Aug 1982 to Mar 1984)** assigned to the SEO in the capacity of Power Engineer and Assistant Head-SEO, responsible to the Head-SEO for the Power Division effort. During the construction and startup testing phase of the plant, responsible for directing engineers and designers in the resolution of problems dealing with fluid systems and related components, such as piping, valves, mechanical equipment, and equipment erection. Provided engineering and coordination support to the client for the emergency diesel generator design revalidation program ASLB qualification effort. Plant preoperational phase responsibilties included developmental support of the station modification programs and engineering the specific modification packages for the upgrade of

mechanical systems and equipment. In addition, in the absence of the Head-SEO, responsible for the operation of the SEO.

As **ENGINEER (May 1981 to July 1982)** assigned to the SEO, responsible for resolving various engineering related construction problems, principally with piping and mechanical components, requiring an immediate solution to support the construction schedule. In addition, working directly with the client's start-up organization to resolve system operation deficiencies.

As **ENGINEER** and **CAREER DEVELOPMENT ENGINEER (Nov 1979 to Apr 1981)** in the Nuclear Engineering Group, responsible for preparing reactor plant flow diagrams, and update of FSAR and technical specifications. Responsible for the interpretation of purchase specification requirements and the disposition of vendor nonconformances. As a Career Development Engineer, spent four months at the SEO; responsibilities included maintainability study of of all plant equipment to ensure accessibility and proper physical arrangement to meet maintenance requirements for the 850 MWe power plant.

**North Anna Power Station - Units 3 & 4, Virginia Electric and Power Company (June 1979-Nov 1979)**

As **CAREER DEVELOPMENT ENGINEER**, assigned to Nuclear Engineering Group as a system engineer responsible for preparing reactor plant flow diagrams, sizing of system components such as pumps and valves, purchasing of equipment, including preparation of specifications, and preparing FSAR sections.

**U.S. Navy (Sept 1969-July 1975)**

**USS James K. Polk, SSBN - 645 (Apr 1972-June 1975)**

As **SENIOR QUALIFIED REACTOR OPERATOR**, responsible for repair and maintenance of reactor instrumentation and supervision of division training. Received honorable discharge with ETR-2(SS) rating, commendation from Commander, Submarine Squadron Sixteen.

TDI OWNERS GROUP

for

VOGTLE ELECTRIC GENERATING PLANT - UNIT 1

CYLINDER BLOCK
COMPONENT PART NO. 02-315A

## I INTRODUCTION

The TDI Emergency Diesel Generator Owners Group Program for the Vogtle Electric Generating Plant requires Design and Quality Revalidation reviews of the cylinder blocks to determine the adequacy of design for their intended use at Vogtle. The blocks are manufactured by TDI and are supplied under their part number 02-315-03-AE. The cylinder block forms the framework of the liquid cooled engine and provides passage for coolant and support for the cylinder liners and cylinder heads.

## II OBJECTIVE

The objective of this review was to evaluate the structural adequacy of the cylinder block for its intended use at Vogtle Electric Generating Plant.

## III METHODOLOGY

In order to meet the stated objective, the following methods were used:

- Review of liquid penetrant inspections of Vogtle DSRV-16-4 Engine 1 and 2 engine blocks.
- Review of operating history. 1
- Review of engine operating conditions at Vogtle and identification of any differences from those at Comanche Peak.
- Performance of dimensional check and evaluation of liner/block interaction.
- Evaluation of steady state stresses, alternating stresses and stiffness in key portions of the cylinder block.
- Evaluation of crack growth rate for cylinder block landing counterbore diameter by comparison with conservative Shoreham data and analysis.
- Review of metallurgical/microstructural analysis of cylinder block material.
- Review of Vogtle site, nuclear and non-nuclear experience (see Appendix C).

- Review of Quality Revalidation Checklist results for acceptability.

## IV RESULTS AND CONCLUSIONS

A generic investigation of the structural adequacy of the TDI R-4 and RV-4 series diesel engine cylinder blocks for emergency standby service in nuclear power plants is summarized in Reference 1. The investigation considers the cause, extent, and consequences of cylinder block cracking, and the inspections required to assure a sufficient margin of safety during continued operation under test and postulated accident conditions. 1

Evaluation of steady state stresses, alternating stresses and stiffness in key portions of the cylinder block was accomplished as part of the strain gauge testing at Shoreham, and the results were included in the cumulative damage and crack growth analyses. The cumulative damage analysis is explained in Reference 1.

Diesel generators 1 and 2 have had limited operational experience. Engine hours accumulated to date consist of factory test hours performed by TDI.

The engine operating conditions at Vogtle were compared to those at Comanche Peak and Shoreham. No significant differences were found that would affect the structural integrity assessment of the Vogtle blocks.

Results of dimensional inspection of the cylinder liner bore and mating block surfaces were used to evaluate the interaction of the block and cylinder liner in the analysis of steady state and alternating stresses. These results were utilized in the cumulative damage analysis. 1

The power output for this engine is 7000 kW at 100 percent load. Maximum output required for LOOP/LOCA is 6032 kW. The duration of a LOOP/LOCA used in this analysis is 168 hours.

Strain gauge testing of the original Shoreham EDG 103 block, inspection data from before and after extensive test operation and materials testing were used as a basis to predict adequate life for cylinder blocks. The rate of propagation of cracks between stud holes during operation in the 1
original Shoreham EDG 103 block, when compared with the LOOP/LOCA requirements at Vogtle, indicates that even if the Vogtle blocks had ligament cracks they are predicted to withstand with sufficient margin a LOOP/LOCA event.

Block tops have been inspected and no detectable ligament, stud-to-stud or stud-to-end cracks have been reported. In addition, a material microstructure evaluation has been performed on all engine blocks at Vogtle verifying that the block material is characteristic of typical Class 40 grey cast iron.

Application of the cumulative damage analysis (Figure 5-1 of Reference 1) shows that the Vogtle engines can perform for 490 hours at 100 percent load (or operation resulting in equivalent cumulative damage), without inspection, with sufficient margin for a LOOP/LOCA event (Ref. 2).

Engine operation in excess of the above time period without repeated inspection is justified if the fatigue damage index since the last inspection does not exceed the allowable fatigue damage index based upon 1
the last inspection. In the future this process may be repeated, and additional engine operation without inspection may continue until the additional fatigue damage index equals the allowable fatigue damage index established by the last inspection which showed no cracking.

Optionally, in the future, after additional engine operation without repeated inspection has accumulated a fatigue damage index which exceeds the allowable fatigue damage index, continued engine operation can continue without removal of cylinder heads and maintain sufficient margin to withstand a LOOP or LOOP/LOCA event provided periodic eddy current inspections described in Figure 5-1 of Reference 1 are performed between the heads.

One block of Unit 2 Engine No. 1 has been found to contain a weld repair region in cylinder No. 1. Vogtle is planning to replace this block with a new RV-5 design. Based on review of dimensional changes made in this design, and test engine experience in excess of 5000 hours, block top stresses are reduced from the R-4 levels thereby descreasing the possibility of block top crack formation. Assuming satisfactory inspection results from all Appendix B inspections, application of the cumulative damage algorithm as described above shows that engine operation, without subsequent inspections for 490 hours at 100 percent power level (or operation resulting in equivalent cumulative damage) would be possible with sufficient margin remaining for a LOOP/LOCA event (Reference 2).

Therefore, the RV-5 block is acceptable for emergency standby service provided that all Appendix B inspections are completed satisfactorily and the cumulative damage algorithm as outlined in Reference 1 is applied to determine future inspection frequency period.

The information provided on the following TERs has been reviewed and is consistent with the final conclusions of this report: 11-049, 11-010 and 11-050.

Quality Revalidation Inspection results identified in Appendix B have been reviewed and considered in the performance of this design review and the results are consistent with the final conclusions of this report.

Based on the above review and implementation of routine inspections, it is concluded that the cylinder blocks are acceptable for their intended use at Vogtle.

V. REFERENCES

1. Design Review of TDI-R4 and RV-4 Series Emergency Diesel Generator Cylinder Blocks. FaAA-84-9-11.

2. FaAA Support Package Number SP-84-6-12(j).

REV. 1
CARRY OVER FROM
PREVIOUS PAGE

COMPONENT DESIGN REVIEW CHECKLIST
VOGTLE ELECTRIC GENERATING PLANT - UNIT 1

COMPONENT Cylinder Block-Liners and Water Manifold: Cylinder Block

UTILITY Georgia Power Company

GROUP PARTS LIST NO. 02-315A

TASK DESCRIPTION NO. DR-11-02-315A-0

SNPS GPL NO. 03-315A

CLASSIFICATION TYPE A

TASK DESCRIPTIONS

Review liquid penetrant inspections of Vogtle DSRV-16-4 engine block tops and review engine operating experience.

Review engine operating conditions of Vogtle and identify any differences from those at Comanche Peak.

Perform dimensional check on cylinder block and cylinder liners and evaluate liner/block interaction.

Evaluate steady state stresses, alternating stresses and stiffness in key portions of the cylinder block.

Evaluate crack growth rate for cylinder block landing and counterbore diameter by comparison with conservative Shoreham data and analysis.

Review metallurgical/microstructural analysis of cylinder block top material.

Review of Vogtle site, nuclear and non-nuclear experiences (see Appendix C).

Review of Quality Revalidation Checklist results for acceptability.

Review information provided on TERs.

PRIMARY FUNCTION

To provide framework for engine components and to provide cooling water passages.

COMPONENT DESIGN REVIEW CHECKLIST

ATTRIBUTE TO BE VERIFIED

That components have sufficient strength and stiffness to react major loads.

SPECIFIED STANDARDS

None.

REFERENCES

None.

DOCUMENTATION REQUIRED

Manufacturer's drawings for DSR-48 and RV blocks, liners and studs, including all specifications for material, torques, valve train loads and gas cycles.

Engine operating history (time vs. load) for operation prior to block top inspection, and for total engine hours.

Anticipated engine operating profile (time vs. load) for fuel cycle, including pre-operational, qualification, and surveillance testing.

Engine factory test logs that report firing pressures and exhaust temperatures for each cylinder.

GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature]

## COMPONENT QUALITY REVALIDATION CHECKLIST

COMPONENT Cylinder Block

UTILITY Georgia Power Company Vogtle Electric Generating Plant - Unit 1

GPL NO. 02-315A

REV. NO. 2

SNPS GPL NO. 03-315A

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### TASK DESCRIPTIONS

#### Engine 1

1. Assemble and review existing documentation.

2. Perform a dimensional check on the area around the cylinder liner for all cylinder block liner landings.

3. Perform a Liquid Penetrant or Magnetic Particle test on the cylinder block liner landing along the top landing surface, fillet radius, and vertical face adjacent to the landing surface. Four liner landings (3L, 4L, 5L, 6L and 3R, 4R, 5R, 6R) should be inspected with the liners removed. If linear indications are found, increase inspection plan to all liner landings.

4. Perform a Liquid Penetrant or Magnetic Particle test on the cylinder head mating surface on top of the cylinder block. The area between stud hole and liner, and between adjacent cylinder stud hole should be inspected. The inspection plan should include cylinders 3L, 4L, 5L, 6L and 3R, 4R, 5R and 6R. If linear indications are found, increase inspection plan to all cylinders.

5. Perform an Eddy Current test on the cylinder head stud holes if required (i.e., linear indications found at stud hole extending into threads).

6. Remove a sample from each cylinder block by drilling and cutting. The samples shall be tetrahedral in shape with a one inch square base and a height of 5/8 inch. Attachment B shows the location where the samples should be taken.

#### Engine 2

Same as Engine 1

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ATTRIBUTES TO BE VERIFIED

Engine 1

1. Quality status of Component Document Package

2. Dimensions of the cylinder block liner landing area

3-5. Surface integrity of the cylinder block liner landing

6. Samples are taken from the cylinder block in accordance with TER# 99-016.

Engine 2

Same as Engine 1

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ACCEPTANCE CRITERIA

Engine 1

1. Satisfactory Document Package

2. Review of inspection report by the Design Group

3-4. See Attachment A

5-6. Review of inspection report by the Design Group

Engine 2

Same as Engine 1

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REFERENCES

Engine 1

1. QCI No. 52

2. Approved Site NDE Procedures

3-4. TER#s 99-004, 99-018, 99-036

REFERENCES (continued)

Engine 1 (continued)

5. FaAA Procedure NDE 11.8

6. TER# 99-016, 99-031

Engine 2

Same as Engine 1

DOCUMENTATION REQUIRED

Engine 1

1. Document Summary Sheet

2-6. Inspection Report

Engine 2

Same as Engine 1

GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature]

COMPONENT REVIEW

Engine 1

1. No EDGCTS site experience documents are in evidence.

2. A dimensional check was performed on all cylinder block liner landings. The results were reported by TER# 11-049.

3. A Liquid Penetrant test was performed on all cylinder block liner landings. The results were reported by TER# 11-049.

4. A Liquid Penetrant test was performed on all the cylinder head mating surfaces. The results were reported by TER# 11-049.

COMPONENT REVIEW (continued)

Engine 1 (continued)

5. An Eddy Current test was performed on all cylinder head stud holes and counterbore areas with no indications noted. This was reported by TER# 11-049.

6. A sample was taken from each cylinder block as required. Results of the analysis were reported by TER# 11-090.

Engine 2

1. No EDGCTS site experience documents are in evidence.

2. A dimensional check was performed on all cylinder block liner landings. The results were reported by TER#s 11-010 and 11-049.

3. A Liquid Penetrant test was performed on all cylinder block liner landings. The results were reported by TER#s 11-010 and 11-049.

4. A Liquid Penetrant test was performed on all the cylinder head mating surfaces The results were reported by TER#s 11-010 and 11-049.

5. An Eddy Current test was performed on all cylinder head stud holes and counterbore areas with no indications noted. This was reported by TER#s 11-010 and 11-049.

6. A sample was taken from each cylinder block as required. Results of the analysis were reported by TER# 11-090.

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RESULTS AND CONCLUSION

Engine 1

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

Engine 2

Same as Engine 1

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GROUP CHAIRPERSON Neita A Saleta PROGRAM MANAGER K.J. Fitzpatrick

ACCEPTANCE CRITERIA

A. Area to be inspected

1. Top of Block
2. Liner counterbore

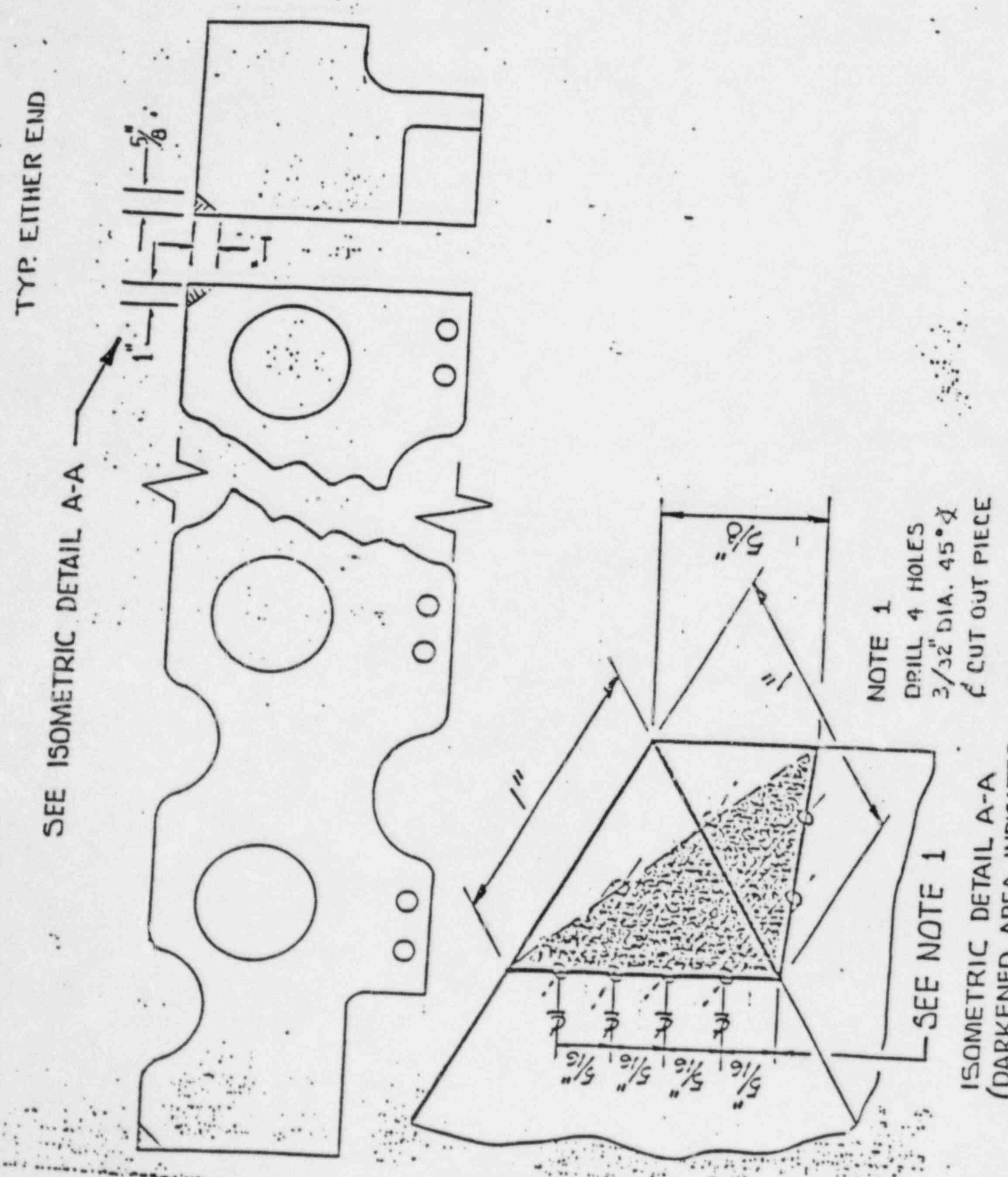
B. Reference Standard ASTM E125

C. Evaluation of indications

1. Relevant indications are:
   a. Hot tears and cracks, linear indications that exceed ASTM E125 Class I-2
   b. Shrink that exceeds ASTM E125 Class II-3
   c. Inclusions that exceed ASTM E125 Class III-3
   d. Porosity that exceeds ASTM E125 Class V-1
2. All indications exceeding the specification listed above shall be documented and submitted to the Design Group.
3. Indications that do not exceed the ASTM E125 reference regardless of size and quantity are acceptable.

D. Non-Relevant Indication

1. The indications referenced below shall be considered non-relevant.
   a. Magnetic writing
   b. Linear grain boundaries (carbon, ferrite, or graphite induced)
   c. Rounded grain boundaries (carbon, ferrite, or graphite induced)


SEE ISOMETRIC DETAIL A-A
TYP. EITHER END
1"
5/8"
NOTE 1
DRILL 4 HOLES
3/32" DIA. 45° ℄
℄ CUT OUT PIECE
SEE NOTE 1
5/16"
1"
ISOMETRIC DETAIL A-A
(DARKENED AREA INDICATES

# TDI OWNERS GROUP

for

VOGTLE ELECTRIC GENERATING PLANT - UNIT 1

STARTING AIR MANIFOLD: PIPING, TUBING, AND FITTINGS
(LARGE BORE SCOPE ONLY)
COMPONENT PART NO. 02-441A

## I INTRODUCTION

The TDI Emergency Diesel Generator Owners Group Program for the Vogtle Electric Generating Plant requires Design and Quality Revalidation reviews of the structural adequacy of the starting air manifold piping for the effects of normal operating and earthquake loadings.

The primary function of the starting air manifold piping is to provide adequate starting air from the off-skid supply piping to each engine cylinder.

The scope of piping embraced by this report includes the large bore (greater than 2-inch diameter) piping components as noted on the as-built information obtained during Impell field verification (Ref. 1), plus small bore piping, which was included because of the configuration.

Piping components are defined as piping spool pieces, elbows, tees, flanges, Dresser couplings and the interconnecting welds. This scope is uniquely defined in terms of Transamerica Delaval, Inc. (TDI) part numbers in Reference 1.

## II OBJECTIVE

The objective of this review was to verify the adequacy of the subject piping components for normal operating and earthquake loadings.

## III METHODOLOGY

The evaluation of the piping components is performed in accordance with the philosophy and intent of the ASME Code Section III, for Class 3 Nuclear Piping. Towards this end, a criteria document was developed, "Design Criteria for Diesel Generator Large Diameter Piping for Vogtle," which describes the background and provides the techniques for evaluating the subject piping. These criteria are presented in their entirety in Reference 2.

Quality Revalidation Checklist results were reviewed for acceptability.

The TDI Emergency Diesel Generator Component Tracking System was reviewed for the Vogtle site, nuclear and non-nuclear industry experience.

## IV RESULTS AND CONCLUSIONS

All piping stresses were within the design allowables specified by the ASME Section III Code.

With respect to the Dresser couplings, Impell evaluated the couplings against the manufacturer's selection and service requirements. These include the design service conditions, relative end displacements from both translation and rotation of the joined pipes, and shelf and service life. The movements at the Dresser couplings are within the manufacturer's end movement requirements (Ref. 3). There are no service life constraints (Ref. 4) because this style of coupling has no significant history of failure. Shelf life (Ref. 4) is unlimited as long as the gaskets remain packaged and protected from the elements (light, water, etc). The couplings are adequate with respect to manufacturer's service condition limits.

It is recommended that support modifications be effected in order to provide stiffer load paths and to relieve thermal restraint in certain directions by partial support removal through bolt hole elongations. The support modifications are summarized in Reference 5.

Historical corrosion data for carbon steel starting air systems was not available. However, the subject starting air piping and interconnecting welds have a limiting wall thickness of 5.15 times that required (Ref. 2), which should be sufficient margin against corrosion.

All pipe loads on the engine have been tabulated and issued for evaluation. These evaluations were performed as part of the development of reports for component Nos. 02-315A and 02-441B.

There are no TERs associated with this component.

The Quality Revalidation Inspection results identified in Appendix E have been reviewed and considered in the performance of this design review, and the results are consistent with the final conclusions of this report.

Based on the above review, it is concluded that the subject piping components, with the above recommended modifications, are adequate for their intended design function at Vogtle.

## V REFERENCES

1. "Supporting Calculations for the Evaluation of Vogtle Diesel Generator Large Diameter Piping and Supports," Impell Report No. 02-0630-1301, Rev. 0, December 1984.

2. "Design Criteria for Diesel Generator Large Diameter Piping for Vogtle," Impell Report No. 02-0630-1300, Rev. 0, December 1984. This is included in Appendix III of the final DR/QR report.

3. Dresser Pipe Couplings, Pipe Fittings, and Pipe Repair Products Catalog, No. 63.

4. Telephone Conversation between A. Palumbo (Impell) and M. Riley (Dresser Manufacturing Co.), dated June 5, 1984.

5. Letter from R. Markovich/G. Shears (Impell) to J. Kammeyer (SWEC), "Required Modification for Validation of Impell's Design Review for Component No. 02-441A-Vogtle," dated December 7, 1984.

# COMPONENT DESIGN REVIEW CHECKLIST
# VOGTLE ELECTRIC GENERATING PLANT - UNIT 1

COMPONENT Starting Air Manifold: Piping (Large Bore Scope Only)

UTILITY Georgia Power Company

GROUP PARTS LIST NO. 02-441A

TASK DESCRIPTION NO. DR-11-02-441A-0

SNPS GPL NO. 03-441A

CLASSIFICATION TYPE B

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## TASK DESCRIPTIONS

Evaluate structural integrity of the starting air manifold piping spool pieces and fittings for the effects of normal operating and earthquake loadings by (a) comparison to previous analyses, (b) review of previous analyses, (c) review of previous qualification documentation, and/or (d) actual performance of stress evaluation in accordance with the intent and philosophy of ASME III Class 3 and Impell Design Criteria.

Review information provided on TER.

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## PRIMARY FUNCTION

Provide adequate starting air from off-skid supply piping to each engine cylinder.

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## ATTRIBUTE TO BE VERIFIED

Structural integrity of large bore (greater than 2 in. dia.) piping spool pieces and fittings to withstand the effects of normal operating and earthquake loadings.

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## SPECIFIED STANDARDS

None

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REFERENCES

"Design Criteria for Diesel Generator Large Diameter Piping for Vogtle," Impell Report No. 02-0630-1300, Rev. 0, December 1984.

DOCUMENTATION REQUIRED

Verified piping isometric, material specification, size and schedule, design parameters, (temp., pressure), contents, insulation, fitting and gasket design parameters.

GROUP CHAIRPERSON ____________ PROGRAM MANAGER ____________

# COMPONENT QUALITY REVALIDATION CHECKLIST

COMPONENT Starting Air Manifold - Piping Tubing and Fittings UTILITY Georgia Power Company Vogtle Electric Generating Plant - Unit 1

GPL NO. 02-441A REV. NO. 1

SNPS GPL NO. 03-441A

## TASK DESCRIPTIONS

Engine 1

1. Assemble and review existing documentation.
2. Obtain sufficient data to support the design review effort. This may be accomplished by developing quality verified as-builts in accordance with Procedure DG-7, or by the Design Group performing a field walkdown.

Engine 2

Same as Engine 1

## ATTRIBUTES TO BE VERIFIED

Engine 1

1. Quality status of Component Document Package
2. Information necessary for the design review effort

Engine 2

Same as Engine 1

## ACCEPTANCE CRITERIA

Engine 1

1. Satisfactory Document Package
2. Review of detailed information by the Design Group

Engine 2

Same as Engine 1

REFERENCES

Engine 1

1. QCI No. 52

2. Procedure DG-7

Engine 2

Same as Engine 1

DOCUMENTATION REQUIRED

Engine 1

1. Document Summary Sheet

2. Quality verified as-built isometric drawings for the piping, tubing and fittings if available from the Owner.

Engine 2

Same as Engine 1

GROUP CHAIRPERSON Steven M. Schwartz PROGRAM MANAGER [signature]

COMPONENT REVIEW

Engine 1

1. No EDGCTS site experience documents are in evidence.

2. The Design Group will be responsible for closing out the as-built drawings as per Procedure DG-7. The as-built drawings will be Quality verified by the appropriate site Quality organization. The performance of an engineering walkdown by the Design Group, precludes the issuance of a quality verified as-built drawing or sketch.

Engine 2

Same as Engine 1

RESULTS AND CONCLUSION

Engine 1

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

Engine 2

Same as Engine 1

GROUP CHAIRPERSON Victor A. Szalesi PROGRAM MANAGER J. C. Kammeyer

## EDG COMPONENT TRACKING SYSTEM: VOGTLE SITE, NUCLEAR AND NON-NUCLEAR INDUSTRY EXPERIENCE SUMMARY

COMPONENT NO. 02-441A

Effective Printout Date: 12/3/84

COMPONENT TYPE: Starting Air Manifold: Piping, Tubing And Fittings

| EXPERIENCE | REFERENCE DOCUMENTS | VOGTLE STATUS |
|---|---|---|
| **VOGTLE** | | |
| None | | |
| **NUCLEAR** | | |
| Manifold purge from turbo exhaust to prevent moisture/corrosion. | TDI SIM 323 | TDI SIM No. 323 is concerned with purging moisture from the starting air manifold. Historical data on corrosion in carbon steel starting air lines was not available. However, Impell evaluation of subject piping determined that the nominal available pipe wall thickness was 5.15 times the minimum required. Therefore, there is adequate pipe margin against corrosion in the subject lines. TDI SIM No. 323 is concerned mainly with fouling of starting air valves from corrosion. |
| **NON-NUCLEAR** | | |
| None | | |

COMPONENT DESIGN REVIEW CHECKLIST
VOGTLE ELECTRIC GENERATING PLANT - UNIT 1

COMPONENT Connecting Rod Bearing Shells

UTILITY Georgia Power Company

GROUP PARTS LIST NO. 02-340B

TASK DESCRIPTION NO. DR-11-02-340B-1

SNPS GPL NO. 03-340B

CLASSIFICATION TYPE A

TASK DESCRIPTIONS

Design review for this component is not required based on the following:

- A review of the Comanche Peak and Shoreham DR/QR reports, which establish the acceptability of the bearing shells for their intended purpose, with a margin of safety that will account for small variances in loading.
- The applicable engine dimensions and operating parameters at Vogtle are identical or very similar to those for the same component at Comanche Peak (Lead Engine).
- A review of the EDG Component Tracking System nuclear, and non-nuclear industry experience. There is no site experience listed in the Component Tracking System.

Maintenance recommendations based on the Shoreham DR/QR report to ensure proper performance under normal operating conditions are as follows:

- Inspect and measure the connecting rod bearing shells to verify lube oil maintenance, which affects wear rate. The visual and dimensional inspection of the bearing shells should be conducted at the refueling outage, which precedes 500 hours of operation by at least the sum of hours of operation in a LOOP/LOCA event plus the expected hours of operation between outages.
- Perform an X-ray examination on all replacement bearing shells using a procedure with sufficient resolution to implement recommendations for acceptance criteria as documented in the TDI Owners Group connecting rod bearing shells Phase I Report.

No modifications are recommended for this component.

The results of Quality inspections performed for this component have been reviewed and found satisfactory.

COMPONENT DESIGN REVIEW CHECKLIST

PRIMARY FUNCTION

Not required

ATTRIBUTE TO BE VERIFIED

Not required

SPECIFIED STANDARDS

Not required

REFERENCES

Not required

DOCUMENTATION REQUIRED

Not required

GROUP CHAIRPERSON John J Cadogan PROGRAM MANAGER K.T. Fitzpatrick for JCK

# COMPONENT QUALITY REVALIDATION CHECKLIST

COMPONENT Connecting Rods-Bearing Shells

UTILITY Georgia Power Company Vogtle Electric Generating Plant - Unit 1

GPL NO. 02-340B

REV. NO. 2

SNPS GPL NO. 03-340B

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## TASK DESCRIPTIONS

### Engine 1

1. Assemble and review existing documentation.
2. Perform a visual inspection of the connecting rod bearing shells.
3. Perform a Liquid Penetrant test on the connecting rod bearing shells.
4. Perform a dimensional check of the connecting rod bearing shells.
5. Peform a Radiographic inspection of the connecting rod bearing shells.
6. Perform an Eddy Current test as required to identify surface discontinuities.

### Engine 2

Same as Engine 1

---

## ATTRIBUTES TO BE VERIFIED

### Engine 1

1. Quality status of Component Document Package

2-3. Surface integrity of the bearing shells

4. Proper bearing shell dimensions

5-6. Integrity of the bearing shells

ATTRIBUTES TO BE VERIFIED (continued)

Engine 2

Same as Engine 1

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ACCEPTANCE CRITERIA

Engine 1

1. Satisfactory Document Package

2-3. Review of inspection report by the Design Group

4. Dimensions are in accordance with the TDI Instruction Manual

5. See Attachments A & B.

6. Review of inspection report by the Design Group

Engine 2

Same as Engine 1

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REFERENCES

Engine 1

1. QCI No. 52

2-3. Approved Site NDE Procedure

4. TDI Instruction Manual or applicable drawing

5. FaAA NDE Procedure 9.3, TER# 99-011

6. Approved Site NDE Procedures

Engine 2

Same as Engine 1

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DOCUMENTATION REQUIRED

Engine 1

1. Document Summary Sheet

2-6. Inspection Report

Engine 2

Same as Engine 1

GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature]

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COMPONENT REVIEW

Engine 1

1. No EDGCTS site experience documents are in evidence.

2. A visual inspection was performed on all connecting rod bearing shells with satisfactory results. This was reported by TER# 11-087.

3. A Liquid Penetrant test was performed on all connecting rod bearing shells with satisfactory results. This was reported by TER# 11-087.

4. A dimensional inspection was performed on all connecting rod bearing shells with satisfactory results. This was reported by TER# 11-087.

5. A Radiographic inspection was performed on all connecting rod bearing shells with unsatisfactory results. Results were reported by TER# 11-087 and dispositioned by NCR Nos. 84-88 and 84-34.

6. An Eddy Current test was performed on eleven bearing shells with satisfactory results. The results were reported by TER# 11-087.

Engine 2

1. No EDGCTS site experience documents are in evidence.

2. A visual inspection was performed on the connecting rod bearing shells. Scratches were noted for the no. 1, 7, and 8 top bearing shells. Results were reported by TER#s 11-014 and 11-087 and dispositioned by NCR No. 84-9.

COMPONENT REVIEW (continued)

Engine 2

3. A Liquid Penetrant test was performed on all connecting rod bearing shells with no relevant indications noted. Results were reported by TER#s 11-014 and 11-087.

4. A dimensional inspection was performed on all connecting rod bearing shells with satisfactory results. This was reported by TER#s 11-014 and 11-087.

5. A Radiographic inspection was performed on all connecting rod bearing shells with unsatisfactory results. Results were reported by TER#s 11-014 and 11-087 and dispositioned by NCR nos. 84-035, 84-078, and 84-088.

6. An Eddy Current test was performed on all connecting rod bearing shells with satisfactory results. Results were reported by TER#s 11-014 and 11-087.

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RESULTS AND CONCLUSION

Engine 1

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

Engine 2

Same as Engine 1

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GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature]

Component: Connecting Rod Bearing Shells, Upper and Lower.

Examination: X-ray, FaAA NDE 9.2 (R-48); FaAA NDE 9.3 (V-12, V-16, V-20).

Examination: Area — Upper Bearing Shell, see attached figures:

R-48: 0.050 inch area, 0.4 inch inward from each side to a line 1.4 inches inward from each side, extending circumferentially 2.5 inches on either side of the oil hole. This is the critical area.

V-12, V-16, V-20: 0.050 inch area, 0.4 inch inward from each side to a line 1.4 inches inward from each side, extending circumferentially 5.0 inches on either side of the center of the bearing. This is the critical area.

0.250 inch area, remainder of bearing.

Lower Bearing Shell: 0.250 inch area, all of bearing.

Acceptance: Criteria — The following are unacceptable, based on 3/4 inch reference radiographs of ASTM E-155, for aluminum.

| | UPPER BEARING 0.050 INCH AREA | UPPER & LOWER BEARING 0.250 INCH AREA |
|---|---|---|
| Gas Holes | 0.050 diameter | Grade 5 |
| Gas Porosity (Rounded) | Grade 5 | Grade 7 |
| Gas Porosity (Elongated) | Grade 3 | Grade 5 |
| Shrinkage Sponge | Grade 3 | Grade 4 |
| Foreign Material Less Dense | 0.050 diameter | Grade 3 |
| Foreign Material More Dense | 0.050 diameter | Grade 4 |
| Cracks | Unacceptable | Unacceptable |
| Shrinkage Cavity | Unacceptable | 0.250 |

Note:
- ° Mottling/segregation and micro shrinkage shall not be evaluated for rejection.
- ° Radiographic features that are associated with the babbitt (lead alloy) layer on the bearing I.D. shall not be evaluated for rejection.

For further clarification of these criteria, please contact the Owner's Group.

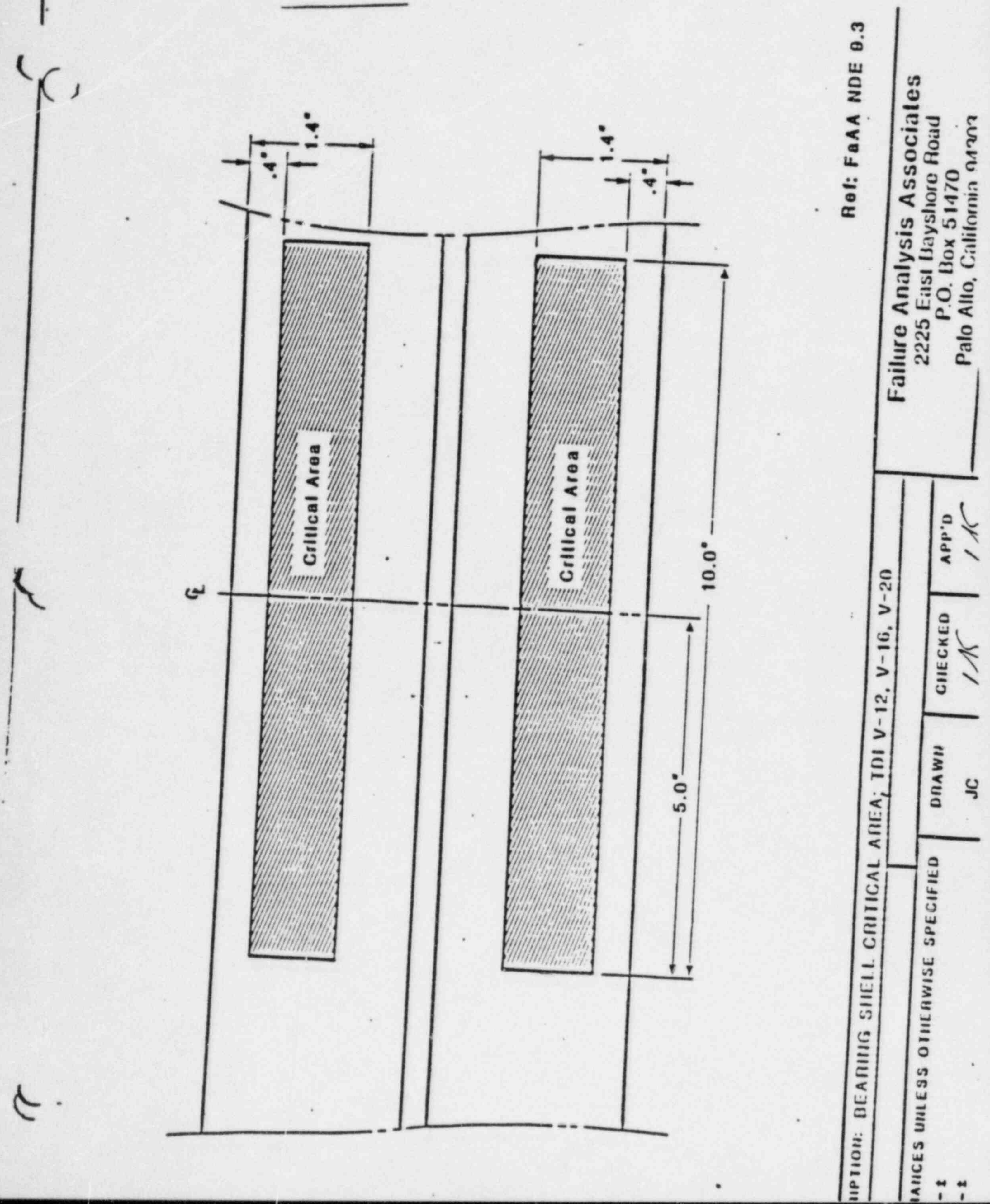
Ref: FaAA NDE 8.3
Failure Analysis Associates
2225 East Bayshore Road
P.O. Box 51470
Palo Alto, California
1.4"
.4"
1.4"
.4"
Critical Area
Critical Area
10.0"
5.0"
BEARING SHELL CRITICAL AREA; TDI V-12, V-16, V-20
UNLESS OTHERWISE SPECIFIED
DRAWN
JC
CHECKED
APP'D

EXHIBIT 2

VEGP REPORT REFERENCING LEAD ENGINE REPORTS

TDI OWNERS GROUP

for

COMANCHE PEAK STEAM ELECTRIC STATION - UNIT 1

CONNECTING ROD BEARING SHELLS
COMPONENT PART NO. 02-340B

## I INTRODUCTION

The TDI Emergency Diesel Generator Owners Group Program for the Comanche Peak Steam Electric Station requires Design and Quality Revalidation reviews of connecting rod bearing shells to determine the adequacy of their design for the intended use at Comanche Peak. The primary function of the connecting rod bearing shells is to provide a low friction sliding interface between the connecting rod and the crankpin through the formation of a hydrodynamic oil film. This interface transmits the cylinder firing pressure to the crankshaft, converting the force into torque.

The connecting rod bearing shells are manufactured by TDI from permanent mold aluminum alloy 852-T5 castings purchased from ALCOA (Ref. 1). The TDI part number for the components used at Comanche Peak is 02-340-04-AG.

## II OBJECTIVE

The objective of this review was to evaluate the adequacy of the connecting rod bearing shells for their intended service at the Comanche Peak Steam Electric Station. Specifically, the following tasks were performed:

- Journal orbit analysis to determine the pressure distribution in the hydrodynamic oil film.
- Finite element analysis to determine the stress distribution in the connecting rod bearing shells.
- Fracture mechanics analysis to determine the resistance to fatigue cracking.
- Computation of acceptance criteria for radiographic NDE of connecting rod bearing shells.
- Evaluation of material selection and dimensional accuracy.
- A review of maintenance procedures.

- A review of Comanche Peak site, nuclear, and non-nuclear experience.
- A review of the Quality Revalidation Checklist results for acceptability.

## III METHODOLOGY

As described in Reference 1, the design review of connecting rod bearing shells consisted of several steps. First, laboratory investigations of wear patterns, chemical, metallurgical and physical properties were conducted. A journal orbit analysis, using dimensions, weights, and weight distributions for DSRV-16-4 engines, as well as engine operation parameters, was performed. The output of the journal orbit analysis, which is the pressure distribution in the oil film under conditions of ideal geometry, was modified based on observed babbit contact patterns to provide input data to the finite element analysis using the ANSYS code. The stress distribution computed by the finite element analysis was used to calculate the fatigue life of the connecting rod bearing shells based on nuclear site experience. The stress distribution was also used to calculate the maximum discontinuity that could be present without decreasing the fatigue resistance.

The material selection was evaluated with respect to friction coefficient, and resistance to corrosion, fatigue and wear. Dimensional accuracy was evaluated from TER inspection results.

Details of the methodology and analysis are contained in Reference 1.

The applicability of the analysis to Comanche Peak was determined.

The TDI Emergency Diesel Generator Component Tracking System was reviewed for the Comanche Peak, nuclear, and non-nuclear industry experience.

## IV RESULTS AND CONCLUSIONS

Calculation of the maximum tensile stress in the connecting rod bearing shells in DSRV-16-4 engines, in combination with other nuclear experience, was used to predict a fatigue life of about 38,000 hours for the DSRV-16-4 bearing shells (Ref. 1 and 3). This fatigue life, which safely exceeds the expected usage of the engines during the operational life of the station, can be assured if an approved radiographic procedure such as Failure Analysis Associates' "Radiographic Examination of Diesel Engine Upper and Lower Bearing Shells," (Ref. 2) is followed.

Design and operating parameters for the Comanche Peak DSRV-16-4 engines (Ref. 4) were compared to the generic analysis of Ref. 1. Those parameters were found to be within 5 percent of the generic case, confirming the applicability of the generic analysis to Comanche Peak.

The material selection was appropriate based on professional judgment and experience with similar bearings. Dimensional accuracy was verified as summarized in Appendix B.

The wear resistance of the connecting rod bearings has been proven adequate in nuclear experience, provided all TDI recommended lubricating oil maintenance procedures (Ref. 4) are followed.

The connecting rod bearing shells should be inspected visually and dimensionally to verify lubrication maintenance which affects wear rate. The visual and dimensional inspection of the bearing shells should be conducted at the fuel outage which precedes 500 hours of operation by at least the sum of expected hours of operation in a LOOP/LOCA event plus the expected hours of operation between outages.

The information provided on the following TERs has been reviewed and is consistent with the final conclusions of this report: 10-079, 10-008, 10-026.

Quality Revalidation Inspection results identified in Appendix B have been reviewed and considered in the performance of this design review and the results are consistent with the final conclusions of this report.

Based on the above review and assuming implementation of the radiographic acceptance criteria, it is concluded that the connecting rod bearing shells are acceptable for their intended use at Comanche Peak Steam Electric Station.

## V REFERENCES


1. Failure Analysis Associates, "Design Review of Connecting Rod Bearing Shells for Transamerica Delaval Enterprise Engines," FaAA-84-3-1, Palo Alto, California, March 12, 1984.

2. Failure Analysis Associates, "Radiographic Examination of Diesel Engine Upper and Lower Bearing Shells," NDE 9.3, Palo Alto, California, February 6, 1984.

3. FaAA Support Package No. SP-84-3-1(b).

4. TDI Instruction Manual for Comanche Peak DSRV-16-4 Diesel Generators.

# COMPONENT DESIGN REVIEW CHECKLIST
# TEXAS UTILITIES

COMPONENT Connecting Rod Bearing Shells CLASSIFICATION TYPE A

COMPONENT PART NUMBER 02-340B TASK DESCRIPTION NO.: DR-10-02-340B-1
(SNPS PART NUMBER 03-340B)

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TASK DESCRIPTIONS:

Compare and evaluate differences in design and operating conditions which are site specific.

Review NDE and other inspection results.

Review information provided on TERs.

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PRIMARY FUNCTION:

Provides hydrodynamic oil film sliding surface and load transmission between connecting rod and crankpin.

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ATTRIBUTES TO BE VERIFIED:

Corrosion, fatigue, and wear resistance.

Coefficient of friction, dimensional accuracy, operation parameters.

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SPECIFIED STANDARDS:

None.

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REFERENCES:

None.

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DOCUMENTATION REQUIRED:

Manufacturer's drawings, cylinder firing pressure, lubrication specifications, and reciprocating weights.

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GROUP CHAIRPERSON: ______ PROGRAM MANAGER: ______ for JCK

## COMPONENT QUALITY REVALIDATION CHECKLIST

COMPONENT Connecting Rod Bearing Shells

UTIILITY Texas Utilities Generating Co., Comanche Peak Station

GPL NO. 02-340B

REV. NO. 2

SNPS GPL NO. 03-340B

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### TASK DESCRIPTIONS

D.G. CP1-MEDGEE-01

1. Assemble and review existing documentation.
2. Perform a visual inspection of the connecting rod bearing shells.
3. Perform a Liquid Penetrant test on the connecting rod bearing shells.
4. Perform a dimensional check of the connecting rod bearing shells.
5. Perform a Radiographic inspection of the connecting rod bearing shells.
6. Perform an Eddy Current test as required to identify surface discontinuities.

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

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### ATTRIBUTES TO BE VERIFIED

D.G. CP1-MEDGEE-01

1. Quality status of Component Document Package

2-3. Surface integrity cf bearing shells

4. Proper bearing shell dimensions

5-6. Integrity of the bearing shells

ATTRIBUTES TO BE VERIFIED (continued)

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

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ACCEPTANCE CRITERIA

D.G. CP1-MEDGEE-01

1. Satisfactory Document Package

2-3. Review of inspection report by Design Group

4. Dimensions are in accordance with the TDI Instruction Manual

5-6. Review of inspection report by Design Group

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

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REFERENCES

D.G. CP1-MEDGEE-01

1. QCI-FSI-F11.1-020

2-3. Approved Site NDE Procedures

4. TDI Instruction Manual or applicable drawing

5. Approved Site NDE procedure

6. FaAA NDE Procedure 9.2

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

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DOCUMENTATION REQUIRED

D.G. CP1-MEDGEE-01

1. Document Summary Sheet

DOCUMENTATION REVIEWED (continued)

D.G. CP1-MEDGEE 01 (continued)

2-6. Inspection Report

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature]

COMPONENT REVIEW

D.G. CP1-MEDGEE-01

1. All EDGCTS site experience documents were assembled and reviewed with unsatisfactory results. NCR 80-00220 remains open.

2. A visual inspection was performed with unsatisfactory results. This was reported by TER# 10-008 and dispositioned by NCR 84-0076.

3. A Liquid Penetrant test was performed with unsatisfactory results. This was reported by TER# 10-026 and dispositioned by NCR 84-0076.

4. A dimensional check was performed with results reported by TERs# 10-026 and 10-008.

5. A Radiographic test was performed with unsatisfactory results. This was reported by TER# 10-026.

6. An Eddy Current test was performed on selected bearings with satisfactory results as reported by TER# 10-026.

D.G. CP1-MEDGEE-02

1. All EDGCTS site experience documents were assembled and reviewed with unsatisfactory results. NCR 80-00220 remains open.

2. A visual inspection was performed with unsatisfactory results. Subsequently, the bearing shells with indications were replaced due to the Radiographic test results. This was reported by TER# 10-079.

3. A Liquid Penetrant test was performed. Unsatisfactory bearing shells were replaced because of the Radiographic test results. This was reported by TER# 10-079.

4. A dimensional check was performed with satisfactory results. This was reported by TER# 10-079.

COMPONENT REVIEW (continued)

D.G. CP1-MEDGEE-02 (continued)

5. A Radiographic test was performed with unsatisfactory results. Bearing shells with indications were replaced with new bearing shells. This was reported by TER# 10-079.

6. An Eddy Current test was not required. This was reported by TER# 10-079.

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RESULTS AND CONCLUSION

D.G. CP1-MEDGEE-01

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

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GROUP CHAIRPERSON Nita A. Saleta PROGRAM MANAGER X Kammeyer

EDG COMPONENT TRACKING SYSTEM: COMANCHE PEAK SITE,
NUCLEAR AND NON-NUCLEAR INDUSTRY EXPERIENCE SUMMARY

COMPONENT NO. 02-340B

Effective Printout Date 07/02/84

COMPONENT TYPE: Connecting Rod Bearing Shells

| EXPERIENCE | REFERENCE DOCUMENTS | COMANCHE PEAK STATUS |
|---|---|---|
| COMANCHE PEAK | | |
| Inspection performed on connecting rod bearing shells revealed a level of scratching for which bearings were still suitable. | NCR 84-0076 and MEE #84-005 | Expected condition from normal diesel engine service. Bearing suitable for continued use. |
| NUCLEAR | | |
| Diesel tripped due to changes in oil and coolant temp. and crank-case pressure caused by initial failure of connecting rod bearing. | LER Hatch 2<br>LER 366-82079<br>LER 820727<br>SER 67-82<br>SOER 83-1 | Not applicable. Fairbanks-Morse engine does not use cast aluminum bearings. |
| Conrod big end bearing failed. The dowel pin fixing the bearing failed. | Maanshan Service Report TPC Nuclear Plant No. 3, dated Dec. 9, 1983 (File No. T-45) | Not applicable. Dowel pin failure not related to bearing shell design. |
| Connecting rod bearing shell dowel pin was broken. | Maanshan - Service Report TPC Nuclear Plant No. 3, dated Dec. 9, 1983 (File No. T - 45) | Not applicable. Dowel pin failure not related to bearing shell design. |

| EXPERIENCE | REFERENCE DOCUMENTS | COMANCHE PEAK STATUS |
|---|---|---|
| NON-NUCLEAR | | |
| Connecting rod shells were found badly worn or unfit for further use. Delaval advised that connecting rod shell cracking on Columbia could have resulted from bad alloy makeup by their vendors. (M/V Columbia). | Hunton & Williams (12/29/83) to C. Seaman. Memo from M. Zbinden to R. Ward dated 11/06/80. (Mtg.) Letter from M. Zbinden (State of Alaska) to D. Martini (TDI) dated 03/19/79. Letter from M. Zbinden to W. Hudson dated 02/02/79. | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. |
| Letter contains drawings outlining connecting rods that had cracked bearing shells, damaged bolts and/or threads. New torques values: Link rod to pin 1050 ft-lbs; new 1.5 in. rod bolts 1700 ft-lbs; old rod bolts 2600 ft-lbs; new rod box out of roundness spec: 0.004 in max. (M/V Columbia) | Hunton & Williams (12/29/83) to C. C. Seaman. Memo from M. Zbinden to file dated 02/05/80. | Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Lost #8 rod bearing (10/07/75) engine no. 18. | Engine incidence report (City of Homestead, Fl.) dated 9/30/78 (File no. T-10) | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increase clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |

| EXPERIENCE | REFERENCE DOCUMENTS | COMANCHE PEAK STATUS |
|---|---|---|
| #6 connecting rod bearing broke (01/10/77) engine no. 18 | Engine incidence report (City of Homestead, Fl.) dated 9/30/78 (File no. T-10) | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force eliminates bearing cracking in connecting rod assembly from relative motion of master rod and rod box. |
| #5, 7 & 10 connecting rod bearings broken. Replaced all rod bearing with new style bearings (04/05/76) engine no. 18 | Engine incidence report (City of Homestead, Fl.) dated 9/30/78 (File no. T-10) | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Replaced #6 and #10 connecting rods with new con rods due to excessive fretting at bearing fit (05/17/77) engine no. 18. | Engine incidence report (City of Homestead, Fl.) dated 9/30/78 (File no. T-10) | Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Five connecting rod bearings broken. One connecting rod bearing eroded (01/06/76-01/23/76) engine no. 19. | Engine incidence report (City of Homestead, Fl.) dated 9/30/78 (File no. T-10) | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |

| EXPERIENCE | REFERENCE DOCUMENTS | COMANCHE PEAK STATUS |
|---|---|---|
| The connecting rod bearing box babbit surfaces were completely wiped off as a result of a crankshaft failure that occurred during a low lube oil pressure alarm. | Failure Analysis report no. 0135 dated 12/10/80 (File no. T-39) (M/V Glencoe, MN) | Problem related to lube oil system. Not applicable to bearing shell design review. |
| Broken connecting rod bearing shells (05/82) engine no. 19 | Interoffice memo from E. Sigrist (TDI) to G. E. Trussel (TDI) dated 11/08/82 (File no. T-10). (City of Homestead, Fl.) | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Connection rod bearing shell failures - in general. | Interoffice memo from E. Sigrist (TDI) to J. Pabers (TDI) dated 11/01/82 (File no. T-10). Letter from A. Muxo (City of Homestead) to C. S. Mathews and R. J. Bazzini (TDI) dated 05/13/82 (File no. T-10). Letter from A. Muxo (City of Homestead) to C. S. Mathews (TDI) dated 10/13/82 (File no. T-10). | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Conrod bearing shell rotated; cause of failure was sheared dowel pin-crush and spread valves out of spec. | Memo from H.V. Schilling (TDI) G. E. Trussel (TDI) 01/04/82 (File #T-4) (M/V Uark AFB) | Manufacturing improvements maintain crush and spread specification. |

| EXPERIENCE | REFERENCE DOCUMENTS | COMANCHE PEAK STATUS |
|---|---|---|
| Broken connecting rod bearings on unit #19 | Letter from R. Pratt (TDI) to John Smith (City of Homestead, Fl.) dated 06/17/82 (File no. T-2) Telex from R. J. Bazzini (TDI) to C. Mathews (TDI) dated 06/08/82 (File no. T-2). | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Connecting rod bearing shells originally installed failed after short periods of operation. A new type of bearing was installed and likewise failed. A continuing effort to develop alternate design con-rod bearing shells was begun. | Letter from A. Muxo (City of Homestead) to C. S. Mathews and R. J. Bazzini (TDI) dated 05/13/82 (File no. T-10). | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Connecting rod shells #10 upper & lower and #9 upper had crack indications. All cracks resulted from fretting in connecting rod bore. | Failure Analysis report no. 0116 dated 09/25/78 (File no. T-19) | Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Connecting rod bolts & shells failed as a result of low torque preload conditions which allowed the assembly to flex, joint to separate and parts to fret and crack. | TDI Failure Analysis report no. 0127 dated 01/07/80 (File no. T-23). | Increased clamping force connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Connecting rod bearings shell failed while engine was operating at 2500 kw load. Failure was attributed to inadequate stoning and polishing of the crank pin surface. | Failure Analysis report no. 0108 dated 11/14/77 (File no. T-22) | Not applicable. Problem related to crankshaft, not bearing shell design. |

| EXPERIENCE | REFERENCE DOCUMENTS | COMANCHE PEAK STATUS |
|---|---|---|
| Con rod bearing failures caused by movement between the master rod and the link rod box. | Report "Investigation of Con Rod Bearing Failures Medan-TITI Kuning" by Robert Gray (File no. T-49) | Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Con rod bearing shoe failures caused by rapid bearing wear from inadequate oil filtration and non-rigid bearing housing from lock bolts. | TDI Failure Analysis report no. 0144 dated 04/29/82 (File no. T-58) | Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Failed connecting rod bearings. | Letter G. E. Trussell (TDI) from John Smith (City of Homestead) 06/14/77 (file no. T-55) (City of Homestead, Fl) | X-ray examination of Comanche Peak bearing shells excludes possible bad alloy. Incorporated into design review. Increased clamping force in connecting rod assembly eliminates bearing cracking from relative motion of master rod and rod box. |
| Various reports of bearing shell failures and replacements. | Chrononological summary of Glencoe events - 4 pages - dated 02/20/80 eng. S/N 72052 (File no. T-57) | Not applicable. Problem caused by out-of-round connecting rod. |

TDI OWNERS GROUP

for

SHOREHAM NUCLEAR POWER STATION - UNIT 1

CONNECTING ROD BEARING SHELLS
COMPONENT PART NO. 03-340-B

## I INTRODUCTION

The TDI Emergency Diesel Generator Owners Group Program for the Shoreham Nuclear Power Station requires Design and Quality Revalidation reviews of the connecting rod bearing shells to determine the adequacy of its design for the intended use at Shoreham. The primary function of the connecting rod bearing shells is to provide a low-friction sliding interface between the connecting rod and the crankpin, through the formation of a hydrodynamic oil film, which transmits the cylinder firing pressure to the crankshaft, converting the force into torque.

The connecting rod bearing shells are manufactured by TDI from permanent mold aluminum alloy B-852-T5 castings purchased from ALCOA (Ref. 1). The TDI part number for the components used at the Shoreham Nuclear Power Station is 03-340-05-AE.

## II OBJECTIVES

The objective of this review was to evaluate the adequacy of the connecting rod bearing shells for their intended service at the Shoreham Nuclear Power Station. Specifically, the objective was to perform the following analyses:

- o Journal orbit analysis to determine the pressure distribution in the hydrodynamic oil film.
- o Finite element analysis to determine the stress distribution in the connecting rod bearing shells.
- o Fracture mechanics analysis to determine the resistance to fatigue cracking.
- o Computation of acceptance criteria for radiographic NDE of connecting rod bearing shells.
- o Evaluation of babbitt adhesion.
- o A review of maintenance procedures.
- o A review of nuclear, non-nuclear and Shoreham site experience.

## III METHODOLOGY

As described in Reference 1 Report on connecting rod bearing shells, the analysis consisted of several steps. First, laboratory investigation of wear patterns, chemical, metallurgical and physical properties, and fracture surface morphology were conducted. Journal orbit analysis, using dimensions, weights and weight distributions confirmed by direct measurement at Shoreham, as well as engine operating parameters from the Shoreham engines, was performed. The output of the journal orbit analysis, which is the pressure distribution in the oil film under conditions of ideal geometry, was modified based on observed babbitt contact patterns to provide the input data to finite element analysis using the ANSYS code. The stress distribution computed by the finite element analysis was used to calculate the fatigue life of the connecting rod bearing shells based on the Shoreham experience with the bearing shells, and to calculate the maximum discontinuity that could be present without decreasing the fatigue resistance.

The influence of babbitt adhesion was assessed by inspection of bearing shells with marginal babbit adhesion after significant exposure to operating conditions in the Shoreham diesel engines.

Details of the methodology and analysis are contained in the Reference 1 Reports.

## IV RESULTS AND CONCLUSIONS:

Comparison of the maximum tensile stress in the original and the current connecting rod bearing shells at Shoreham shows that the stress is reduced by 50 percent in the replacement bearing shells (Ref. 1). This result was used to predict a fatigue life of about 38,000 hours for the current bearing shells. This fatigue life, which safely exceeds the expected usage of the engines during the 40-year operational life of the plant (Ref. 1), can be assured if an approved radiographic procedure such as Failure Analysis Associates "Nondestructive Examination of Diesel Engine Upper and Lower Bearing Shells" (Ref. 2) followed. This procedure has been reviewed and approved by LILCO, and is followed at Shoreham. The recommendation is implemented in E&DCR F-46505 (Ref. 4).

Babbitt adhesion was found to be adequate for successful functioning of the connecting rod bearing shells at Shoreham. The normal inspection intervals are adequate to monitor performance of the babbitt overlay.

Quality Revalidation Inspection results identified in Appendix B have been reviewed and considered in the performance of this design review and the results are consistent with the final conclusions of this report.

Based on the above review and implementation of the radiographic acceptance criteria, it is concluded that the connecting rod bearing shell is acceptable for its intended design function at Shoreham.

V REFERENCES

1. Failure Analysis Associates, "Design Review of Connecting Rod Bearing Shells for Transamerica Delaval Enterprise Engines", FaAA-84-3-1, Palo Alto, California, March 12, 1984.

2. Failure Analysis Associates, "Radiographic Examination of Diesel Engine Upper and Lower Bearing Shells", NDE 9.2, Palo Alto, California, February 6, 1984.

3. FaAA Support Package No. SP-84-3-1.

4. E&DCR F-46505

COMPONENT DESIGN REVIEW CHECKLIST

COMPONENT Connecting Rod Bearing Shells CLASSIFICATION A

PART NUMBER 03-340-B

TASK DESCRIPTION:

Obtain and review pressure vs crank angle data. Perform journal orbit analysis, finite element analysis, and fracture mechanics life estimate. Determine maximum void size in castings. Examine GGNS bearing shells. Evaluate babbit adhesion and thickness variation effects. Evaluate maintenance procedures.

Review information provided on TERs: Q-42, Q-47, Q-69, Q-182, Q-216, Q-221, Q-303, Q-312, Q-332, Q-334, Q-359, Q-372, Q-436, Q-447, Q-485, DR-34, DR-110, DR-248, Q-505.

PRIMARY FUNCTION:

Provides hydrodynamic oil film sliding surface and load transmission between connecting rod and crankpin.

ATTRIBUTE TO BE VERIFIED:

Corrosion, fatigue, and wear resistance. Coefficient of friction, dimensional accuracy, operation parameters.

SPECIFIED STANDARDS:

None

REFERENCES:

Seismic Qualification Review, TDI Emergency Diesel Generators at Shoreham Nuclear Power Station, "Stone & Webster Engineering Corp., Shoreham Project Job Book No. 244.7.

DOCUMENTATION REQUIRED:

Manufacturer's drawings, cylinder firing pressure, lubrication specifications and reciprocating weights.

GROUP CHAIRPERSON [signature] for G.W. Rogers PROGRAM MANAGER [signature] for JCK

COMPONENT REVIEW:

Journal orbit analysis to determine the pressure distribution in the hydrodynamic oil film.
Finite element analysis to determine the stress distribution in the connecting rod bearing shell.
Fracture mechanics analysis to determine the resistance to fatigue cracking.
Computation of acceptance criteria for radiographic NDE of connecting rod bearing shells.
Evaluation of babbitt adhesion.
A review of maintenance procedures.
A review of nuclear, non-nuclear and Shoreham site experience.

RESULTS AND CONCLUSIONS:

Based on the above review and implementation of the radiographic acceptance criteria, it is concluded that the connecting rod bearing shells are acceptable for their intended design function at Shoreham.

Seismic qualification for the connecting rod bearing shells is addressed in "Seismic Qualification Review, TDI Emergency Diesel Generators at Shoreham Nuclear Power Station, "Stone & Webster Engineering Corp., Shoreham Project Job Book No. 244.7.

GROUP CHAIRPERSON [signature] for C. W. Rogers PROGRAM MANAGER [signature] for JCK

COMPONENT REVALIDATION CHECKLIST

COMPONENT Connecting Rod Bearing Shells DOCUMENT NO. QR-03-340B

PART NO. 03-340B INCORPORATES DOC. NOS. QR-1,Rev.1,QR-2,QR-3

---

TASK DESCRIPTIONS

ENGINE 101

1. Assemble and review existing documentation.
2. Perform a Radiographic Test on the connecting rods 1 through 8.
3. Perform a Liquid Penetrant Test on all the connecting rod bearing shell surfaces for all 8 cylinders. (Thoroughly clean with solvent only the bearing shell O.D. Do not use any form of abrasive cleaner.)
4. Perform a visual inspection of the connecting rod bearing on the upper shell of cylinder 8.

ENGINE 102

1. Assemble and review existing documentation.
2. Perform a Radiographic Test on the connecting rods 1 through 8.
3. Perform Liquid Penetrant Test on all the connecting rod bearing shell surfaces for cylinders 5, 7 and 8. (Thoroughly clean with solvent only the bearing shell O.D. Do not use any form of abrasive cleaner.)

ENGINE 103

1. Assemble and review existing documentation.
2. Perform a Radiographic Test on the connecting rods 1 through 8.
3. Perform a Liquid Penetrant Test on all the connecting rod bearing shell surfaces for all 8 cylinders. (Thoroughly cleaning with solvent only the bearing shell O.D. Do not use any form of abrasive cleaner.)

SPARES

1. Perform a material analysis of the connecting rod bearing shells.

---

ATTRIBUTES TO BE VERIFIED

ENGINE 101

1. Quality status of Component Document Package
2. Internal discontinuities are within engineering guidelines for the connecting rod bearing shells.
3. Surface integrity of the connecting rod bearing shells
4. Surface integrity of the cylinder 8 on the upper connecting rod bearing shell

ENGINE 102

1. Quality status of Component Document Package
2. Internal discontinuities are within engineering guidelines for the connecting rod bearing shells.
3. Surface integrity of the connecting rod bearing shells

## ATTRIBUTES TO BE VERIFIED (continued)

### ENGINE 103

1. Quality status of Component Document Package
2. Internal discontinuities are within engineering guide lines for connecting rod bearing shells.
3. Surface integrity of connecting rod bearing shells

### SPARES

1. Material of the connecting rod bearing shells

---

## ACCEPTANCE CRITERIA

### ENGINE 101

1. Satisfactory Document Package

2-4. Review of Inspection Report by Design Group

### ENGINE 102

1. Satisfactory Document Package

2-3. Review of Inspection Report by Design Group

### ENGINE 103

1. Satisfactory Document Package

2-3. Review of Inspection Report by Design Group

### SPARES

1. Review of Inspection Report by Design Group

---

## REFERENCES

### ENGINE 101

1. QCI-FSI-F11.1-020
2. SH1-089, applicable Site/Vendor Documents, FaAA Bearing Report, Alcoa Design Manual, TERs DR-110, Q-91
3. TERs Q-216, DR-34, Q-91, LILCO Approved Inspection Procedures
4. TER DR-248, LILCO Approved Inspection Procedures

### ENGINE 102

1. QCI-FSI-F11.1-020
2. TER DR-110, SH1-089, applicable Site/Vendor Documents, FaAA Bearing Report, Alcoa Design Manual
3. LILCO Approved Inspection Procedures

REFERENCES (continued)

ENGINE 103

1. QCI-FSI-F11.1-020
2. TERs DR-110, Q-91, SH1-089, applicable Site/Vendor Documents, FaAA Bearing Report, Alcoa Design Manual
3. TER Q-91, LILCO Approved Inspection Procedures

SPARES

1. TER Q-485

---

DOCUMENTATION REQUIRED

ENGINE 101

1. Document Summary Sheet
2-4. Inspection Report

ENGINE 102

1. Document Summary Sheet
2-3. Inspection Report

ENGINE 103

1. Document Summary Sheet
2-3. Inspection Report

SPARES

1. Inspection Report

GROUP CHAIRPERSON [signature] PROGRAM MANAGER Richard K VanGalder

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COMPONENT REVIEW

ENGINE 101

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results.
2. All sixteen bearing shells were subject to Radiographic Examination, five findings were reported by TER Q-372. This was dispositioned by LDR 2291 and remains open.

COMPONENT REVIEW (continued)

ENGINE 101 (continued)

3. Liquid Penetrant Examination was performed on fifteen of sixteen shells. The upper shell for cylinder 8 was rejectable upon visual examination as reported by TER Q-312. The other fifteen evidenced indications as reported by TER Q-332 and dispositioned by LDR 2278. The Eddy Current Examination showed that indications were cosmetic in nature and acceptable for use. LDR 2265 was generated to disposition the failed cylinder 8 shell (Q-312) which was replaced. The failed shell was forwarded to the Design Group for further analysis.
4. Visual inspection of cylinder 8 upper shell reported by Q-312 as noted above.

ENGINE 102

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results with the exception of LDR 2119 which remains open.
2. All sixteen bearing shells were subject to Radiographic Examination. Thirteen were accepted and three were rejected. All results were reported by TER Q-64. LDR 2119, generated for Liquid Penetrant indications recommends replacement of these three shells. Rejected shells were forwarded to Design Group for further analysis.
3. Liquid Penetrant Examination was performed on the six referenced shells with three displaying indications. These results were dispositioned by LDR 2119.

ENGINE 103

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results.
2. All sixteen bearing shells were subject to Radiographic Examination. Seven shells evidenced findings as reported by TER Q-182 with disposition recorded by LDR 2210. LDR 2210 remains open.
3. Liquid Penetrant Examination was performed on all sixteen shells with satisfactory results on all surfaces of all shells.

SPARES

1. Material analysis was performed on connecting rod bearing shells as reported by TER Q-505.

---

RESULTS AND CONCLUSIONS

ENGINE 101

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

RESULTS AND CONCLUSIONS (continued)

ENGINE 102

Same as Engine 101

ENGINE 103

Same as Engine 101

SPARES

Same as Engine 101

GROUP CHAIRPERSON Rudolph Chung PROGRAM MANAGER JC Kammeyer

# EDG COMPONENT TRACKING SHOREHAM SITE, NUCLEAR AND NON-NUCLEAR INDUSTRY EXPERIENCE

COMPONENT NO. 03-340-B

Effective Printout Date 4/20/84

COMPONENT TYPE: Connecting Rod Bearing Shell

| EXPERIENCE | REFERENCE DOCUMENTS | SHOREHAM STATUS |
|---|---|---|
| **SHOREHAM** | | |
| Reverse bearing shells. Perform NDE Exam Engine 101. | RRR 1037 | Normal maintenance procedure. Does not impact design. |
| **NON-NUCLEAR** | | |
| Connecting rod bearing shells unfit for further use. Delaval advised possibility of bad alloy from vendor. M/V "Columbia" DSRV-16-4. | Letters from M. Zbinden 11/6/80,3/19/79 2/2/79. | X-ray examination of Shoreham bearing shells excludes possible bad alloy. Incorporate into design review. |
| Cracked bearing shells found in conjunction with damaged rod box bolts and/or threads. M/V "Columbia" DSRV-16-4. | Letter from M. Zbinden 2/5/80. | Not applicable. DSR-48 has no rod box bolts. |
| **NUCLEAR** | | |
| Diesel trip on oil and caused coolant temperature, caused by initial rod bearing failure in Fairbanks-Morse engine. | LER Hatch-2 366-82079,820727 | Not applicable. Fairbanks-Morse engine does not use cast aluminum bearings. |

# COMPONENT DESIGN REVIEW CHECKLIST
# VOGTLE ELECTRIC GENERATING PLANT - UNIT 1

| | |
|---|---|
| COMPONENT Rocker Shaft Assemblies: Intake/Intermediate & Exhaust | UTILITY Georgia Power Company |
| GROUP PARTS LIST NO. 02-390A&B | TASK DESCRIPTION NO. DR-11-02-390A&B-2 |
| SNPS GPL NO. 03-390A&B | CLASSIFICATION TYPE B |

## TASK DESCRIPTIONS

Design review for this component is not required based on the following:

- A review of the Comanche Peak and Shoreham DR/QR reports, which establish the acceptability of the rocker shaft assemblies for their intended purpose.
- A review of applicable industry experience listed in the EDG Component Tracking System indicated there had been no design related failures associated with this component. There is no Vogtle site experience listed for this component.

There are no maintenance or modification recommendations for this component.

Quality inspections conducted on both engines at Vogtle were reviewed for acceptability. Visual inspection of all intake, intermediate, and exhaust rocker arms were satisfactory and material comparator test on all intake and exhaust rocker arm shafts verified proper material. Hardness tests were also performed on all the rocker shafts, though not an Owners Group requirement. The results were acceptable and are reported on TER 11-074 and 11-032.

## PRIMARY FUNCTION

Not required

## ATTRIBUTE TO BE VERIFIED

Not required

COMPONENT DESIGN REVIEW CHECKLIST

SPECIFIED STANDARDS

Not required

REFERENCES

Not required

DOCUMENTATION REQUIRED

Not required

GROUP CHAIRPERSON K. T. Fitzpatrick PROGRAM MANAGER J.C. Kammeyer

# COMPONENT QUALITY REVALIDATION CHECKLIST

COMPONENT Rocker Arms & Pushrods - Intake and Intermediate Rocker Shaft Assembly

UTILITY Georgia Power Company Vogtle Electric Generating Plant - Unit 1

GPL NO. 02-390A

REV. NO. 1

SNPS GPL NO. 03-390A

---

## TASK DESCRIPTIONS

### Engine 1

1. Assemble and review existing documentation.
2. Perform a visual inspection of the intake and intermediate rocker arm assembly for signs of distress, linear indications and chipped pieces in the outer lips of the pushrod cups.
3. Determine the material of one intake and intermediate rocker arm shaft.

### Engine 2

1. Assemble and review existing documentation.
2. Perform a visual inspection of the intake and intermediate rocker arm assembly for signs of distress, linear indications, and chipped pieces in the outer lips of the pushrod cups.

---

## ATTRIBUTES TO BE VERIFIED

### Engine 1

1. Quality status of Component Document Package
2. Surface integrity of the rocker arm assembly
3. Material of rocker arm shafts

### Engine 2

1. Quality status of Component Document Package
2. Surface integrity of the rocker arm assembly

## ACCEPTANCE CRITERIA

### Engine 1

1. Satisfactory Document Package
2. No linear indications/chipped pieces in the outer lips of the pushrod cups
3. Material to be AISI-4142

### Engine 2

1. Satisfactory Document Package
2. No linear indications/chipped pieces in the outer lips of the pushrod cups.

## REFERENCES

### Engine 1

1. QCI No. 52

2-3. Approved Site NDE Procedures

### Engine 2

1. QCI No. 52
2. Approved Site NDE Procedures

## DOCUMENTATION REQUIRED

### Engine 1

1. Document Summary Sheet

2-3. Inspection Report

### Engine 2

1. Document Summary Sheet
2. Inspection Report

GROUP CHAIRPERSON Victor A. Selch PROGRAM MANAGER [signature] for JCK

COMPONENT REVIEW

Engine 1

1. No EDGCTS site experience documents are in evidence.

2. A visual inspection was performed on all intake and intermediate rocker arm assemblies with satisfactory results. This was reported by TER# 11-074.

3. Material Comparator and hardness tests were performed on all intake rocker arm shafts. Results were reported by TER# 11-074.

Engine 2

1. No EDGCTS site experience documents are in evidence

2. A visual inspection was performed on all intake and intermediate rocker arm assemblies with satisfactory results. This was reported by TER#s 11-032 and 11-074.

Note: Material Comparator and hardness tests were performed on all intake rocker arm shafts. Results were reported by TER#s 11-032 and 11-074.

---

RESULTS AND CONCLUSION

Engine 1

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

Engine 2

Same as Engine 1

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GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature] for JCK

# TDI OWNERS GROUP

for

## COMANCHE PEAK STEAM ELECTRIC STATION - UNIT 1

## INTAKE/INTERMEDIATE AND EXHAUST ROCKER SHAFT ASSEMBLIES
## COMPONENT PART NOs. 02-390A and 02-390B

## I INTRODUCTION

The TDI Emergency Diesel Generator Owners Group Program for the Comanche Peak Steam Electric Station requires a Design and Quality Revalidation review to determine the adequacy of the intake/intermediate and exhaust rocker shaft assemblies for their intended use at Comanche Peak. The primary function of the intake/intermediate and exhaust rocker shaft assemblies is to translate the motion of the main pushrods into the reciprocating motion of the intake and exhaust valves and connector pushrod. The part numbers for the rocker shafts as assigned by the manufacturer, TDI, are 1A-5532 and 1A-5465.

## II OBJECTIVE

The objective is to evaluate the adequacy of the rocker shafts for their intended use at Comanche Peak. Specifically, the following tasks were performed:

- Review of Comanche Peak site, nuclear and non-nuclear industry.
- Evaluation of state of stress in rocker shaft assemblies.
- Evaluation of resistance to bending and fatigue.
- Review of pushrod socket installation.
- Evaluation of load in rocker arm assembly and pushrod sockets.
- Evaluation of rocker shaft supports.
- Review of Quality Revalidation Checklist results for acceptability.

## III METHODOLOGY

The Emergency Diesel Generator Component Tracking System records for Comanche Peak were reviewed to determine the nuclear, non-nuclear, and specific Comanche Peak experience of the rocker shaft assemblies.

The calculations for loads and stresses of rocker arms at the Shoreham Nuclear Power Station were used for this analysis. The rocker arms used at Comanche Peak are nearly identical to those used at Shoreham with any differences being judged inconsequential to the results of these calculations (Ref. 1).

A theoretical model was developed to compute the dynamic response of the valve systems, and to estimate the pushrod, rocker arm, and shaft forces. These forces were used to conduct a stress analysis of the rocker shaft assemblies, and to evaluate their resistance to fatigue.

The bearing stresses on the rocker shaft support were calculated in order to verify that resistance to lateral loads on the rocker arms is provided by 1) the friction forces between the rocker support and shaft assemblies, and 2) the rocker shaft and support dowel and not by bearing between the rocker shaft bolt and the support.

## IV RESULTS AND CONCLUSIONS

The maximum pushrod and rocker arm forces were computed (Ref. 2). These forces were used to compute the peak shear and bending stresses in the rocker shaft assemblies. The maximum shear stress was found to be 7.9 ksi, and the maximum bending stress was found conservatively to be 24 ksi. These are both below the endurance limit stresses of 19.2 ksi for shear and 30 ksi for bending (Ref. 2).

Conservative stress analysis of the intake, intermediate, and exhaust rocker arms indicate a minimum factor of safety against failure of 1.1 (Ref. 2). The forces acting on the pushrod sockets induce stresses in the sockets (59.2 ksi max, Ref. 2) which are below the allowable of 200 ksi.

The capscrew (P/N 02-390-05-AA) connecting the rocker shaft to the rocker support is torqued to 365 ft-lb (Ref. 2), which develops a tensile preload of 21.9 kips (Ref. 2). This is sufficient to provide frictional resistance to lateral forces on the intake rocker-side of both rocker shaft assemblies. On the other side (intermediate rocker), the support dowel (P/N 03-362-01-OB) is engaged by the rocker shaft end, and transfers the shear from the rocker shaft to the sub-base assembly boss. The shear resistance supplied by friction at this end is minimal, due to the uplift forces on the rocker shaft by the main exhaust and intermediate pushrods (Ref. 2), and calculations indicate that these shear stresses exceed the endurance limit stress for the dowel at full engine load (Ref. 2). However, there is no evidence (nuclear or non-nuclear) indicating dowel failures. Specifically, Shoreham experience indicates that approximately 400 hours (Ref. 3 and 4) have been logged on these dowels at full engine load. Recognizing that the pushrod loads and material strengths used in the calculations may be conservative, and that the dowels have been subjected to more than 5 x $10^6$ cycles at full load without failures, it is concluded that the dowels are capable of transferring the shear loads to the sub-base assembly.

The information provided on the following TERs has been reviewed and is consistent with the final conclusions of this report: 10-005, 10-006, 10-097.

Quality Revalidation Inspection results identified in Appendix B have been reviewed and considered in the performance of this review. These results are consistent with the final conclusion of this report.

Based on the above design review, it is concluded that the intake/intermediate and exhaust rocker shaft assemblies are acceptable for their intended design function at Comanche Peak.

## V REFERENCES


1. FaAA Report No. 84-6-2(a). "TDI Owners Group for Shoreham Nuclear Power Station - Unit 1--Intake/Intermediate and Exhaust Rocker Shaft Assemblies - Components Nos. 03-390A and 03-390B," 06/29/84.

2. "Rocker Shaft Assembly Support Package," SP-84-6-2(a).

3. "Emergency Diesel Generator Crankshaft Failure Investigation - Shoreham Nuclear Power Station," FaAA report #83-10-2.1.

4. "Evaluation of Emergency Diesel Generator Crankshaft at Shoreham Nuclear Power Station," FaAA report #84-3-16.

COMPONENT DESIGN REVIEW CHECKLIST
TEXAS UTILITIES

COMPONENT Rocker Arms and Pushrods Intake/Intermediate Exhaust Rocker Shaft Assemblies

CLASSIFICATION TYPE B

COMPONENT PART NUMBER 02-390A&B
(SNPS PART NUMBER 03-390A&B)

TASK DESCRIPTION NO: DR-10-02-390A&B-1

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TASK DESCRIPTIONS:

Evaluate rocker shaft assembly stresses.

Review pushrod socket installation.

Review information provided on TERs.

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PRIMARY FUNCTION:

Actuate intake valves, exhaust valves, and intermediate pushrods.

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ATTRIBUTES TO BE VERIFIED:

Review loads, rocker arm assembly and pushrod cups

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SPECIFIED STANDARDS:

None.

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REFERENCES:

None.

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DOCUMENTATION REQUIRED:

Valve and pushrod loading, installation drawings.

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GROUP CHAIRPERSON: W. E. Pettwaen PROGRAM MANAGER: C. Kammeyer

# COMPONENT QUALITY REVALIDATION CHECKLIST

COMPONENT Rocker Arms & Pushrods - Intake and Intermediate Rocker Shaft Assembly

UTILITY Texas Utilities Generating Co., Comanche Peak Station

GPL NO. 02-390A

REV. NO. 2

SNPS GPL NO. 03-390A

---

## TASK DESCRIPTIONS

D.G. CP1-MEDGEE-01

1. Assemble and review existing documentation.
2. Perform a visual inspection of the intake and intermediate rocker arm assembly for signs of distress, linear indications and chipped pieces in the outer lips of the pushrod cups.
3. Determine the material of one rocker arm assembly.

D.G. CP1-MEDGEE-02

1. Assemble and review existing documentation.
2. Perform a visual inspection of the intake and intermediate rocker arm assembly for signs of distress, linear indications, and chipped pieces in the outer lips of the pushrod cups.

---

## ATTRIBUTES TO BE VERIFIED

D.G. CP1-MEDGEE-01

1. Quality status of Component Document Package
2. Surface integrity of the rocker arm assembly
3. Material of rocker arm assembly

D.G. CP1-MEDGEE-02

1. Quality status of Component Document Package
2. Surface integrity of the rocker arm assembly

## ACCEPTANCE CRITERIA

D.G. CP1-MEDGEE-01

1. Satisfactory Document Package
2. No linear indications/chipped pieces in the outer lips of the pushrod cups
3. Material to be AISI-4142

D.G. CP1-MEDGEE-02

1. Satisfactory Document Package
2. No linear indications/chipped pieces in the outer lips of the pushrod cups.

---

## REFERENCES

D.G. CP1-MEDGEE-01

1. QCI-FSI-F11.1-020

2-3. Approved Site NDE Procedures

D.G. CP1-MEDGEE-02

1. QCI-FSI-F11.1-020
2. Approved Site NDE Procedures

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## DOCUMENTATION REQUIRED

D.G. CP1-MEDGEE-01

1. Document Summary Sheet

2-3. Inspection Report

D.G. CP1-MEDGEE-02

1. Document Summary Sheet
2. Inspection Report

GROUP CHAIRPERSON [signature]    PROGRAM MANAGER [signature] for JCK

COMPONENT REVIEW

D.G. CP1-MEDGEE-01

1. No EDGCTS site experience documents are in evidence.

2. A visual inspection was performed with unsatisfactory results. This was reported by TER# 10-006.

3. The material was determined by use of a material comparitor test. This was reported by TER# 10-005.

D.G. CP1-MEDGEE-02

1. No EDGCTS site experience documents are in evidence

2. A visual inspection was performed with satisfactory results. This was reported by TER# 10-097.

RESULTS AND CONCLUSION

D.G. CP1-MEDGEE-01

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

GROUP CHAIRPERSON Victor A Saleta    PROGRAM MANAGER [signature] for JCK

# COMPONENT QUALITY REVALIDATION CHECKLIST

COMPONENT Rocker Arms & Pushrods - Exhaust Rocker - Shaft Assembly

UTIILITY Texas Utilities Generating Co., Comanche Peak Station

GPL NO. 02-390B

REV. NO. 2

SNPS GPL NO. 03-390B

## TASK DESCRIPTIONS

D.G. CP1-MEDGEE-01

1. Assemble and review existing documentation.
2. Perform a visual inspection of the intake and intermediate rocker arm assembly for signs of distress, linear indications, and chipped pieces in the outer lips of the pushrod cups.
3. Determine the material of one rocker arm assembly.

D.G. CP1-MEDGEE-02

1. Assemble and review existing documentation.
2. Perform a visual inspection of the intake and intermediate rocker arm assembly for signs of distress, linear indications, and chipped pieces in the outer lips of the pushrod cups.

## ATTRIBUTES TO BE VERIFIED

D.G. CP1-MEDGEE-01

1. Quality status of Component Document Package
2. Surface integrity of the rocker arm assembly
3. Material of rocker arm assembly

ATTRIBUTES TO BE VERIFIED (continued)

D.G. CP1-MEDGEE-02

1. Quality status of Component Document Package

2. Surface integrity of rocker arm assembly

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ACCEPTANCE CRITERIA

D.G. CP1-MEDGEE-01

1. Satisfactory Document Package

2. No linear indications/chipped pieces in the outer lips of the pushrod cups.

3. Material to be AISI-4142

D.G. CP1-MEDGEE-02

1. Satisfactory Document Package

2. No linear indications/chipped pieces in the outer lips of the pushrod cups.

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REFERENCES

D.G. CP1-MEDGEE-01

1. QCI-FSI-F11.1-020

2-3. Approved Site NDE Procedures

D.G. CP1-MEDGEE-02

1. QCI-FSI-F11.1-020

2. Approved Site NDE Procedures

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DOCUMENTATION REQUIRED

D.G. CP1-MEDGEE-01

1. Document Summary Sheet

2-3. Inspection Report

D.G. CP1-MEDGEE-02

1. Document Summary Sheet

2. Inspection Report

GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature: DC Kammeyer]

---

COMPONENT REVIEW

D.G. CP1-MEDGEE-01

1. No EDGCTS site experience documents are in evidence.

2. A visual inspection was performed with satisfactory results as reported by TER# 10-055.

3. The material was determined by use of a material comparator test. This was reported by TER# 10-005.

D.G. CP1-MEDGEE-02

1. No EDGCTS site experience documents are in evidence.

2. A visual inspection was performed with satisfactory results as reported by TER# 10-097.

---

RESULTS AND CONCLUSION

D.G. CP1-MEDGEE-01

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

RESULTS AND CONCLUSION (continued)

D.G. CP1-MEDGEE-02

Same as D.G. CP1-MEDGEE-01

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GROUP CHAIRPERSON Nestor A. Seleta PROGRAM MANAGER J.C. Kammeyer

EDG COMPONENT TRACKING SYSTEM: COMANCHE PEAK SITE, NUCLEAR AND NON-NUCLEAR INDUSTRY EXPERIENCE SUMMARY

COMPONENT NO.: 02-390A and 02-390B

Effective Printout Date: 07/02/84

COMPONENT NAME: ROCKER ARMS AND PUSHRODS - INTAKE/INTERMEDIATE ROCKER SHAFT ASSEMBLY EXHAUST ROCKER SHAFT ASSEMBLY

| EXPERIENCE | REFERENCE DOCUMENTS | COMANCHE PEAK STATUS |
|---|---|---|
| COMANCHE PEAK | | |
| None | | |
| NUCLEAR | | |
| Intake rocker arm broke due to binding between it and rocker stand. Binding was due to inadequate end clearance. | Zion 1, LER 295-81036 295-810106 | Different manufacturer (Cooper Bessemer). There is no history of clearance problems with TDI engines. |
| NON-NUCLEAR | | |
| Action taken since vessel delivery - plug welded rocker arm assembly drilled oil passages to reduce oil flooding of rocker boxes (M/V Columbia). | Hunton & Williams (12/29/83) to C. Seaman. Letter to TDI (D. Martini) (03/22/80) from M. Zbinden (State of Alaska). | Inspections performed at Comanche Peak on the rocker arms indicate that the plugs are tight. |
| Intake rocker arm broke on #3 left bank and #6 right intermediate rocker arm broke. | Engine Incidence Report (City of Homestead, Florida) dated 09/30/78 (File No. T-10) (V-20) | One incident caused by improperly tightened bolts. Other incident due to flaw in metal. No design problems. |
| Replaced partially broken oil supply 3/8 tubing to #8 cylinder rocker shafts. | Customer service report by C. McCluney (TDI) dated 02/02/84 (File No. T-38) | Found on new engine. Not a design problem, Both Shoreham and Comanche Peak have run successfully without this problem. |

TDI OWNERS GROUP

for

SHOREHAM NUCLEAR POWER STATION - UNIT 1

INTAKE/INTERMEDIATE AND EXHAUST
ROCKER SHAFT ASSEMBLIES
COMPONENT PART NO. 03-390-A and B

## I INTRODUCTION

The TDI Emergency Diesel Generator Owners Group Program for the Shoreham
Nuclear Power Station requires Design and Quality Revalidation reviews to
determine the adequacy of the intake/intermediate and exhaust rocker shaft
assemblies for their intended use at Shoreham. The primary function of
the intake/intermediate and exhaust rocker shaft assembly is to translate 1
the motion of the main pushrods into the reciprocating motion of the
intake valves and connector pushrod. The part numbers for both rocker
shaft assemblies as assigned by the manufacturer, TDI, are 1A-5446 and
1A-5465.

## II OBJECTIVE

The objective of this review is to evaluate the adequacy of the rocker shaft assemblies for their intended use at Shoreham. Specifically, the following tasks were performed:

- Review of nuclear, non-nuclear, and Shoreham site experience.
- Evaluation of state of stress in rocker shaft assemblies.
- Evaluation of resistance to bending and fatigue.
- Review of pushrod socket installation.
- Evaluation of load in rocker arm assembly and pushrod sockets.
- Evaluation of rocker shaft supports.
- Evaluation of the Quality Revalidation Checklist results for acceptability.

## III METHODOLOGY

The Emergency Diesel Generator Component Tracking System records for Shoreham were reviewed to determine the nuclear, non-nuclear, and specific Shoreham experience of the rocker shaft assemblies.

A theoretical model was developed to compute the dynamic response of the valve systems, and to estimate the pushrod rocker arm, and shaft forces. These forces were used to conduct a stress analysis of the rocker shaft assemblies and to evaluate the resistance to fatigue.

The bearing stresses on the rocker shaft support were calculated in order to verify that resistance to lateral loads on the rocker arms is provided by 1) the friction forces between the rocker support and shaft assembly, and 2) the rocker shaft and support dowel and not by bearing between the rocker shaft bolt and the support.

## IV RESULTS AND CONCLUSIONS

The maximum pushrod and rocker arm forces were computed (Ref. 1). These
forces were used to compute the peak shear and bending stresses in the
rocker shaft assemblies. The maximum shear stress was found to be 7.9
ksi, and the maximum bending stress was found conservatively to be 24 ksi. 1
These are both below the endurance limit stresses of 19.2 ksi for shear
and 30 ksi for bending (Ref. 1).

Conservative stress analysis of the intake, intermediate, and exhaust
rocker arms indicate a minimum factor of safety against failure of 1.1
(Ref. 1). The forces acting on the pushrod sockets induce stresses in the
sockets (59.2 ksi max, Ref. 1) which are below the allowable of 200 ksi. 1

The capscrew (P/N 02-390-01-0J) connecting the rocker shaft to the rocker
support is torqued to 365 ft-lb (Ref. 1), which develops a tensile preload
of 21.9 kips (Ref. 1). This is sufficient to provide frictional resist-
ance to lateral forces on the intake rocker-side of both rocker shaft
assemblies. On the other side (intermediate rocker), the support dowel
(P/N 03-362-02-0B) is engaged by the rocker shaft end, and transfers the
shear from the rocker shaft to the sub-base assembly boss. The shear
resistance supplied by friction at this end is minimal, due to the uplift
forces on the rocker shaft by the main exhaust and intermediate pushrods
(Ref. 1), and calculations indicate that these shear stresses exceed the
endurance limit stress for the dowel (Ref. 1). However, there is no
evidence (nuclear or non-nuclear) indicating dowel failures. Specific-
ally, Shoreham experience indicates that approximately 400 hours (Ref. 2
and 3) have been logged on these dowels at full engine load. Recognizing
that the pushrod loads and material strengths used in the calculations 1
may be conservative, and that the dowels have been subjected to more than
$5 \times 10^6$ cycles at full load without failures, it is concluded that the
dowels are capable of transferring the shear loads to the sub-base
assembly.

Quality Revalidation Inspection results identified in Appendix B have been reviewed and considered in the performance of this design review and the results are consistent with the final conclusions of this report.

Based on the above review, it is concluded that the intake/intermediate and exhaust rocker shaft assemblies are acceptable for their intended function at Shoreham. 1

## V REFERENCES


1. "Rocker Shaft Assembly Support Package," SP-84-6-2(a).

2. "Emergency Diesel Generator Crankshaft Failure Investigation - Shoreham Nuclear Power Station," FaAA Report #83-10-2.1.

3. "Evaluation of Emergency Diesel Generator Crankshaft at Shoreham Nuclear Power Station," FaAA Report #84-3-16.

# COMPONENT DESIGN REVIEW CHECKLIST

COMPONENT Rocker Arms and Pushrods Intake/Intermediate Exhaust Rocker Shaft Assemblies

CLASSIFICATION TYPE B

PART NUMBER 03-390-A and 03-390-B

## TASK DESCRIPTION:

Evaluate rocker shaft assembly stresses.

Review pushrod socket installation.

Review information provided on TERs: Q-43, Q-44, Q-70, Q-79, Q-126, Q-127, Q-131, Q-132, Q-133, Q-147, Q-148, Q-151, Q-175, Q-197, Q-199, Q-200, Q-201, Q-270, Q-278, Q-279, Q-280, Q-281, Q-295, Q-296, Q-297, Q-319, Q-346, Q-444, Q-481, Q-515, Q-516, DR-1, DR-24, DR-88, DR-170, DR-176, DR-195, DR-196, DR-197, DR-198, DR-215, DR-224.

## PRIMARY FUNCTION:

Actuate intake valves, exhaust valves, and intermediate pushrods

## ATTRIBUTE TO BE VERIFIED:

Review loads rocker arm assembly and pushrod sockets.

## SPECIFIED STANDARDS:

None

## REFERENCES:

"Seismic Qualification Review, TDI Emergency Diesel Generators at Shoreham Nuclear Power Station," Stone & Webster Engineering Corp., Shoreham Project Job Book No. 244.7.

DOCUMENTATION REQUIRED:

Valve and pushrod loading, installation drawings.

GROUP CHAIRPERSON: O.H. Wells for G.W. Rogers PROGRAM MANAGER J.P. Power for JCK

COMPONENT REVIEW:

Review of nuclear, non-nuclear and Shoreham site experience.

Evaluation of state of stress in rocker shaft assemblies.

Evaluation of resistance to bending and fatigue.

Review of pushrod socket installation.

Evaluation of load in rocker arm assembly and pushrod sockets.

Evaluation of rocker shaft supports.

Evaluation of the Quality Revalidation Checklist results for acceptability.

RESULTS AND CONCLUSIONS:

The intake/intermediate/exhaust rocker shaft assemblies are acceptable for their intended design function at Shoreham.

Seismic qualification for the intake/intermediate/exhaust is addressed in "Seismic Qualification Review, TDI Emergency Diesel Generators at Shoreham Nuclear Power Station," Stone & Webster Engineering Corp., Shoreham Project Job Book No. 244.7.

GROUP CHAIRPERSON O.H. Wells for G.W. Rogers PROGRAM MANAGER J.P. Power for JCK

COMPONENT REVALIDATION CHECKLIST

COMPONENT Rocker Arms & Pushrods - Intake & Intermediate Rocker Shaft Assembly including Capscrews

DOCUMENT NO. QR-03-390A

PART NO. 03-390A

INCORPORATES DOC. NOS. QR-1, Rev. 1; QR-2, Rev. 1

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TASK DESCRIPTIONS

ENGINE 101

1. Assemble and review existing documentation.
2. Review the pushrod cup installation documentation and ensure the overhang is properly ground flush (TDI P/N 08-390-01-0F) for cylinders 5, 7 and 8.
3. Perform visual inspections of cylinders 5, 7 and 8 intake and intermediate rocker arm assemblies for signs of debris, chipping, loose metal and damaged parts prior to subcover removal. Document with photographs.
4. Determine the material and the hardness of both the shaft (TDI P/N 03-390-01-0A) and the capscrews (TDI P/N 02-390-01-0J) for cylinders 5, 7, and 8.
5. Perform visual inspections of intake and intermediate rocker arm assemblies for signs of wear & distress, cylinders 5, 7, 8.
6. Perform a dimensional inspection of the rocker arm bushing bore, cylinders 5, 7, 8.

ENGINE 102

1. Assemble and review existing documentation.
2. Review the pushrod cup installation documentation and ensure the overhang is properly ground flush. (TDI P/N 08-390-01-0F) for cylinders 5, 7 and 8.
3. Determine material and hardness of the shaft (TDI P/N 03-390-01-0A) for cylinder 7.
4. Perform visual inspections of intake and intermediate rocker arm assemblies for signs of wear & distress, cylinders 5, 7, 8.
5. Perform dimensional inspection of rocker arm bushing bore, cylinders 5, 7, 8.

ENGINE 103

Same as Engine 101

SPARES

1. Perform material analysis of rocker arm shaft

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ATTRIBUTES TO BE VERIFIED

ENGINE 101

1. Quality status of Vendor Component Package
2. All sockets (TDI P/N 08-390-01-0F) ground in accordance with TDI Letter April 15, 1983. L. McHugh to N. Rudikoff.
3. Absence of debris, loose metal and damaged parts in the rocker arm assemblies.

ATTRIBUTES TO BE VERIFIED (continued)

ENGINE 101 (continued)

4. Proper material and hardness of the shaft (TDI P/N 03-390-01-0A) and capscrews (TDI P/N 02-390-01-0J).
5. Visual integrity of the rocker arm assemblies
6. Dimensions of the rocker arm bushing bores

ENGINE 102

1. Quality status of Vendor Component Package
2. All sockets (TDI P/N 08-390-01-0F) ground in accordance with TDI Letter April 15, 1983. L. McHugh to N. Rudikoff.
3. Proper material and hardness of the shaft (TDI P/N 03-390-01-0A)
4. Visual integrity of the rocker arm assemblies
5. Dimensions of the rocker arm bushing bores

ENGINE 103

Same as Engine 101

SPARES

1. Materials of the rocker arm shaft

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ACCEPTANCE CRITERIA

ENGINE 101

1. Satisfactory Document Package

2-6. Review Inspection Report by Design Group

ENGINE 102

1. Satisfactory Document Package

2-5. Review of Inspection Report by Design Group

ENGINE 103

Same as Engine 101

SPARES

1. Review of Inspection Report by Design Group

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REFERENCES

ENGINE 101

1. QCI-FSI-F11.1-020
2. TER Q-91, LDRs 1851, 1252
3. LILCO approved inspection procedures, Q-126, Q-91
4. TERs Q-91, DR-33, Q-143, Q-16, DR-24

REFERENCES (continued)

ENGINE 101 (continued)

5. TERs DR-24, Q-91
6. LDRs 1235, 1245

ENGINE 102

1. QCI-FSI-F11.1-020
2. LDRs 1252 & 1851, QR-1 Rev.1
3. TERs DR-24, Q-16, DR-33, Q-143
4. TER DR-24
5. LDRs 1234, 1245

ENGINE 103

Same as Engine 101

DOCUMENTATION REQUIRED

ENGINE 101

1. Document Summary Sheet
2-6. Inspection Report

ENGINE 102

1. Document Summary Sheet
2-5. Inspection Report

ENGINE 103

Same as Engine 101

SPARES

1. Inspection Report

GROUP CHAIRPERSON [signature] PROGRAM MANAGER Richard K VanHallen

COMPONENT REVIEW

ENGINE 101

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results.
2. A visual inspection of the intake rocker arm push rod cups was performed for cup overhang. The findings were reported by TER Q-346 and dispositioned by LDR 2279. The visual inspection of the intermediate rocker arm pushrod cups was found to be satisfactory.

COMPONENT REVIEW (continued)

ENGINE 101 (continued)

3. A visual examination was performed for debris, chipping, loose metal, and damaged parts. The findings were reported by TER Q-270 and dispositioned by LDR 2241.
4. Material tests were accomplished with a Bausch & Lomb 3600 Mobile Metal Analyzer on the shaft and the (2) two capscrews for cylinders 5, 7 & 8. The results were reported by TER Q-295. Hardness Tests were performed with an Equotip hardness tester. The results of the hardness tests for shafts were reported by TER Q-319 and those for the capscrews were reported by TER Q-297.
5. A visual inspection was performed with findings reported by TER Q-280 and dispositioned by LDR 2246.
6. A dimensional inspection was performed as reported by TER Q-278.

ENGINE 102

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results.
2. Positive verification of cups being ground flush was reported by TER DR-170 for cylinder 5 only. Documentation to support inspection of 7 & 8 was reported by TER Q-44 and dispositioned by LDR 2070.
3. Visual inspections of 5, 7 & 8 rocker arm assemblies were accomplished. The results were reported by TER Q-44 and dispositioned by LDR 2070.
4. Materials were determined by Bausch & Lomb 3600 Mobile Metal Analyzer for cylinder 7. The results were reported by TER DR-197 for the intake and intermediate shafts. Hardness tests were performed on the shafts for cylinder 7 by use of an Equotip hardness tester as reported by TER DR-215.
5. A dimensional inspection was performed as reported by TER DR-170.

ENGINE 103

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed as were done for Engine 101.
2. A visual inspection of the pushrod cups for overhang was satisfactory. The results of the inspection of intermediate for cylinders 5, 7 & 8 were reported by TER Q-131.
3. A visual inspection was performed for evidence of damaged parts. The results are reported by TER Q-147 and dispositioned on LDR 2194.
4. Materials were determined by Bausch & Lomb 3600 Mobile Metal Analyzer. The results of the tests performed the on shafts were reported by TER Q-200. The test results for the capscrews were reported by TER Q-199. An Equotip hardness test was performed on the shafts and the capscrews for cylinders 5, 7 & 8. The results were reported by TER Q-175.
5. A visual inspection was performed with findings reported by TER Q-147 and dispositioned by LDR 2194.
6. A dimensional inspection was performed as reported by TER Q-133.

SPARES

1. Material analysis was performed on rocker arm shaft as reported by TER Q-505.

RESULTS AND CONCLUSIONS

ENGINE 101

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

ENGINE 102

Same as Engine 101

ENGINE 103

Same as Engine 101

SPARES

Same as Engine 101

GROUP CHAIRPERSON ______________________ PROGRAM MANAGER ______________________

COMPONENT REVALIDATION CHECKLIST

COMPONENT Rocker Arm & Pushrods Exhaust Rocker Shaft Assembly DOCUMENT NO. QR-03-390B

PART NO. 03-390B INCORPORATES DOC. NOS. QR-1

TASK DESCRIPTIONS

ENGINE 101

1. Assemble and review existing documentation.
2. Review the pushrod cup installation documentation and perform a visual inspection to verify the overhang is properly ground flush (TDI P/N 08-390-01-0F) for cylinders 5, 7, and 8.
3. Visually inspect the rocker arm shaft assembly for any signs of wear, scoring and pitting on cylinders 5, 7, and 8.
4. Measure rocker arm bushing bore on cylinders 5, 7, and 8.
5. Determine the material and hardness of the shaft (TDI P/N 03-390-01-0A) for cylinders 5, 7, and 8.

ENGINE 102

1. Assemble and review existing documentation.
2. Review the pushrod cup installation documentation and perform a visual inspection to ensure the overhang is properly ground flush (TDI P/N 08-390-01-0F) for cylinders 5, 6, 7, and 8.
3. Visually inspect the rocker arm shaft assembly for any signs of wear, scoring and pitting on cylinders 5, 6, 7, and 8.
4. Measure rocker arm bushing bore on cylinders 5, 6, 7, and 8.
5. Determine the material and hardness of the shaft (TDI P/N 03-390-01-0A) for cylinder 7.

ENGINE 103

Same as Engine 101

ATTRIBUTES TO BE VERIFIED

ENGINE 101

1. Quality status of Component Document Package
2. Pushrod cup overhang properly ground flush
3. Absence of wear, scoring and pitting on the rocker arm shaft
4. Proper rocker arm bushing bore dimension
5. Proper material and hardness of the shaft (TDI P/N 03-390-01-0A)

ENGINE 102

Same as Engine 101

ENGINE 103

Same as Engine 101

## ACCEPTANCE CRITERIA

### ENGINE 101

1. Satisfactory Document Package
2-5. Review of Inspection Report by Design Group

### ENGINE 102

Same as Engine 101

### ENGINE 103

Same as Engine 101

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## REFERENCES

### ENGINE 101

1. QCI-FSI-F11.1-020
2. TERs Q-91, Q-444, Letter from W. Lenny McHugh (TDI) to Neil Rudikoff (LILCO) dated 4/15/83 (LDR 1252)
3. TERs Q-91, DR-88, DR-481
4. TERs Q-91, DR-88, DR-481
5. TERs Q-91, Q-143, Q-16, DR-88

### ENGINE 102

1. QCI-FSI-F11.1-020
2. TERs Q-444, Q-481, Letter from W. Lenny McHugh (TDI) to Neil Rudikoff (LILCO) dated 4/15/83 (LDR 1252)
3. TER DR-88
4. TERs DR-88, Q-481
5. TERs DR-88, Q-16, Q-143, Q-481

### ENGINE 103

Same as Engine 101

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## DOCUMENTATION REQUIRED

### ENGINE 101

1. Document Summary Sheet
2-5. Inspection Report

### ENGINE 102

Same as Engine 101

DOCUMENTATION REQUIRED (continued)

ENGINE 103

Same as Engine 101

GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature]

COMPONENT REVIEW

ENGINE 101

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results.
2. A review of pushrod cup installation documentation showed the overhang to be ground flush satisfactorily.
3. The rocker arm shaft assembly was visually inspected. The results were reported by TER Q-281 and dispositioned by LDR 2247.
4. The rocker arm bushing bore was measured. The results were reported by TER Q-279.
5. Materials were determined by use of a Bausch & Lomb 3600 Mobile Metal Analyzer. Results for cylinders 5, 7 and 8 reported by TER Q-296. Equotip hardness tests were performed on the shaft for cylinders 5, 7, and 8 and reported by TER Q-319. The report was documented by TER Q-297.

ENGINE 102

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results.
2. The pushrod cup overhang was inspected. The results were documented by TER DR-198.
3. A visual inspection of rocker arm shaft assembly was performed. The results were reported by TER DR-176.
4. The rocker arm bushing bores were measured. The results were reported by TER DR-198.
5. The material of the shaft was determined by use of the Technicorp Model 850/950 wt Alloy Seperator. This was reported by TER Q-79 (cylinder 7). An Equotip hardness test was performed. The results were reported by TER Q-79 (cylinder 7).

ENGINE 103

1. All preassembly EDGCTS Shoreham experience documents were assembled and reviewed with satisfactory results.
2. A visual inspection was performed on cylinders 5, 7 and 8 to ensure that the overhang is properly ground flush. Cylinders 7 and 8 were found satisfactory as reported by TER Q-132. Cylinder 5 was found unsatisfactory. This was reported by TER Q-132 and dispositioned by LDR 2184.
3. A visual inspection of the rocker arm shaft assembly was accomplished. Unsatisfactory results for cylinder areas 5, 7 and 8 were reported by TER Q-148 and dispositioned by LDR 2195.
4. Rocker arm bushing bore dimensions were taken and reported by TER Q-151.
5. Materials were determined by use of a Baush and Lomb 3600 Mobile Metal Analyzer on the shafts for cylinders 5, 7 and 8. The results of this test are reported by TER Q-201. Equotip hardness tests were performed on the shafts for cylinders 5, 7 and 8 and reported by TER Q-175.

## .ESULTS AND CONCLUSIONS

### ENGINE 101

The Quality Revalidation effort with respect to this component, as outlined above, is complete. The results have been forwarded to the Design Review Group for their evaluation and conclusions in support of the final report.

### ENGINE 102

Same as Engine 101

### ENGINE 103

Same as Engine 101

GROUP CHAIRPERSON [signature] PROGRAM MANAGER [signature] J C Kammeyer

# EDG COMPONENT TRACKING: SHOREHAM SITE, NUCLEAR AND NON-NUCLEAR INDUSTRY EXPERIENCE SUMMARY

COMPONENT NO. 03-390-A and 03-390-B

Effective Printout Date 4/20/84

COMPONENT TYPE: Rocker Arms and Pushrods
Intake/Intermediate Rocker Shaft Assembly

| EXPERIENCE | REFERENCE DOCUMENTS | SHOREHAM STATUS |
|---|---|---|
| SHOREHAM | | |
| Replace pushrod sockets on Engines 101 and 102. Repair pushrod cups on cylinder no. 7 on Engine 103. | LDR 1235<br>1245<br>RRR 885<br>887 | Damage to pushrod sockets frequently occurs during installation. All pushrod sockets at Shoreham have been inspected and found satisfactory. |
| Adjust engine lifter rocker arms, clean oil passages for Engine 103. | RRR 374 | Lifter oil hole blocked with dirt. These have been cleaned out. Routine maintenance. |
| Replace cracked engine rocker arm pushrod socket on Engine 103. | RRR 637<br>LDR 0991<br>1851 | Damage to pushrod sockets frequently occurs during installation. All pushrod sockets at Shoreham have been inspected and found satisfactory. |
| Replace damaged subcover and rocker arm assembly for cylinder no. 3 on Engine 101. | RRR 1329<br>LDR 1954<br>1955<br>1956 | Capscrews were not torqued properly, resulting in damage to rocker shaft assemblies. Capscrews have been inspected to verify proper installation. |

COMPONENT NO. 03-390-A and 03-390-B

Effective Printout Date 4/20/84

COMPONENT TYPE: Rocker Arms and Pushrods Intake/Intermediate Rocker Shaft Assembly

| EXPERIENCE | REFERENCE DOCUMENTS | SHOREHAM STATUS |
|---|---|---|
| SHOREHAM | | |
| Machine lip of rocker arm socket on Engine 102. | RRR 1530 | Damage to pushrod sockets frequently occurs during installation. All pushrod sockets at Shoreham have been inspected and found satisfactory. |
| Repair/replace discrepancies on rocker arm assembly on Engine 102. | RRR 1517<br>LDR 2070 | Repair work completed and satisfactory. |
| NUCLEAR | | |
| Intake rocker arm broke due to binding between it and rocker stand. Binding was due to inadequate end clearance. | LER 295-81036<br>295-810106 | Different manufacturer (Cooper Bessemer). There is no history of clearance problems with TDI engines. |
| NON-NUCLEAR | | |
| Action taken since vessel delivery - plug welded rocker arm assembly drilled oil passages to reduce oil flooding of rocker boxes. (M/V "Columbia") | Hunton & Williams 12/29/83 to C. Seaman Letter to TDI (D. Martini) dated 03/22/80 from M. Zbinden (State of Alaska) | Rocker arm plug size increased from 1/8" to 1/4" for a more secure fit. |