SAFETY EVALUATION REPORT
TRANSAMERICA DELAVAL DIESEL GENERATORS
PERRY NUCLEAR POWER PLANT

I. INTRODUCTION

Concerns regarding the reliability of large bore, medium speed diesel engines manufactured by Transamerica Delaval, Inc. (TDI), for application at domestic nuclear plants, including Perry, were first prompted by a crankshaft failure that occurred at the Shoreham Nuclear Power Plant (Shoreham) in August 1983. However, a broad pattern of deficiencies in critical engine components became evident at Shoreham and other nuclear and non-nuclear facilities employing the TDI engines. These deficiencies were found to stem from inadequacies in design, manufacture and the quality assurance/quality control at TDI. As a result, the staff introduced, in Section 9.6.3.1 of SSER No. 4, the need to verify the reliability of the TDI diesel engines at Perry as an outstanding unresolved issue. Two TDI diesel generators are installed in each Perry unit for use in providing emergency electrical power in the event of the loss of offsite power. As such, the proven reliability of the TDI engines is essential from a safety-related standpoint.

In a letter dated December 10, 1984 (B. J. Youngblood (NRC) to M. R. Edelman (CEI)), the applicant was advised of the TDI diesel generator design verifications required by the staff to determine the acceptability of the engine design at Perry. By letter dated January 17, 1985 (M. R. Edelman to B. J. Youngblood), the applicant submitted the Perry TDI Diesel Generator Program Plan (the Program Plan) which describes the approach being followed at Perry to resolve this outstanding issue. The Perry Program Plan consists of an extensive plant-specific application of the TDI Diesel Generator Owners Group (TDI Owners Group) program, a

group participated in by CEI for Perry. The Perry Program Plan parallels that of the TDI Owners Group program involving the following phases of effort: (1) Resolution of known generic problems; (2) design review of important attributes for selected engine components; (3) expanded engine testing and inspection; and (4) a maintenance and surveillance program. Copies of the TDI Owners Group Phase 2 design review/quality revalidation (DR/QR) reports for Perry were included as an attachment to the Perry Program Plan. The staff, with the assistance of its consultant, Pacific Northwest Laboratory (PNL), reviewed the information provided with the applicant's January 17, 1985 letter, and from other nuclear plant owners of TDI diesel engines, and found that although some actions remained to be performed on the Perry diesels prior to licensing, significant progress has been made by the TDI Owners Group and by the applicant in verifying the reliability of their TDI diesel engine designs. The staff concluded that actions already taken by the applicant and those proposed to be performed prior to licensing are adequate to ensure that the TDI diesel generators at Perry Unit 1 can reliably generate on-site emergency power. The staff, however, required in SSER No. 6 that the applicant complete certain actions prior to licensing and that the maximum load be limited to 5740 KW until concerns about the crankshaft are resolved. In a letter dated June 28, 1985 (M. R. Edelman to B. J. Youngblood), the applicant provided information to address these outstanding concerns. The results of the staff's review of this information is presented below.

II. EVALUATION

Upon completion of the Atomic Safety and Licensing Board (ASLB) hearing held on the reliability of the Perry engines, the ASLB concluded that the Perry diesel engines have met regulatory standards and that emergency power will be available when needed and that the engines comply with GDC 1 and 17. The Board also concluded that the applicant must complete the items described in the staff's SER.

Given below are the actions described in SSER No. 6 which the staff concluded need to be completed prior to licensing, the applicant's response to each item, and the staff's evaluation of that response.

1. Staff Concern

Submit the maintenance and surveillance program that CEI intends to use on the Perry engines for staff approval. The staff will review this program to the same extent it has those on other engines (e.g., Comanche Peak, Grand Gulf, and Catawba).

Applicant Response

PNPP will utilize the maintenance and surveillance program developed by the TDI Owners Group. This program is included as Appendix II to the Design Review and Quality Revalidation (DR/QR report) which was submitted to the staff on January 17, 1985 (PY-CEI/NRR-0156 L) and revised March 18, 1985 (PY-CEI/NRR-0203 L).

Staff Evaluation

The staff, with assistance from PNL, has performed an audit review of the Shoreham and Comanche Peak DR/QR reports and has concluded that the reports were complete and had adequately addressed the design and/or quality aspects of the components. Additionally, the maintenance and surveillance requirements given in Appendix II of the DR/QR were reviewed for the audited components and it was concluded that they were adequate. Some recommendations were made; however, these recommendations were not of sufficient concern to be the subject of an NRC requirement. Thus, it was concluded that the plant specific DR/QR efforts, including the maintenance and surveillance plans, have been effective and comprehensive and, as a result, no further detailed reviews of DR/QR reports need to be performed.

Consequently, the staff concludes that the maintenance and surveillance requirements presented in Appendix II of the Perry DR/QR are acceptable. The staff is currently finalizing the maintenance and surveillance requirements for the Phase 1 components and will document these results in a forthcoming SER on the adequacy of the generic Phase 1 components. Until this SER is published, the maintenance and surveillance requirements presented by the staff at a meeting with the NRC Advisory Committee on Reactor Safeguards (ACRS) as March 20, 1985 (Enclosure 1) should be used; no major changes to these requirements are anticipated.

The applicant will be required to follow any additional maintenance requirements for Phase 1 components when these are finalized.

The applicant has not proposed any operational or standby surveillance requirements. As a minimum, the applicant will be required to perform the operational and standby surveillances given in Tables 1 and 2 (attached).

It is reasonable to expect that certain changes to the M/S program may become appropriate in the future based on operating experience. The staff will require that any changes to the M/S program be subject to the provisions of 10 CFR 50.59. In addition, the NRC staff/PNL conclusions relating to the adequacy of the crankshafts, engine blocks, and cylinder heads are particularly dependent on certain periodic inspections and/or surveillance checks. Thus, inspections of these components will be subject to the license conditions given in the conclusions.

2&3 Staff Concern

- Perform a torsiograph test that includes both variable speed tests and variable load tests and a subsequent stress analysis that confirms that stresses in the crankshaft are acceptable.

- Address the effects of engine imbalance on crankshaft adequacy as part of the torsiograph test report to be submitted to the staff.

Applicant Response

- A torsiograph testing program which included variable speed and variable load tests was performed on each Unit 1 engine. The test report, submitted to the staff on June 14, 1985, concludes that the crankshafts are adequate for their intended use at Perry.

- A special engine imbalance torsiograph test was conducted on each Unit 1 engine. The test results are addressed in the addendum to the torsiograph test report submitted on June 14, 1985.

Staff Evaluation

The staff, with assistance from PNL, has completed its review of the Phase 1, V-16 crankshaft review as it applies to the Perry engine. This Phase 1 report, currently in draft form, concludes that the V-16 crankshaft at Perry is adequate for its intended full-rated load of 7000 KW and its rated overload of 7700 KW for the 2 hours out of every 24 as specified by the manufacturer. These conclusions are based on analyses performed by the Owners Group and PNL, the results of torsiograph test including a torsiograph test with cylinder imbalance, and satisfactory performance of the crankshaft during operational tests supported by the absence of any fatigue crack initiation in the crankshaft during post-test inspection. The staff, however, will require that:

a) To avoid the effects of the 4th order resonance, operating and emergency procedures should be revised so that steady operation at speeds more than a few rpm below the rated speed of 450 rpm are avoided.

b) Operating and emergency procedures should be modified to incorporate precautions to prevent sustained engine operation with a cylinder imbalance or misfiring. These precautions should include monitoring exhaust gas temperatures to assure that the differences between individual cylinder temperatures and the average temperature for all cylinders remain in the range recommended by TDI and measuring cylinder firing pressures according to intervals recommended by TDI.

c) The oil holes and fillets of the three main bearing journals subject to the highest torsional stresses (Nos. 4, 5, 8) should be examined with fluorescent liquid penetrant and, as necessary, eddy current techniques during each 5-year disassembly. The same inspections on oil holes and fillets should be performed on at least three crankpin journals between 3 and 8.

d) Hot and cold crankshaft deflections should be measured at each refueling outage to assure that the crankshaft alignment remains within TDI recommendations. (This item will be included as a generic NRC position in the forthcoming generic SER addressing resolution of the Phase 1 issues.)

Although the staff concluded that the V-16 crankshaft at Perry is adequate for its rated overload capacity of 7700 KW for 2 hours out of 24 hours allowed by the manufacturer, the staff finds the applicant's request to perform month by surveillance testing at loads less than 7000 KW to be acceptable. Modifications to Technical Specifications regarding surveillance testing which the staff considers acceptable as a result of this review are provided as

an enclosure to this SER. This conclusion regarding surveillance testing at loads less than 7000 KW is documented in PNL report entitled "A Review and Evaluation of TDI, Inc., Diesel Engine Reliability and Operability - Final Report" which is in preparation.

The enclosed Technical Specifications include limited surveillance testing at 7000 KW to be performed at 18-month intervals. Such tests need not be performed as part of preoperational testing since test loads during preoperational testing were conservative relative to the maximum emergency service loads the engines are required to handle.

4. Staff Concern

Confirm that Owners Group recommendations have been followed regarding:

(a) random sample testing of pushrods
(b) proper torquing of the jacket water pump shafts

Applicant Response

(a) Destructive random sample testing to verify the weld quality of future friction welded pushrods is recommended by the TDI Owners Group. This will be done. The pushrods that are presently installed have been subjected to the inspections required by the DR/QR including:

- Verification that the main and connector pushrods are friction welded.

- Performance of a liquid penetrant test on all friction welded main and connector pushrods, or, as an alternative, visual inspection. No surface cracks were found along the bond line between the rod end and the tube.

(b) The Owners Group recommends torquing the castle nut on the engine drive jacket water pump shaft to a value between 120 and 660 ft-lbs. The Division 2 pump was disassembled and reassembled onsite with the castle nut torqued to 120 ft-lbs. A rebuilt jacket water pump assembled at the factory was installed on the Division 1 engine. Castle nut torque was not verified during the Division 1 engine revalidation effort. It will be verified during the post operation (approx 100 hrs.) inspection.

Staff Evaluation

The staff concludes that the actions taken by the applicant and those proposed to be performed on the pushrods and the jacket water pump adequately address the staff concerns regarding the ability of these components to perform their intended functions.

4. Staff Concern

Demonstrate the adequacy of control panel assembly/panel system.

Applicant Response

The control panel assembly/panel system for PNPP has been found to be acceptable per the requirements of the DR/QR. Inspection results were submitted to the staff by letter PY-CEI/NRR-0188L dated February 8, 1985. Inspections were performed in accordance with the Component Quality Revalidation Checklist prepared for Perry by the Owners Group. Original issue of the PNPP DR/QR contained the Component Design Review Checklist for the Vogtle Plant. This was in error. Subsequent revision to the DR/QR on March 18, 1985 (PY-CEI/NRP-0203L) corrected this error.

Staff Evaluation

The corrected DR/QR report for the control panel assembly/panel system concludes that this component is acceptable. The staff and PNL have performed an audit review of the DR/QR report for Shoreham and Comanche Peak and concluded that the reports were complete and had adequately addressed the design and/or quality aspects of the components. As a result, no further detailed reviews of DR/QR reports need to be performed.

Thus, this component was not specifically reviewed for Perry. Rather, the review of this component was accomplished through the overall audit review approach used on the Comanche Peak DR/QR.

5. Staff Concern

Demonstrate the adequacy of the bearing stresses on the chock plates.

Applicant Response

Minimum load surfaces for the chock plates used on the PNPP engines have been calculated, and in all cases, the actual field measurements of the bearing surfaces exceed the calculated minimum requirements. Additionally, hot and cold crankshaft deflection measurements have also been taken. These measurements show that deflection is well within the acceptable limits established by the manufacturer. This indicates that the engine is properly supported.

Staff Evaluation

The response by the applicant and successful operation of the engines for approximately 200 hours on each engine with no visible signs of support deficiencies are adequate to address the staff concern.

6. Staff Concern

Replace the 4R cylinder head with one that does not contain a through-wall weld repair where the repair was performed from one side only, or demonstrate that the present cylinder head does not contain such a repair.

Applicant Response

Cylinder head 4R (serial #A76) does not conta n a through-wall weld repair performed from one side only. Details were provided to the staff by letter dated February 21, 1985 (PY-CEI/NRR-0198 L). Transcripts from the ASLB hearing on the PNPP diesel generators (Issue 16), also address this issue (pages 2428 and 2429).

All PNPP TDI engine cylinder heads were returned to Transamerica Delaval, Inc. (TDI) to be reconditioned in accordance with the latest recommendations established by the TDI Owners Group. This included reworking the valve seats, water discharge ports, steam vent hole, and injector hole. Additionally, each head was stress relieved and pickled. Upon completion of the rework, cylinder head 4R (serial #A76) was inspected by a CEI representative and rejected because of combustion face (fire deck wall) pitting and weld indications. These indications were excavated (not through-wall), and built up with weld material per accepted procedures. The CEI representative reinspected the head and found it acceptable.

Staff Evaluation

As a result of reviewing the inspection results, PNL found that the 4R cylinder head on the Division 2 engine contains a weld repair in the firedeck area. The staff has not accepted through-wall weld

repairs in the firedeck area of the cylinder heads where the repair was performed from one side only. The applicant's response demonstrates, to the staff's satisfaction, that no cylinder heads currently in use contain weld repair where the repair was performed from one side only. As part of the maintenance and surveillance program recommended by the Owners Group for Perry, the staff has strongly relied upon the Owners Group recommended procedure of barring over of the engines with the stopcocks open prior to planned starts and after engine shutdowns. The staff believes that this procedure, performed 4-8 hours after engine shutdown and again after 24 hours, and before any planned starts, is an effective way to detect cylinder head defects which would allow water to enter the cylinder.

III. CONCLUSION

This SSER precedes final completion of the NRC/PNL review of the generic resolution of all Phase 1 components by the Owners Group and of the final SER on Perry. The NRC staff and PNL conclude that the generic Phase 1 reviews and Comanche Peak DR/QR review upon which the Perry DR/QR review is based have progressed sufficiently such that all significant issues warranting priority attention as a basis for issuance of an operating license have been adequately resolved. Consequently, the NRC staff concludes that the diesel generators will provide a reliable standby source of onsite power in accordance with General Design Criteria 17. This conclusion is subject to the following:

A. License Conditions

1. As a result of a major crankshaft failure that occurred at Shoreham (DSR-8) and lesser cracking that was evidenced around the crankshaft oil holes at San Onofre (DSRV-20) and because of the criticality of the crankshaft to successful engine operation, the crankshaft should be inspected as follows:

The oil holes and fillets of the three main bearing journals subject to the highest torsional stresses (Nos. 4, 6, 8) should be examined with fluorescent liquid penetrant and, as necessary, eddy current, during each 5-year major disassembly. The same inspections on oil holes and fillets should be performed on at least three crankpin journals between journals 3 and 8.

2. Cylinder blocks should be inspected at intervals calculated using the cumulative damage index (CDI) model and using inspection methodologies described by Failure Analysis Associates, Inc., (FaAA) in report entitled "Design Review of TDI R-4 Series Emergency Diesel Generator Cylinder Blocks" (FaAA-84-9-11) dated December 1984. Liquid penetrant inspection of the cylinder liner landing area should be performed any time liners are removed.

3. The engines should be rolled over with the airstart system and the cylinder stopcocks open prior to any planned starts, unless that start occurs within 4 hours of a shutdown. The engines should also be rolled over with the airstart system and the cylinder stopcocks open after 4 hours, but no more than 8 hours after engine shutdown and then rolled over once again approximately 24 hours after each shutdown. In the event an engine is removed from service for any reason other than the rolling over procedure prior to expiration of the 8-hour or 24-hour periods noted above, that engine need not be rolled over while it is out of service. The licensee should air-roll the engine over with the stop-cocks open at the time it is returned to service. The origin of any water detected in the cylinders must be determined and any cylinder head which leaks due to a crack shall be replaced. No cylinder heads that contain a through-wall weld repair where the repair was performed from one side only shall be used on the engines.

4. Except as noted below, the staff is not imposing additional reporting requirements pertaining to the TDI diesels at Perry beyond that already required in the regulations (Parts 21, 50.72, and 50.73) and by the plant Technical Specifications. The exceptions involve any cracks which may be found in the crankshafts or in the engine blocks between stud holes of adjacent cylinders. Either of these unexpected situations would constitute a potentially serious concern regarding the future operability of the engine. In these cases, the staff will require by license condition that any proposed resolution to either of these conditions be approved by the NRC staff prior to returning the the engine to an "operable" status.

5. Operation beyond the first refueling outage shall require staff approval based on the staff's final review of the Owners Group generic findings and of the overall implementation status of Owners Group recommendations at Perry. These conclusions will be documented in a final SER on Perry.

6. Any changes to the maintenance and surveillance requirements identified in Section B below not governed by these license conditions should be subject to the provisions of 10 CFR 50.59.

B. Maintenance and Surveillance Requirements

The applicant should utilize the maintenance and surveillance requirements given in Appendix II of the Perry DR/QR as committed to. Maintenance and surveillance requirements for Phase 1 components should encompass the requirements presented to the NRC Advisory Committee on Reactor Safeguards (ACRS) by the staff on March 20, 1985 (Enclosure 1) The staff will finalize these requirements in an SER on the generic Phase 1 components and although no major changes are expected, any modifications to these requirements will have to be adhered to by the applicant. The applicant will also be required to perform the operational and stand-by surveillances given in Tables 1 and 2 (enclosed).

C. Other

1. Operating and emergency procedures should be revised to address engine operation below 450 rpm and cylinder imbalance/misfiring as described in Section II.

2. Technical Specifications regarding surveillance testing should be revised using the enclosure as a guide.

TABLE 1 Diesel Engine Operating Surveillance Parameters and Frequency

Component	Frequency
Lube Oil Inlet Pressure to Engine	Log every 60 minutes
Turbocharger Oil Pressure	
Pump	
Fuel Oil Filter/Strainer ΔP	
Lube Oil Filter/Strainer ΔP	
Jacket Water Pressure	
Crankcase Vacuum	
Engine Speed	
Stack Temperature (RB, LB)	
Lube Oil Temperature	
Jacket Water Temperature (In, Out)	
Lube Oil Sump Level	
Room Temperature	
Engine Cylinder Temperature (all)	
Kilowatt Load	
Exhaust Temperature Inlet to Turbo (RB, LB)	
Fuel Oil Transfer Pump Strainer ΔP	Log every 60 minutes unless pump is auto/duplexed and alarmed
Starting Air Pressure (RB, LB)	Check hourly
Fuel Oil Day Tank Level	Check hourly
Manifold Air Pressure (RB, LB)	Log every 60 minutes
Manifold Air Temperature (RB, LB)	Log every 60 minutes
Visual Inspection for Leaks, etc.	Check hourly

TABLE 2 Diesel Engine Standby Surveillance Parameters and Frequency

Component	Frequency
Starting Air Pressure	Log every 24 hours
Lube Oil Temperature (In, Out)	↓
Jacket Water Temperature (In, Out)	↓
Lube Oil Sump Level	↓
Fuel Oil Day Tank Level	↓
Room Temperature	↓
Test Annunciators	Log every 24 hours
Check Alarm Clear	Check daily
Check Operation of Comp. Air Traps	↓
Governor Oil Level	↓
Inspect for Leaks	↓
Air Butterfly Valve and Cylinder	Check monthly
Operation of Fuel Rack	Check daily; lube monthly
Check Internals of Block and Base for Leaks	At each refueling outage
Keepwarm Oil Filter ΔP	Weekly
Test Jacket Water for pH, Conductivity, Corrosion Inhibitor	After adding makeup water, or monthly
Cylinder Compression/Peak Pressure	At each refueling outage
Air Start Distributor Filter	Monthly
Air Start Admission Valve Strainer	Every 3 months
Lube Oil	Analyze monthly

Enclosure 1

NRR STAFF PRESENTATION TO THE ACRS

SUBJECT: STATUS OF NRC TASK FORCE EVALUATION OF TDI DIESEL GENERATOR RELIABILITY

DATE: MARCH 20, 1985

PRESENTER: CARL H. BERLINGER

PRESENTER'S TITLE/BRANCH/DIV: BRANCH CHIEF
TDI PROJECT GROUP
DIVISION OF LICENSING

PRESENTER'S NRC TEL. NO.: 492-9794

SUBCOMMITTEE: ELECTRICAL SYSTEMS SUBCOMMITTEE

Summary of Conclusions and Recommendations on Resolution of Known Problems in TDI Diesel Generator Components (Phase I of Owners' Group Program)

Pacific Northwest Laboratory

Participants in Reviews

Consultants

- S.H. Bush
- A.J. Henriksen
- B.J. Kirkwood
- P.J. Louzecky
- Ricardo Consulting Engineers plc, West Sussex, England
- A. Sarsten

PNL Technical Coordinators

- F.R. Zaloudek, Task Leader
- J.M. Alzheimer
- J.F. Nesbitt

Information Considered by PNL in Reviews of Resolution of Known Problems

- Owners' Group reports on known problems
- Operating experience in nuclear and non-nuclear applications
- Plant-specific reviews
  - Grand Gulf (July)
  - Catawba (August)
  - Comanche Peak (September)
  - San Onofre (November)
  - Shoreham (December)

Air Start Valve Capscrew

Type Failures:

1) Loosened capscrew at Shoreham and Grand Gulf due to bottoming-out during torquing

2) No failures have occurred

Air Start Valve Capscrew

Conclusions:

Capscrew design is adequate, provided that
- sampling procedure is established to ensure capscrews are of specified length
- installation is made according to SWEC recommendations

M/S Recommendations:

Capscrews should be torqued to Owners' Group recommendations and retorqued following first period of engine operation whenever an air-start valve is removed/replaced

Auxiliary Module Wiring and Terminations

Concern:

Suitability of all class IE auxiliary module wiring and terminations

- Flame retardancy
- Qualification to industry standards
- Routing in conduit
- Compatibility with circuit requirements

Conclusions:

PNL concurs with OG that wiring and terminations are adequate with indicated modifications

- Shoreham
  - Replace crankcase ventilating fan wiring
  - Inspect sliding link terminal block
- Catawba
  - Replace wiring of questionable integrity
  - Inspect sliding link terminal blocks
- San Onofre
  - Replace wiring of questionable integrity

Connecting Rods (DSR-48 Engines)

Type Failures:

1) None reported in nuclear service

2) One failure in non-nuclear service after 8000 hours at 1975 psi peak firing pressure

Connecting Rods (DSR-48 Engines)

Conclusions:

PNL concurs with OG that

- Rods adequate for intended service
- Indications in rod eye bushing within ± 15° of bottom center are not acceptable
- Rod eye cracks more than 0.04 inch deep are not acceptable
- No detectable cracks allowed at root of rod bolt threads

Recommendation:

Connecting rod bolts should be torqued to OG/TDI recommendations at each major engine disassembly (approx. every 5 years)

Connecting Rods (DSRV-4 Engines)

Type Failures:

1) None in nuclear service

2) Fatigue cracking of connecting rod bolts, link rod box, and fretting of serrations (non-nuclear service)

Connecting Rods (DSRV-4 Engines)

Conclusions:

1) Analytical evidence alone does not provide a sufficient basis for concluding that connecting rods are adequate
2) Service history provides confidence that, with suitable M/S, continued use is justified

Recommendations:

1) Implement OG recommendations
   - Inspect and measure every 5 years
   - Measure clearance between link pin and link rod every 5 years
   - Visually inspect rack teeth; verify minimum specified contact surface
   - Inspect 1 7/8-inch bolts and bolt holes each 270 hours above 50% load
2) Bolt torque (both 1 1/2 and 1 7/8-inch bolt sizes) should be checked every 270 hours of operation above 50% load or every 5 years

Connecting Rod Bearing Shells

Type Failures:

1) Cracked bearing shells at Shoreham after only 600-800 hours of operation

2) No other reported failures in nuclear service

Connecting Rod Bearing Shells

Conclusion:

Bearing shells are suitable for continued use with enhanced M/S

M/S Recommendations of Owners' Group:

- **Inspect and measure every 5 years**
- **Bump test at each refueling cycle**
- **X-ray new bearing shells per OG criteria**

Crankshaft
(R-48, Shoreham)

Type Failures:

1) Fracture of Shoreham EDG 102
   11-inch crankshaft

2) Cracks in EDG 101 and 103

Crankshaft
(R-48, Shoreham)

Conclusions regarding replacement 12-inch crankshafts:

1) Test to 10^7 stress cycles proves adequacy of Shoreham crankshafts for "qualified" load (3300 kW)

2) Portion of test at higher loads provides basis for concluding loads to 3430 kW are acceptable for limited period in emergency

3) Momentary (<1 minute) loads to 3900 kW in emergency would not compromise operability

M/S Recommendation:

1) NDT fillets and oil holes of crankpin journals 5, 6, and 7 and main journals between them in EDG 101 and 102 engines at first refueling outage

2) NDT of fillets and oil holes of two most heavily

Crankshaft
(DSRV-16-4, Grand Gulf)

Type Failures:

None reported in nuclear service

Crankshaft
(DSRV-16-4, Grand Gulf)

Conclusions:

1) Comply with DEMA recommendations for torsional stresses at rated speed

2) System has 4th order critical at 432 rpm (within ± 5% DEMA range)
   - Engine should not be operated below 440 rpm
   - Cylinder load balance is important
   - Misfiring especially undesirable

M/S Recommendations:

1) Measure hot and cold deflections at 270 hours or each refueling (OG)

2) Inspect journals 4, 6, 8 (OG)

3) Determine adequacy of TDI cylinder balance/governer speed variations by torsiograph (OG)

4) Following major maintenance, balance cylinders carefully per TDI procedures (PNL)

5) Monitor for misfiring via exhaust temperatures (PNL)

Crankshaft
(DSRV-20-4, San Onofre)

Type Failures:

Linear crack discovered in both crankshafts

- Torsional vibration during rapid startup likely cause
- Cracks removed by remachining oil holes

Crankshaft
(DSRV-20-4, San Onofre)

Conclusions:

1) At rated load and speed, torsional stresses within DEMA limits

2) Engines conservatively rated
   - Vibratory stresses low at 450 rpm

3) Crankshafts are adequate for their intended function, provided that:
   - requirement for rapid start testing is removed
   - M/S is implemented to detect future cracking

M/S Recommendations:

1) Hot and cold deflection checks at 270 hours or each refueling (OG)

2) Inspection of oil hole regions of journals 9, 10 and 11 at refuelings (OG)

3) Following major maintenance, balance cylinders carefully per TDI procedures (PNL)

4) Monitor for misfiring via exhaust temperatures (PNL)

Cylinder Block

Type Failures:

1) Camshaft gallery cracks (8-cylinder engine)

2) Circumferential cracks in cylinder liner counterbore

3) Cracks in ligament between liner counterbore and stud

4) Stud-to-stud cracks

Cylinder Block

Conclusions:

1) Camshaft gallery cracks
   - Hot tears
   - Not expected to propagate

2) Circumferential cracks
   - Caused by liner proudness
   - Not detrimental to engine performance

3) Ligament cracks
   - Not detrimental to engine performance
   - Increase probability of stud-to-stud cracks

4) Stud-to-stud cracks
   - Potential threat to engine integrity
   - Must be evaluated on case-by-case basis

Recommendations:

1) Camshaft cracks should be monitored

2) Circumferential cracks need not be monitored

3) Where ligament cracks exist, check for stud-to-stud cracks after each operation at >50% load

4) Blocks with known stud-to-stud cracks should be analyzed for suitability for further service

Cylinder Heads

Type Failures:

Crack originating at stellite valve seal allowing entrance of water into cylinder

Failures have involved principally ''Group I'' heads (of the three groups in service)

Cylinder Heads

Conclusions:

Heads from all three groups are suitable for intended service, provided that:

- firedeck has no plug welds
- engine is rolled over 4 to 8 hours after shutdown, again at 24 hours, to detect water leaks. Engine is rolled again before planned starts

Recommendations:

- Liquid penetrant inspection of firedeck
- Record cold compression and maximum firing pressures at each refueling
- Roll over engine per PNL recommendations after shutdowns
- Visually inspect fuel injection ports during surveillance tests
- Return leaking heads to vendor for repair

2) Inspections prior to nuclear service

- Ultrasonic inspection of firedeck to verify thickness is at least 0.400 inch
- Surface inspection of firedeck and valve seats to verify absence of unacceptable defects. Any heads with plug welds in firedeck should be rejected

Cylinder Head Studs (Straight and Necked Designs)

Type Failure:

1) None in nuclear service

2) Isolated failures in non-nuclear service from insufficient preload

Cylinder Head Studs
(Straight and Necked Designs)

Conclusion:

PNL concurs with OG that both designs are suitable for intended service

M/S Recommendation:

Torque per Owners' Group/TDI recommendations whenever a head is removed/replaced

Engine Base and Bearing Caps

Type Failures:

1) Cracks in main bearing saddles of DSR-48 engines (at Shoreham) from improper stud removal

2) Cracks in main bearing saddles from insufficient stud preload (marine service)

3) Nut pocket failure due to defective casting (non-nuclear)

Engine Base and Bearing Caps

Conclusions:

PNL concurs with OG that base and caps are adequate, provided that:

- LP examination of saddles is performed at alternate fuel cycles (DSR-48)
- main bearing saddle stud torque is checked at alternate cycles
- OG recommendations on removal of oil from mating surfaces before assembly are implemented

Recommendation:

Additional inspection of cap and base mating surfaces to ensure absence of imperfections preventing tight bolt-up

Jacket Water Pump

Type Failures:

Fatigue failure of pump shaft initiating at keyway (Saudi Arabia and Shoreham)

Jacket Water Pump

Conclusions:

1) Concur with latest Shoreham redesign and proposed River Bend and Rancho Seco redesign

2) Concur with OG that V-12, V-16 and V-20 designs are adequate with addition of torque values and limits to assembly procedures

M/S Recommendations:

None

Types AF and AE Piston Skirts

Type Failure:

Fatigue cracks in skirt-to crown attachment bosses

Types AF and AE Piston Skirts

Conclusions:

1) Type AF skirts suitable
   - Up to 130 BMEP with initial inspection only
   - Over 130 BMEP
     Initial inspection
     100% boss area inspection at each refueling

2) Type AE skirts suitable to normal TDI ratings

M/S Recommendations:

1) Inspection as above
2) Inspection, measurement of pin and skirt per TDI recommendations

Types AN and AH Piston Skirts

Type Failures:

1) **AN - Numerous reports of cracks in nuclear and non-nuclear applications**

2) **AH - No reports**

Type AN and AH Piston Skirts

Conclusions:

1) AN skirts not suitable

2) AH skirts suitable
   - Normal TDI ratings
   - Subject to 10^7 cycle test on lead engine

M/S Recommendation:

Inspect skirt and pin every 5 years per TDI recommendations

Push Rods (Ball-End, Forged-End and Friction-Welded Designs)

Type Failures:

Numerous failures of ball-end design in weld area

Push Rods (Ball-End, Forged-End and Friction-Welded Designs)

Conclusions:

1) Concur with OG that ball-end rods should be removed from service

2) Concur with OG that forged-end design and friction-welded design are acceptable

M/S Recommendations:

1) Inspect after 800 hours with LP; replace rods with detectable cracks

2) Implement OG recommendation for destructive examination of friction-welded design

Rocker Arm Capscrews (Original and Modified Designs)

Type Failures:

Isolated fatigue failures from insufficient preload

Rocker Arm Capscrews
(Original and Modified Designs)

Conclusions:

1) PNL predicts stress may be 3 times higher than SWEC prediction, but margin remains adequate

2) Both designs are adequate
   - based on conservative PNL stress estimate
   - based on service history

M/S Recommendations:

1) Torque per Owners' Group/TDI recommendations whenever capscrews are removed/replaced

Elliott Model 65G/90G Turbochargers

Type Failure:

Thrust bearing failure from inadequate lubrication during startup

Elliott Model 65G/90G Turbochargers

Conclusions:

1) Turbochargers are suitable, provided that FaAA recommendations on drip and full-flow prelube systems are followed
2) Flange and piping alignment and surge margin are possible plant-specific items

Recommendations:

Follow OG recommendations on M/S

- Inspect bearings after 50 fast/100 total starts
- Measure clearances, clean bearings, analyze oil at each refueling
- Inspect bearings, other items each 5 years

Consider operation of manual prelube system for brief period following engine shutdown, to cool down bearings

Inlet Nozzle Ring
Elliott Model 90G Turbocharger

Type Failures:

1) Vanes
   - Missing vanes
   - Fatigue cracks in roots (low operating hours)

2) Broken bolts

3) Cracked washers

4) Cracked hub

Inlet Nozzle Ring
Elliott Model 90G Turbocharger

Conclusions:

1) No evidence that missing vanes had, in fact, been installed

2) Fatigue cracks pose potential threat

   Turbocharger destruction

   Performance degradation

3) Other isolated failures (e.g., bolts and washers) pose a less serious threat to operability

Recommendations:

1) Inspect at every refueling outage

2) Replace missing or cracked components

4.8.1.1.1 Each of the above required independent circuits between the offsite transmission network and the onsite Class 1E distribution system shall be:

a. Determined OPERABLE at least once per 7 days by verifying correct breaker alignments and indicated power availability, and

b. Demonstrated OPERABLE at least once per 18 months during shutdown by transferring unit power supply from the normal circuit to the alternate circuit.

4.8.1.1.2 Each of the above required diesel generators shall be demonstrated OPERABLE:

a. In accordance with the frequency specified in Table 4.8.1.1.2-1 on a STAGGERED TEST BASIS by:

1. Verifying the fuel level in the day tank.

2. Verifying the fuel level in the fuel storage tank.

3. Verifying the fuel transfer pump starts and transfers fuel from the storage system to the day tank.

4. Verifying the diesel starts from ambient conditions and accelerates to at least 441 rpm for Div 1 and Div 2 and 882 rpm for Div 3 in less than or equal to 10 seconds*. The generator voltage and frequency shall be 4160 ± 420 volts and 60 ± 1.2 Hz within 10 seconds* after the start signal.

5. Verifying the diesel generator is synchronized, loaded to ~~within the rated load of 2850 kw~~ between 5600-5800 kw** for diesel generators Div 1 and Div 2 and 2600 kw for diesel generator Div 3 in less than or equal to 60 seconds*, and operates with this load for at least 60 minutes. TDI

6. Verifying the diesel generator is aligned to provide standby power to the associated emergency busses.

*All diesel generator starts for the purpose of this Surveillance Requirement may be preceded by an engine prelube period. The diesel generator start (10 sec)/load (60 sec) from ambient conditions shall be performed at least once per 184 days in these surveillance tests. All other engine starts for the purpose of this surveillance testing may be preceded by other warmup procedures recommended by the manufacturer so that the mechanical stress and wear on the diesel engine is minimized.

** This band is meant as guidance to avoid routine overloading of the engine. Loads in excess of this band shall not invalidate the test; the loads, however, shall not be less than 5600 kw nor greater than 7000 kw

for diesel generator Div 2, and greater than or equal to 2200 kw (HPCS pump) for diesel generator Div 3 while maintaining voltage at 4160 ± 420 volts and frequency at 60 ± 1.2 Hz or nominal speed plus 75% of the difference between nominal speed and the overspeed trip setpoint or 15% above nominal, whichever is less.

3. Verifying the diesel generator capability to reject a load of 5740 kw for diesel generators Div 1 and Div 2 and 2600 kw for diesel generator Div 3 without tripping. The generator voltage shall not exceed 4784 volts for Div 1 and Div 2 and 5000 volts for Div 3 during and following the load rejection.

4. Simulating a loss of offsite power by itself, and:

   a) For divisions 1 and 2:

      1) Verifying de-energization of the emergency busses and load shedding from the emergency busses.

      2) Verifying the diesel generator starts* on the auto-start signal, energizes the emergency busses with permanently connected loads within 10 seconds, energizes the auto-connected loads through the load sequence (individual load timers) and operates for greater than or equal to 5 minutes while its generator is so loaded. After energization, the steady state voltage and frequency of the emergency busses shall be maintained at 4160 ± 420 volts and 60 ± 1.2 Hz during this test.

   b) For division 3:

      1) Verifying de-energization of the emergency bus.

      2) Verifying the diesel generator starts* on the auto-start signal, energizes the emergency bus with the permanently connected loads within 10 seconds and operates for greater than or equal to 5 minutes while its generator is so loaded. After energization, the steady

*All diesel generator starts for the purpose of this Surveillance Requirement may be preceded by an engine prelube period. The diesel generator start (10 sec)/load (60 sec) from ambient conditions shall be performed at least once per 184 days in these surveillance tests. All other engine starts for the purpose of this surveillance testing may be preceded by other warmup procedures recommended by the manufacturer so that the mechanical stress and wear on the diesel engine is minimized.

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SURVEILLANCE REQUIREMENTS (Continued)

voltage and frequency of the emergency bus shall be maintained at 4160 ± 420 volts and 60 ± 1.2 Hz during this test.

7. Verifying that all automatic diesel generator trips are automatically bypassed with an ECCS actuation signal except:

   a) For divisions 1 and 2, engine overspeed and generator differential current.

   b) For division 3, engine overspeed and generator differential current.

8. Verifying the diesel generator operates for at least 24 hours. During this test, the diesel generator shall be loaded to ~~5740~~ kw for diesel generator Div 1 and Div 2. The Div 3 diesel generator shall be loaded to greater than or equal to 2860 kw for the first two hours of this test and 2600 kw for the remaining 22 hours of this test. The generator voltage and frequency shall be 4160 ± 420 volts and 60 ± 1.2 Hz within 10 seconds after the start signal; the steady state generator voltage and frequency shall be maintained within these limits during this test. Within 5 minutes after completing this 24-hour test, perform Surveillance Requirement 4.8.1.1.2.e.4.a.2 and b.2* or perform Surveillance Requirement 4.8.1.1.2.e.6.a.2 and b.2.* TDI

6800-7000 Kw for the first two hours and 5600-5800** Kw for the remaining 22 hours.

7000 Kw

9. Verifying that the auto-connected loads to each diesel generator do not exceed ~~7800~~ kw for diesel generator Div 1 and Div 2 and 2860 kw for diesel generator Div 3. TDI

10. Verifying the diesel generator's capability to:

    a) Synchronize with the offsite power source while the generator is loaded with its emergency loads upon a simulated restoration of offsite power,

    b) Transfer its loads to the offsite power source, and

    c) Be restored to its standby status.

11. Verifying that with the diesel generator operating in a test mode and connected to its bus, a simulated ECCS actuation signal overrides the test mode by (1) returning the diesel generator to

*If Surveillance Requirements 4.8.1.1.2.e.4.a.2 and b.2 or 4.8.1.1.2.e.6.a.2 and b.2 are not satisfactorily completed, it is not necessary to repeat the preceding 24 hour test. Instead, the diesel generator Div 1 or Div 2 may be operated at 5740 kw or diesel generator Div 3 may be operated at 2600 kw for one hour or until operating temperatures have stabilized.

** This band is meant as guidance to avoid routine overloading of the engine. Loads in excess of this band shall not invalidate the test; the loads, however, shall not be less than 5600Kw nor greater than 7000 Kw.