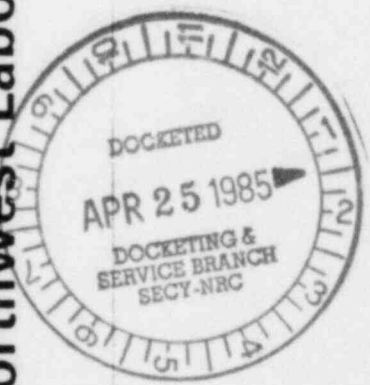


Summary of  
Conclusions and Recommendations  
on  
Resolution of Known Problems  
in  
TDI Diesel Generator Components  
(Phase I of Owners' Group Program)

Pacific Northwest Laboratory

8505070422 850409  
PDR ADOCK 05000440  
G PDR



NUCLEAR REGULATORY COMMISSION  
Docket No. 50-440  
In the matter of PWRP  
Staff ☒ IDENTIFIED ☒  
Applicant ☒ RECEIVED  
Intervenor ☒ REJECTED  
Cont'g Offr  
Contractor  
Other  
DATE 4.9.85  
Witness  
Register G. WALSH

# 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  $\pm 15^\circ$  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  $\pm 5\%$  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/governor speed variations by torsigraph (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 40 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**