

August 20, 1984

MEMORANDUM FOR: Christopher I. Grimes, Acting Chief
Systematic Evaluation Program Branch, DL

FROM: Carl H. Berlinger, TDI Project
Group Leader, DL

SUBJECT: DIESEL GENERATOR INSPECTION REQUIREMENTS -
SAN ONOFRE 1

By letter dated June 29, 1984, Southern California Edison (SCE) submitted a summary of the operating experience, inspection results and analysis results of the Transamerica Delaval Inc. (TDI) V-20 diesel engines at the San Onofre 1 site. That information was reviewed by the TDI Project Group and our consultants, discussed with our consultants on July 12, 1984, in Charlotte, NC and discussed with the licensee on July 27, 1984, at the San Onofre site. Subsequently, the staff issued a letter to SCE dated July 26, 1984, describing actions that must be taken by SCE to insure the reliability of the diesel engines. The enclosure to this memorandum provides the bases for conclusions reached by the staff regarding measures to be taken prior to restart.

Original signed by/

Carl H. Berlinger, TDI Project
Group Leader
Division of Licensing

Enclosure: As stated
cc w/enclosure: E. Marinos

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ENCLOSURE

I. INTRODUCTION

Concerns regarding the reliability of large bore, medium speed diesel generators of the type supplied by TDI at San Onofre Unit 1 and at fifteen (15) other domestic nuclear plants were first prompted by a crankshaft failure at Shoreham in August 1983. However, a broad pattern of deficiencies in critical engine components have since become evident at Shoreham, Grand Gulf Unit 1 and at other nuclear and non-nuclear facilities employing TDI diesel generators. These deficiencies stem from inadequacies in design, manufacture and QA/QC by TDI.

In response to these problems, thirteen U.S. nuclear utility owners, including the licensee, formed a TDI Diesel Generator Owners Group to address operational and regulatory issues relative to diesel generator sets used for standby emergency power. The Owners Group program, which was initiated in October 1983, embodies three major efforts.

1. Resolution of 16 known generic problem areas (Phase I program) intended by the Owners Group to serve as an interim basis for the licensing of plants.
2. Design review of important engine components and quality revalidation of important attributes for selected engine components (Phase II program).
3. Identification of any need additional engine testing of inspections, based on findings stemming from the Phase I and II programs.

Although not in complete compliance with Owners Group recommendations, the licensee has performed inspections of diesel engine components in order to assure the reliability of the diesel engines at San Onofre 1. The inspections were performed in 1981-1982 and again in 1983-1984, after problems developed at Shoreham and Grand Gulf. Results of these inspections along with a summary of operating experience and a basis for concluding adequate engine reliability were submitted to the staff by letter dated June 29, 1984.

II. LOADING REQUIREMENTS

The actual loading requirements at San Onofre 1 are less than either the rated capacity of the diesel generators or the design capability of the TDI DSRV-20-4 diesel engines. The actual loading requirements for the two diesels are 4350Kw and 4443Kw which are below the continuous rated capacity of 6000Kw and overload capacity of 6600Kw. Additional margin exists relative to the design capability of the engine which is 8800Kw. The lower actual loading requirement results in a lower demand on engine components and thus additional safety margins relative to original design.

Specific aspects of the actual loading requirements relative to loadings used in recent analyses of engine components are discussed in the next section.

III. COMPONENT INSPECTION RESULTS AND DISCUSSION

Components of the diesel generators have been inspected in 1981-1982 and 1983-1984 by SCE. The results of the inspections of the 16 generic components are summarized below.

A. Crankshaft

A 30% inspection was performed on both diesel generators using the Owners Group draft criteria resulting in no cracks being found. An analysis of the crankshaft performed by the Owners Group concluded that the crankshafts at San Onofre 1 are adequate for their intended use provided a torsigraph is performed which confirms the natural frequencies and measures the combined response. The cylinder pressures used in the analysis correspond to a load of 8750Kw which is larger than the actual loading requirements at San Onofre 1 discussed in Section II. The staff recommended inspection of the #9 and #10 journals near the oil holes as a precautionary measure because the oil holes represent a stress concentration and the #9 and #10 journals are the most highly stressed. The licensee has informed the staff that a torsigraph of one engine will be performed.

B. Connecting Rod Bearings

In 1981, 100% of the conrod bearings were replaced as a part of the piston modifications. In 1984, a 30% dye penetrant and radiographic inspection was performed on both diesel generators using the Owners Group draft criteria. A linear indication was found on one bearing shell. It was concluded that bearing operability was not affected, however, the bearing shell was still replaced.

C. Pistons

The diesels at San Onofre 1 employ Type AF piston skirts which have been modified and inspected per 10 CFR 21 notices. A 25% inspection was performed in 1984 and no cracks were found even though Type AF piston skirts have developed cracks in other diesel engines. An analysis of both the AE and AF pistons has been performed by the Owners Group and concluded that cracks are predicted to initiate and propagate to a maximum depth of 0.5 inches in the AF skirts. Preliminary conclusions reached by the Owners Group are that the AF pistons are satisfactory for continued service with periodic inspections or for extended service at less than full rated load, provided no relevant indications are found during inspection of the stud boss area. The analysis was performed using a peak firing pressure of 1670 psig obtained from measurements at Shoreham. The Shoreham engine is an in-line 8 cylinder engine whereas the San Onofre 1 engines are V-20 (v shaped/20 cylinders) which results in different peak cylinder firing pressures. At the FSAR rated load of 6000Kw, the peak cylinder firing pressure at San Onofre 1 is

approximately 1150 psig. At a load of 4400Kw, the maximum emergency service load requirements at San Onofre 1, the peak cylinder firing pressure is approximately 1000-1070 psig substantially less than the 1670 psig used in the analysis. Based on the favorable inspection results and the actual loading requirements, the preliminary conclusions of the Owners Group regarding Type AF pistons are being followed at San Onofre 1.

D. Cylinder Heads

A 30% inspection of the heads was performed in 1984 resulting in discovery of shallow seat cracks. The concern relative to cylinder heads is that through wall cracks into the jacket water area may result in water leakage into the cylinder and cause engine failure upon start-up. As part of an augmented maintenance/surveillance program the staff has required an air roll of the engine with cylinder stopcocks open at 4 and 24 hours after each shutdown and prior to planned starts to detect any possible water in-leakage. An example of an augmented maintenance/surveillance program approved by the staff for Grand Gulf 1 is attached to this enclosure.

E. Cylinder Block

A 30% magnetic particle inspection of cylinder head stud areas on DG #2 was performed in 1984 resulting in no cracks found. Preliminary recommendations from the Owners Group pertaining to San Onofre 1 as a result of analyses that have been conducted are:

1. The block tops of engines that have operated at or above rated load should be inspected for ligament cracks (i.e., cracks between the stud holes and the liner counterbore).
2. For blocks with ligament cracks, the absence of detectable cracks between stud holes of adjacent cylinders should be established by eddy current testing. If crack indications are found, removal of adjacent heads and detailed inspection and evaluation of the block top are necessary.
3. Engines that operate at lower maximum pressures and temperatures than the Shoreham engines (e.g., San Onofre 1) may have increased margins against block cracking that could allow relaxation of block top inspection requirements.

As a result of the favorable inspection results, reduced load requirements, and the Owners Group preliminary recommendations, the staff concluded that the engine blocks at San Onofre 1 would be adequate for the next cycle of operation.

F. Engine Base

The licensee did not conduct an inspection of the base since the cracking was limited to only in-line models. Preliminary conclusions reached by the Owners Group for the DSRV 16-4 engines regarding the main bearing saddles, crankcase to base through bolts and nuts, nut pockets, and main bearing caps including the associated studs and nuts are that adequate margins of safety for ultimate and fatigue loading exist in all cases. The Owners Group further concludes that previous problems associated with the engine base are not significant in the DSRV-16 series engines. Since the bearing loads for the DSRV-20-4 engine that exist at San Onofre 1 are lower than those for the DSRV-16-4, the above conclusions also apply to the DSRV-20-4 engine.

G. Cylinder Head Studs

No failures of cylinder head studs have occurred at San Onofre 1. In 1981, all cylinder head studs were re-torqued and in 1984, 30% were re-torqued following engine disassembly and inspection. The Owners Group has analyzed both the old design studs and the new necked down studs and has concluded that both designs are adequate for the intended service, provided that proper stud preload is applied. Re-torquing of the studs, as performed at San Onofre 1, insures that the studs have the correct preload.

H. Push Rods

Three types of push rods were designed and fabricated by TDI - the forged head design, the ball head design and the friction weld design. Some cracking was experienced in the forged head and ball head designs. The Owners Group has performed stress analyses and cycle wear tests to 10⁷ cycles on a sample of the friction welded pushrods resulting in no signs of abnormal wear or deterioration. At San Onofre 1, the ball end design was replaced with the friction welded design on DG 1 and replacement with the friction weld design is scheduled to be done on DG 2 by return to service.

I. Rocker Arm Capscrews

No failures of rocker arm capscrews have occurred at San Onofre 1. In 1984, the licensee checked the torque on 100% of the capscrews on both diesel generators and found no improper torque. The Owners Group has performed stress analyses of both the original capscrew design and a newer design and has concluded that both designs are adequate for the service intended. Failures that have occurred elsewhere have been attributed to under-torquing.

J. Connecting Rods

A 30% inspection was performed at San Onofre 1 in 1984 using the Owners Group draft criteria and no cracks were found. The Owners Group has performed analyses of the connecting rod assembly and has concluded that two possible failure mechanisms exist. The first is a fatigue failure of the link rod bolts resulting from loss of bolt preload. The second is a fatigue cracking of the connecting rod bolts and/or the link rod box in the mating threads. These cracks were attributed to thread fretting which resulted from distortion of the rod bolt under operating loads in the area of the mating threads. The distortion could occur if the bolts had been installed with originally specified lower bolt preloads. Stress analyses performed indicate that both the 1½ inch and 1-7/8 inch connecting rod bolts are adequate for the intended service provided that the conrod bolt preload is checked within time limits specified as related to engine load requirements in terms of percentage of engine nameplate rating. Since both failure mechanisms described above can be traced back to the root cause of inadequate bolt preload, maintaining the correct bolt preload is of obvious importance. As a result, the staff required retorquing of all the connecting rod bolts in accordance with approved procedures before restart and measuring bolt preload ultrasonically if possible.

K. Engine Mounted Electrical Cable

The engine mounted electrical cables were inspected in 1984 by Owners Group engineering personnel with no defects found. The licensee has installed new cable meeting IEEE standards in accordance with the Owners Group recommendation.

L. Fuel Injection Lines

In 1984, a boroscopic examination of the fuel injection lines was performed resulting in no defects found. The Owners Group has analyzed the fuel tubing that has failed elsewhere and has concluded that the failures originated in inner surface flaws initiated during fabrication. The Owners Group preliminary conclusions are that if the inner surface condition of new tubing is found to be within manufacturer specifications through eddy current testing, the tubing is suitable for the intended service.

As a result of the visual inspections performed and favorable results, and the licensees commitment to perform NDE inspection at the direction of the Owners Group prior to return to service, the staff concluded that the fuel injection lines would perform adequately through the next refueling outage.

M. Turbocharger

In 1981, the thrust bearings on the turbocharger were found to be unacceptable due to excessive wear and were replaced. At that time, the lube oil system for the thrust bearing was modified to incorporate a full flow auxiliary lube oil pump which was operated prior to performing engine operability tests. This is in conformance with preliminary recommendations made by the TDI Owners Group. The full flow system has been employed at Grand Gulf resulting in no excessive thrust bearing wear.

N. Jacket Water Pumps

No failures of the jacket water pumps have occurred at San Onofre 1 nor for the V-16 engines. The gear drive has been replaced and aligned in accordance with the manufacturer's recommendations. In 1984, visual inspection was performed on both diesel generators with no defects found except for a minor oil leak on the #1 diesel generator pump. A gasket was replaced and the pump returned to service. The Owners Group has performed analyses of the jacket water pumps at San Onofre 1 as a result of pump shaft failures on a pump of a different design. Preliminary conclusions are that the pumps are adequate for service with additions to the assembly procedure regarding torque limitations on the impeller nut and gear nut. Inspection recommendations were also given. The licensee has informed the staff that the water pump on DG 1 is disassembled and will be reassembled by TDI including the above torque requirements.

O. Air Start Valve Capscrews

The licensee has performed dimensional checks and inspected 100% of the capscrews and has checked the torque on 100% of the capscrews in 1983-1984 and found no improper torque. The Owners Group has made a preliminary recommendation that the 3" capscrews be either shortened by $\frac{1}{2}$ " or replaced with 2-3/4" capscrews and torqued to the proper value. The shortening was recommended to prevent possible bottoming out of the capscrews which could result in false torque readings. As a result of the dimensional checks performed by the licensee, bottoming out of the capscrews will not occur.

P. Liners

The licensee has not removed the liners but has visually inspected 30% of the liners in place in DG 2 and has not observed any unusual wear.

IV. SUMMARY

The licensee has inspected components of the diesel engines on a sampling basis at San Onofre 1 in 1981-1982 and in 1983-1984 after problems at Shoreham and Grand Gulf. Many of the inspections were performed using Owners Group draft criteria with favorable results in the vast majority of cases. Components found to be unacceptable were replaced. In some cases, however, the Owners Group recommendations called for a 100% inspection, whereas a sampling basis was employed at San Onofre 1.

V. CONCLUSIONS

The staff concludes that the following inspections, maintenance and pre-operational testing should be performed prior to restart of San Onofre 1:

- A. Retorque all of the connecting rod bolts in accordance with approved procedures. If possible, measure preload using ultrasonic techniques.
- B. Inspect the #9 and #10 main journals near the oil holes; if this inspection requires that the adjoining connecting rods be removed, then the inspections need not be performed prior to restart.
- C. Conduct the maintenance and surveillance recommended by TDI for the V-20 engine. The maintenance and surveillance should be augmented using the augmented maintenance and surveillance requirements at Grand Gulf as a guide, a summary of which is attached. The maintenance and surveillance requirements should be performed prior to restart and again at the specified intervals.
- D. To the extent not already included in the manufacturer's recommended pre-operational testing and post inspection testing required by the regulations, the following tests should also be performed:
 - 1 Ten modified starts to 40% load (i.e., 40% of nameplate rating). A modified start includes turbocharger prelube and a 3-5 minute loading to the specified load with engine run for a minimum of one hour.
 2. Two fast starts to a load greater than or equal to the maximum emergency service load requirements but not to exceed a load corresponding to 185 psig BMEP.
 3. One 24-hour run at a load greater than or equal to the maximum emergency service load requirements but not to exceed a load corresponding to 185 psig BMEP.

The reasons for performing the above inspections and maintenance have been discussed in Section III above. The above testing requirements are to insure proper engine reassembly.

Upon successful completion of the above requirements, the staff concludes that the diesel engines at San Onofre 1 will operate reliably for the purpose of plant restart through the next cycle of operation based on the low loading requirements specific to San Onofre 1, the generally favorable inspection results obtained thus far, and positive operating experience.

A plant-specific SER regarding the TDI diesels will be issued prior to restart.

AUGMENTED MAINTENANCE - SURVEILLANCE PROGRAM

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

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

Action

Frequency

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| <p>11. Record engine operating parameters:</p> <ul style="list-style-type: none">a. engine inlet lube oil pressureb. turbo L.O. R.F. pressurec. turbo L.O. L.F. pressured. fuel oil pressuree. fuel oil filter differential pressuref. air manifold pressure L.B.g. air manifold pressure R.B.h. lube oil filter differential pressurei. jacket water pressure (inlet and outlet)j. crankcase vacuumk. all cylinder exhaust temperaturesl. stack temperatures at turbine inletm. lube oil temperature (inlet and outlet)n. jacket water temperature (inlet and outlet)o. tachometerp. hourmeterq. engine load | } | <p>During surveillance test, record parameters hourly, unless more frequent recording is recommended by manufacturer.</p> |
| <p>12. Clean and inspect "Y" strainers in starting air system.</p> | | <p>Quarterly</p> |
| <p>13. Flush jacket water system</p> | | <p>Three to four years.</p> |