

## Plant Specific Experience in TDI Diesel Engine Requalification for Nuclear Service

D.A. Dingee, W.W. Laity, J.F. Nesbitt

*Battelle Pacific Northwest Laboratories, P.O. Box 999, Richland, Washington 99352, U.S.A.*

### Abstract

This paper discusses the approach taken to evaluate the readiness of Transamerica Delaval, Inc. (TDI) diesel generators for nuclear service at five power plants: Catawba, Comanche Peak, Grand Gulf, San Onofre, and Shoreham. TDI engines in these and other nuclear power plants have been the subject of a coordinated effort by 13 nuclear utilities to address reliability and quality issues. The utilities formed the TDI Diesel Generator Owners' Group and prepared a comprehensive plan for requalifying the engines as emergency power sources. Prior to full implementation of the plan by the Owners' Group and final review of the findings by the U.S. Nuclear Regulatory Commission, several member plants became candidates for operating licenses. The TDI engines in those plants, including the five listed above, were evaluated on a case-by-case basis, taking into consideration the factors discussed in this paper.

### 1. Introduction

A crankshaft failure and other problems reported in Transamerica Delaval, Inc. (TDI) diesel generators prompted formation of the TDI Diesel Generator Owners' Group by 13 nuclear utilities. The Owners' Group sought to requalify the engines as emergency standby power sources for nuclear systems. In March 1984, the Owners' Group submitted a comprehensive plan for achieving this goal to the U.S. Nuclear Regulatory Commission (NRC). The plan specified an orderly progression of activities for confirming the reliability and operability of TDI engines intended for nuclear service.

NRC authorized the Pacific Northwest Laboratory (PNL), which is operated by the Battelle Memorial Institute for the U.S. Department of Energy, to evaluate actions taken by the Owners' Group to requalify their engines. Tasks associated with this effort included an evaluation of the Owners' Group Program Plan and an evaluation of the actual implementation of the program. In these and related tasks, PNL relied heavily on the experience and judgment of consultants with well-established reputations in diesel engine technology.

Before full implementation of the Owners' Group program and final review by PNL and NRC of program findings, several nuclear power plants equipped with TDI engines became candidates for licenses to meet fuel loading schedules. Another became a candidate for restart following extensive modifications of nuclear systems. It was necessary to evaluate the

engines in these plants on a case-by-case basis, taking into consideration the engine model, predicted loads for emergency operation, results of engine tests and inspections, and applicable engine operating experience in non-nuclear applications. The engines in five plants had been evaluated in this manner at the time this paper was written: Catawba Nuclear Station Unit 1, Comanche Peak Steam Electric Station Unit 1, Grand Gulf Nuclear Station Unit 1, San Onofre Nuclear Generating Station Unit 1, and Shoreham Nuclear Power Station Unit 1.

This paper summarizes the principal factors considered in these evaluations.

## 2. Considerations in Plant-Specific Engine Evaluations

At the time guidelines were recommended by PNL [1] for plant-specific engine evaluations, work was in progress by the Owners' Group to requalify the engines. The Owners' Group had identified 16 engine components with known problems, and those problems were being evaluated and resolved as Phase 1 of the Owners' Group program. Design review and quality revalidation of engine components other than the 16 with known problems had also been initiated, as Phase 2 of the Owners' Group program. In addition, certain utilities were performing engine tests and inspections called for by the Owners' Group, and the Owners' Group had developed information on experience with TDI engines in several non-nuclear applications. Information from these ongoing activities provided a partial basis for PNL's recommended guidelines, which were adopted by NRC [2].

PNL viewed known operating experience as a key consideration in evaluating the readiness of TDI engines for nuclear service prior to full implementation of the Owners' Group program. This was particularly important for two of the 16 components with known problems -- piston skirts and crankshafts -- because the condition of these components cannot be monitored without significant engine disassembly.

PNL's consultants concluded that non-nuclear operating experience known at that time provided a reasonable basis for confidence that type AE piston skirts used in TDI engines would operate satisfactorily in nuclear service at engine loads corresponding to a brake mean effective pressure (BMEP) up to 185 psig. (The rated BMEP of TDI R4-series engines installed in nuclear power plants is 225 psig at the maximum continuous engine rating.) The 185-psig limit was also considered by PNL's consultants to be reasonably conservative for TDI engine crankshafts in nuclear service, pending completion of evaluations then underway to determine crankshaft adequacy at higher loads.

PNL recommended "lead" engine tests<sup>(a)</sup> for verifying that key engine components would meet load and service requirements without evidence of abnormal behavior under conditions that could induce high-cycle fatigue. However, it was PNL's opinion that, if the TDI engines in a nuclear power plant were equipped with type AE piston skirts and if engine BMEP would not exceed 185 psig under emergency conditions, a lead-engine test was not necessary as a prerequisite for placing the engines in nuclear service. Rather, the lead-engine test could be performed in parallel with operation of the power plant, using an engine equipped with the same components and operated at comparable loads. PNL recommended that the test

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(a) Engine testing is discussed at this conference in a paper by J. F. Nesbitt et al., titled The Role of Testing in Requalifying Transamerica Delaval, Inc., Engines for Nuclear Service.

and inspection be completed before the first outage for reactor refueling, and that engine adequacy be reevaluated in light of the test results before the power plant was placed back in operation after the refueling.

If the TDI engines in a nuclear power plant were equipped with piston skirts other than type AE or if engine BMEP would exceed 185 psig under emergency conditions, PNL recommended that a lead-engine test and inspection precede placing the engines in nuclear service. However, this recommendation was modified in one of the five plant-specific engine evaluations that had been performed by PNL at the time this paper was written. PNL concluded that a lead-engine test was not necessary for the 20-cylinder TDI engines installed at San Onofre Nuclear Generating Station Unit 1, even though these engines were equipped with type AF rather than type AE piston skirts. This conclusion was based on the low engine BMEP (less than 130 psig) under design-basis accident conditions, inspections by the utility that revealed no cracks in the piston skirts, and the satisfactory long-term service of type AF piston skirts in a TDI 20-cylinder engine operated at similar loads in a non-nuclear installation.

PNL recommended four other factors for consideration in plant-specific engine evaluations in advance of final review and implementation of the Owners' Group program:

- Each engine should be disassembled to the extent necessary for inspection of key components. Any components that fail to meet acceptance criteria recommended by the Owners' Group and/or the engine manufacturer should be replaced. Proposed exceptions should be evaluated on a case-by-case basis. For example, certain flaws might not disqualify an engine block for service if the flaws are not a pathway for oil or water leakage, are not propagating, and would not otherwise affect the structural or operational integrity of the engine.
- Preoperational tests should be conducted to verify proper engine assembly and operation, and should include tests recommended by the manufacturer and by applicable NRC Regulatory Guides. These tests are in addition to the lead-engine tests discussed earlier in this section.
- As part of its overall maintenance and surveillance program to ensure continued satisfactory performance of the engines, each utility should implement the maintenance and surveillance recommendations of the Owners' Group for the 16 components addressed in Phase 1 of the Owners' Group program. Each utility should also implement any relevant recommendations or requirements from NRC reviews of maintenance and surveillance plans prepared by either the utility or the Owners' Group.
- All tasks of the Owners' Group program that need to be implemented on a plant-specific basis should be completed by each utility no later than the first power plant outage for reactor refueling. Further, all relevant findings of the Owners' Group program and all relevant recommendations or requirements from NRC reviews of the program and its implementation should also be addressed by each utility no later than the first reactor refueling.

PNL's plant-specific evaluations of the readiness of TDI engines for nuclear service included onsite reviews of the engines and pertinent power plant records. PNL staff and consultants reviewed engine operating histories at each power plant, audited the condition of key engine components and action taken to implement recommendations of the Owners' Group

concerning those components, audited maintenance and surveillance plans, and audited records of component inspections. As part of this latter audit, PNL representatives reviewed the qualifications of the inspectors, the written procedures used, and the inspections performed. These onsite reviews, together with the guidelines discussed in this paper, served as the basis for PNL's recommendations to NRC on the five plant-specific engine evaluations performed at the time this paper was written.

### 3. Concluding Remarks

The approach summarized in this paper provided a conservative basis for plant-specific evaluations of TDI engines in nuclear power plants before full implementation of the Owners' Group program and final review of program findings by PNL and NRC. At the time this paper was written, this approach had been used in support of licensing schedules for five nuclear power plants: Catawba, Comanche Peak, Grand Gulf, San Onofre, and Shoreham. In each instance the utility had taken extensive action to implement recommendations of the Owners' Group, verify the quality of key engine components, and establish a detailed surveillance and maintenance program. The PNL reviewers concluded for each power plant that action toward revalidating the operability and reliability of the engines had progressed sufficiently to consider the engines ready for nuclear service, subject to implementation of certain recommendations by the end of the first reactor operating cycle. The NRC staff adopted the PNL recommendations in safety evaluation reports on the engines.

### References

- [1] Pacific Northwest Laboratory. June 1984. Review and Evaluation of TDI Diesel Generator Owners' Group Program Plan. PNL-5161, Richland, Washington.
- [2] U.S. Nuclear Regulatory Commission. August 1984. Safety Evaluation Report, Transamerica Delaval, Inc., Diesel Generator Owners' Group Program Plan. Washington, D.C.