UNITED STATES NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555

June 28, 2002

NRC INFORMATION NOTICE 2002-22: DEGRADED BEARING SURFACES IN GM/EMD EMERGENCY DIESEL GENERATORS

Addressees

All holders of operating licenses for pressurized- or boiling-water nuclear power reactors, including those that have ceased operations but have fuel on site.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to inform addressees of the discovery of degraded bearing surfaces on the piston bearings in General Motors/Electromotive Division (GM/EMD) emergency diesel generator (EDG) engines. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

Surry Power Station, Units 1 and 2

On April 23, 2001, with both units at full power, emergency diesel generator 3 (EDG 3) was taken out of service to investigate an increase in the silver concentration in samples of EDG lubricating oil. The piston wristpin bearing inserts in GM/EMD diesel engines have a silver substrate beneath a lead-tin overlay. An increasing concentration of silver in the lube oil is an indicator of excessive wear of the bearing surfaces.

The engine manufacturer has provided detailed instructions on interpreting the results of lube oil sample analysis. Silver concentrations in the range 0 to 1 parts per million (ppm) are considered normal. The range 1 to 2 ppm is considered borderline, and concentrations above 2 ppm indicate a “high correct condition.” The manufacturer specifies several inspections, including feeling the side of piston pins in situ for signs of distress and measuring the piston-to-head clearance for the high-correct condition.

The silver content of the lube oil samples from Surry EDG 3 gradually rose from 0.63 ppm in April 2000 to more than 2 ppm in October, but the licensee did not notice this trend because the action level in the licensee’s sampling procedure was too high. In April 2001, there were indications of abnormal wear on the wrist pin sides. Examination revealed severe damage on the surfaces of seven of the wristpin bearings and piston carrier bearings. The silver had been displaced from the wristpin bearing surfaces to the carrier bearing surfaces, blocking some or all of the lubricating oil channels. The partially blocked oil channels prevented normal oil flow at

the bearing-to-wristpin interface, resulting in higher oil and bearing temperatures and wear and extrusion of the bearing surfaces. There was base-metal-to-base-metal contact, which can lead to catastrophic bearing failure and engine damage. Surveillance testing required by technical specifications failed to detect the damage in the engine.

Based on the as-found condition of EDG 3, the licensee concluded that this engine was inoperable. All 20 power-pack assemblies (cylinder, cylinder head, piston and connecting rod) were replaced and the EDG was returned to service.

The silver concentration in the oil samples from Surry EDG 1 was also higher than historical values but was in the 1-to-1.2 ppm range when the engine was removed from service in July 2001. Inspecting the removed power-pack assemblies, the licensee found that cylinder #8 had a severely damaged piston wristpin bearing and a piston carrier bearing all of whose oil channels were blocked. Seven other cylinders had partially blocked bearing oil channels. All 20 power-pack assemblies were replaced and the EDG was returned to service.

Sequoyah Nuclear Plant

In June 2001, the licensee tested an oil sample from Sequoyah EDG 2B-B and found an increase in silver content to 1.1 ppm, indicating a borderline condition. Two months later, the wristpin and piston carrier bearings of cylinder #11 were found to be severely degraded. The bearing material had been worn away, oil channels were blocked, the wristpin was burned and heavily scored, and parts of the wristpin and carrier were blued from heat. From a record review, the cylinder #11 measured piston-to-head clearance in March 2001 had exceeded the acceptance criteria of 0.068 inches by 0.001 inches and was significantly changed, 0.027 inches, from the previous measurement in 1999. The vendor recommends that the associated power pack be condemned when a change of 0.030 inches is observed.

In September 2001 the licensee investigated a slightly elevated silver content in EDG 1A-A. Performance of in-situ feel checks, visual inspections and piston-to-head clearance measurements were unable to locate the cause of the elevated silver. Visual examination of the disassembled power packs found damage in cylinder #1 similar to that in EDG 2B-B cylinder #11. Technical specification required testing did not disclose the damage in either EDG 1A-A or 2B-B.

Arkansas Nuclear One (ANO)

In January 1986, damage similar to that at Sequoyah and Surry was observed in EDG 1A at ANO. The wristpins and connecting rod bearing inserts of four cylinders were heavily scored and burned. At that time, lube oil analysis was not done on a regular schedule. The lube oil analysis after the discovery of the damage showed a silver content of 9.2 ppm; the action level was 2.0 ppm. Piston-to-cylinder-head clearances in all four cylinders were found to be greater than the 0.03 inches permitted by the manufacturer. The licensee attributed the wristpin bearing failures to insufficient lube oil film but could not identify the mechanism. The licensee determined that frequent visual inspections of the wristpin bearings and frequent measurements of piston-to-cylinder-head clearance should be made. The licensee also began monitoring and trending lube oil samples.

Discussion

As a result of finding damaged bearings in their GM/EMD diesel generator engines, the three licensees performed technical assessments and root cause analyses. The Surry licensee contracted several technical organizations to perform independent assessments for this purpose (see the reference at the end of this notice).

The licensees generally agreed about the failure mechanism and the probable root causes. The damage to the wristpin was consistent with a "lubrication-deprived failure". Wear and extrusion of the softer silver substrate material is the result of insufficient lubrication or use of a lubricant with insufficient film strength to remain on the bearings between engine starts. The problem is possibly aggravated by oil chemistry.

The failure is initiated by repeated engine starts under marginal lubrication conditions. The silver-and-lead bearing material is displaced into the oil channels of the wristpin bearing, limiting or preventing lubricant flow across the full surface of the bearing. When the channels are substantially or completely blocked, the bearing material wears away until the steel wristpin contacts the steel bearing shell and the bearing fails. Initially, the damage occurs only while the engine is starting, i.e., until the lubricating system supplies oil to the bearing. However, after the oil channels are substantially blocked, the bearing is lubrication-deprived and damage can continue and potentially accelerate while the engine is operating.

From the information provided by the Surry licensee (see reference), the change to nonchlorinated oils appears to be the root cause of their bearing failures. Chlorine compounds previously were added specifically to impart extra "extreme pressure" (EP) resistance to the base lube oil. This EP resistance property provides oil adherence to the bearings when the engine is not run for an extended period, thereby preserving some lubrication for the next start. However, these chlorine compound additives were determined to be carcinogenic and posed disposal problems. Therefore, licensees had changed to a non-chlorinated formulation. Feedback obtained by the licensee from additive formulation experts in the oil industry and from bearing manufacturers confirms that the chlorinated additive in the earlier lube oil was a paraffin wax and was there as an extreme-pressure lubricant.

Although the licensee changed to an oil that met the engine vendor's specifications, the nonchlorinated formulation apparently had not been specifically qualified for the standby duty typically required of diesel engines provided for nuclear power plants. Such oils have been used successfully in locomotive and marine applications in which engines operate continuously for long periods, and shutdowns are infrequent and of relatively short duration.

The problems at Surry, Sequoyah and ANO indicate that the recommended limits for silver in the lube oil need to be reexamined. The current 2 ppm limit at which specific actions are required may not be an appropriate limit for the more stringent demands on the lube oil during extended standby duty. The limit is based upon uniform wear from all cylinders and not for the detection of abnormal degradation on single or a few bearings. It may also be prudent to do more frequent oil analyses and more frequent visual inspections of the relevant engine parts at lower or at step changes in, silver concentrations. Furthermore, with elevated silver concentrations, successful completion of surveillance tests feel checks, and piston-to-head clearance measurements may not be sufficient to confirm that the piston wristpin and piston carrier bearing are free of severe damage. Although not observed at these three plants, degraded turbocharger bearings can also result in elevated silver concentrations.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Reference: Letter dated December 12, 2001, from Virginia Electric and Power Company to the NRC, transmitting technical reports on the root cause of the wristpin damage in the Surry Power Station emergency diesel generators (Accession Nos. ML 0136001720 [Part I] and ML 0136002070 [Part II])

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