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 FACIL: 50-387 Susquehanna Steam Electric Station, Unit 1, Pennsylvania 05000387
 AUTH. NAME AUTHOR AFFILIATION
 WEHRY, R.R. Pennsylvania Power & Light Co.
 STANLEY, H.G. Pennsylvania Power & Light Co.
 RECIP. NAME RECIPIENT AFFILIATION

SUBJECT: LER 90-033-01: on 901219, failed piston pin found on right cylinder 7 of emergency diesel generator D. Caused by arched piston bore not detected by mfg. Corrective actions included insp, debris distribution, repair work & cleanup. W/910521 ltr.

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	NRR/DET/EMEB 7E	1 1	NRR/DLPQ/LHFB11	1 1
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May 21, 1991

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SUSQUEHANNA STEAM ELECTRIC STATION
LICENSEE EVENT REPORT 90-033-01
FILE R41-2
PLAS - 485

Docket No. 50-387
License No. NPF-14

Attached is Licensee Event Report 90-033-01. This is an update to LER 90-033-00 (PLAS-468) which described an event voluntarily reported to provide information related to a failed piston pin bushing found on the 'D' Emergency Diesel Generator during a post maintenance inspection.

H.G. Stanley
Superintendent of Plant - Susquehanna

RRW/mjm

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LICENSEE EVENT REPORT (LER)

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST 500 HRS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE RECORDS AND REPORTS MANAGEMENT BRANCH (P-530), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

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TITLE (4)
Diesel Generator 'D' Piston Pin Bushing Failure

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)		
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)	
1	2	1990	90	033	01	0	5	21	1991	SSes - Unit 2	0 5 0 0 0 3 8 8
											0 5 0 0 0 1 1

OPERATING MODE (9) 1	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)									
POWER LEVEL (10) 100	20.402(b)	20.405(c)	60.73(a)(2)(iv)	73.71(b)						
	20.406(a)(1)(i)	60.38(c)(1)	60.73(a)(2)(v)	73.71(c)						
	20.405(a)(1)(ii)	60.38(c)(2)	60.73(a)(2)(vi)	<input checked="" type="checkbox"/> OTHER (Specify in Abstract below and in Text, NRC Form 366A)						
	20.406(a)(1)(iii)	60.73(a)(2)(i)	60.73(a)(2)(viii)(A)	Voluntary						
	20.406(a)(1)(iv)	60.73(a)(2)(ii)	60.73(a)(2)(viii)(B)							
	20.406(a)(1)(v)	60.73(a)(2)(iii)	60.73(a)(2)(ix)							

LICENSEE CONTACT FOR THIS LER (12)		TELEPHONE NUMBER	
NAME Richard R. Wehry - Power Production Engineer		AREA CODE 7 1 7	5 4 2 1 - 3 6 6 4

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
<input type="checkbox"/> YES (If yes, complete EXPECTED SUBMISSION DATE)	<input checked="" type="checkbox"/> NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single space typewritten lines) (16)

On December 19, 1990, with Unit 1 and Unit 2 operating at 100% power, a failed piston pin bushing was found on the No. 7 Right cylinder of the 'D' Emergency Diesel Generator (EDG) while performing a maintenance inspection. This inspection was being performed after approximately 43 hours of engine operating time following major engine work which had been completed in October 1990. The inspection is a manufacturer's recommended practice following any work which disturbs a piston bolt attachment. The root cause investigation for the bushing failure included an Installation Review, Metallurgical Analyses and Manufacturer's Evaluation. It was determined that the cause of the bushing failure was an arched piston bore that was not detected when the piston was refurbished by the manufacturer. The most probable cause of the arched bore condition was determined to be an earlier operational event or events which created abnormal piston stresses and distorted the piston. The bushing failure was determined by the manufacturer and PP&L to be a unique and isolated type of failure and not indicative of any generic concerns. This event is being voluntarily reported for information purposes. There were no safety consequences or compromise to public health and safety. Corrective actions included inspections to determine extent of damage and debris distribution, repair work, debris cleanup and retesting and re-inspection. The manufacturer will include piston pin bushing bore measurement and straightness checks on all future piston refurbishings and new piston manufacturings.

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TEXT (If more space is required, use additional NRC Form 368A's) (17)

DESCRIPTION OF EVENT

On December 19, 1990, with Unit 1 and Unit 2 operating at 100% power, a failed piston pin bushing was found on the No. 7 Right cylinder of the 'D' Emergency Diesel Generator (EDG; EIIS Code: EK) while performing a post maintenance inspection. This inspection was being performed after approximately 43 hours of engine operating time following major engine work which had been completed in October 1990. The inspection is a manufacturer's recommended practice following any work which disturbs a piston bolt attachment.

The inspection consisted of a topside cylinder wall borescope inspection and an underside visual inspection at each cylinder. A torque check of piston pin bolts and crankshaft end articulating rod bolts was also performed. The bronze piston pin bushing for the No. 7 Right piston was found in several pieces. These pieces, ranging from approximately 1/4 inch square to approximately 2 x 3 inches, were found in the crankcase. Bronze shavings were distributed in the crankcase primarily below the No. 7 Right and No. 7 Left cylinders. After piston removal, the pin and bushing were removed. The pin was blackened from overheated lubricating oil. The bushing came out in pieces and showed evidence of rotating within the piston as well as melting and hammering damage. The appearance of the bushing pieces indicated that they had migrated out of the piston pin area and contacted the cylinder walls. The No. 7 Right cylinder liner was not damaged. A replica check of the liner confirmed proper porosity of the chrome and dimensional checks were within specifications. No other failed piston pin bushings were found during the inspection.

CAUSE OF EVENT

The root cause investigation for failure of the piston pin bushing proceeded along three parallel paths:

- 1) Installation Review
- 2) Materials Analysis
- 3) Manufacturer's (Cooper Energy Services) Evaluation

1) Installation Review

The piston assembly in the No. 7 Right position had been installed in the engine in October 1990. A review was performed on the as-found conditions and installation records for any abnormalities that could have lead to the bushing failure. Lubrication passages were all found to be unrestricted within the piston pin and bushing areas. The pin bolts were found to be properly torqued. Examination of rings, piston walls and liner walls showed no signs of lubrication starvation. No signs of excessive piston to liner drag forces were evident. In October 1990 checks had been made for piston pin straightness and diameter and bushing to pin clearance and contact (blue check) had been determined to be satisfactory.

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Straightness checks of the master rod found the rod to be straight by examination of the lubrication bore. However, checks for the rod to be centered in the cylinder found the rod off centerline by 0.030 inch. Review of this condition by the manufacturer, however, concluded that the rod condition could not have caused the bushing failure. The rod condition was within specification and a review of the manufacturing records revealed that the condition existed since original time of manufacture.

2) Materials Analysis

A metallurgical review of the failed bushing found no material abnormalities. Although severely damaged and overheated, the bushing appeared to have normal composition. There were no observable structural defects. Examinations for surface contaminations found nothing other than elements associated with lubricating oil decomposition from the heat generated by the failure.

3) Manufacturer's Evaluation

The No. 7 Right piston was a Susquehanna piston originally supplied in the 'B' EDG which had been refurbished by the manufacturer (Cooper Energy Services) after removal during a July 1990 engine overhaul. The manufacturer's evaluation concluded that either some problem existed in the fit-up of the bushing to the refurbished piston or a restriction to lubricating oil flow to the piston pin/bushing assembly occurred. Either cause could have resulted in the bushing moving within the piston, resulting in rapid failure. The manufacturer's piston refurbishment proceeds as follows:

1. Clean old piston to remove all dirt, carbon, etc.,
2. Magnaflux inspect to detect any cracking.
3. Perform a 100% dimensional inspection.
4. Remove old pin bushing and visually inspect piston pin bore.
5. Install new pin bushing and precision bore to size. Check for proper pin clearance and blue (contact area) pattern.
6. Strip tin plating from outer diameter and re-tin to specification.
7. Thoroughly clean and check cleanliness with a fibrescope.
8. Final inspect for shipment.

The manufacturer reviewed the refurbishment process for the No. 7 Right piston. They observed that the dimensional check did not include the inside diameter of the piston pin bore or bore straightness without the bushing. The manufacturer's rationale for not making this dimension check was that it was checked when originally manufactured and no mechanism to change this dimension during engine operation normally exists. A field measurement of the actual bore in the No. 7 Right piston at several locations after the event found diameters ranging from 5.7491 to 5.7498 inches. The bore was found arched up to 0.005 inch at the center of the piston. The diameters were all within the

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specified 5.749 to 5.750 limits, however, the variances may have lead to movement of the bushing within the piston bore.

The root cause investigation was continued to thoroughly review potential failure mechanisms. Primary concerns were as follows:

- o Confirm cause of bushing failure to be the arched bore in the piston.
- o Determine the cause of the arched bore condition.
- o Evaluate the potential for other problem pistons.
- o Determine any other actions to prevent recurrence.

To aid in the root cause investigation two refurbished pistons were selected from Susquehanna's spare inventory and shipped to Cooper (the manufacturer). Cooper removed the pin bushings and checked the bores. One of the piston bores was straight. The other had an arched condition. Based on this finding, all 16 remaining spare refurbished pistons at Susquehanna were sent to Cooper for examination. One other refurbished piston was found with an arched condition.

An in depth review was performed to determine the cause of the arched bores in the three pistons. The manufacturing process, process records and the operating histories were reviewed. Additionally, the design of the piston pin and the bushing were reviewed. The reviews determined the probable cause of the arched bore conditions was an operational event or events that caused abnormal piston stresses.

The piston manufacturing process was examined to determine if the production of a new piston could result in an arched bore. Factors with the potential to influence the shape of the bore are material, heat treatment, and machining. Material problems were ruled out because no evidence of porosity, cracking or any other defect was found in any of the three pistons with arched bores.

The process of machining the piston bore was evaluated to assess if an arched condition could possibly occur. While machining if there would be any tendency of the boring tool to deflect it would be toward the open section in the piston center. This would result in an arched condition away from the piston crown opposite to the findings on the three pistons. No other means of machining an arched bore was viewed as possible. Cooper has never noted any tendency for an arched condition to occur. Consequently, it was concluded the arched bores in the three pistons had not resulted from the boring process.

If a piston were improperly heat treated after casting an arched bore could develop over a period of time as engine operating cycles relieved residual internal stresses. Review of the piston heat treatment found the process acceptable.

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Review of manufacturing records found no anomalies that could have led to the arched bores. Review of the operating histories of other pistons manufactured during the same time frame did not lead to any positive conclusions.

An independent review of the piston pin and bushing design was performed by Ricardo Engineering. Ricardo determined the design to be conservative and adequate as applied. Additionally, the many successful hours of operation in all engines of this type demonstrates design adequacy. Ricardo also evaluated the strength of the piston crown area and concluded normal operating stresses would not distort the piston pin bore. PP&L and Cooper agreed that piston design was not the root cause of the bushing failure.

In parallel with the reviews of the design and the manufacturing process the piston maintenance and operating histories were thoroughly examined. Two of the three pistons had been removed from the "C" Diesel Generator in March 1990. These pistons were originally installed in Diesel Generator "C" when it was shipped to Susquehanna. When the "C" Diesel Generator was being overhauled in March 1990 the cylinder positions where these pistons were installed were found to have bent articulated rods and bent piston pins. The cause of the severely distressed components was determined to have been a water lock event on June 24, 1982 that had burst the 3L cylinder at that time. From the review of the "C" Diesel Generator operating history, it was concluded the probable cause of the arched bores in these two pistons was the water lock event in June 1982.

A review of the third piston's (which had been removed earlier from the 'B' EDG) maintenance and operating histories did not find a specific recorded event that could be directly pinpointed as the cause of the arched bore. The engine's history of corrective maintenance and operating events were reviewed. Also, data from past engine analyses was examined and it was found that the piston was one of three which had a history of high firing pressures. However, an assessment by PP&L Nuclear Design and Ricardo Engineering determined that, by itself, a history of high firing pressures would not be expected to cause the arched bore.

In order to verify no other failure mechanisms were possible the failed "D" EDG piston and the most severely distorted piston from the "C" EDG were examined for evidence of internal stress, porosity, structural flaws, cracks and any other observable anomalies. A significant amount of internal stress was measured, but no other abnormalities were found.

The additional reviews have not changed the determination that the bushing failure occurred as a result of an arched bore in the piston. The findings from examination of the sequence of events to failure, the failed components, the installation records and the refurbishment process are consistent with the conclusion. Investigation into the cause of the arched bore determined the distortion occurred prior to piston refurbishment and not as a result of the bushing failure.

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The likely cause of the arched bore in each of the three pistons was an operating event or events which occurred that caused stress severe enough to distort the piston pin bores. This conclusion is supported by several findings during the review as follows:

- o No anomaly was found during the reviews of design, manufacturing process, manufacturing records and material composition.
- o The high level of internal stress measured in the dissected pistons, in Cooper's judgement, is more than expected from residual stress after manufacturing.
- o Cooper believes residual stresses from manufacturing would be further reduced by operating cycles.
- o A severe operating event on the "C" EDG occurred which has been determined to be the likely cause of the arched bores in the two refurbished pistons which originally had been installed on the "C" EDG.

The absence of a recorded event which could have severely stressed the refurbished piston from the "B" EDG leads to two possible conclusions. Either an unrecorded event or events must have occurred during the engine's operating history or an undetected piston problem existed when the piston was originally installed at the factory. Review is continuing to determine the potential of an undetected piston manufacturing problem.

REPORTABILITY/ANALYSIS

This is a voluntary report to provide information on the 'D' EDG failed piston pin bushing.

The 'E' EDG, which is a fifth and spare EDG, had been substituted for the 'D' EDG prior to performing the maintenance inspection. As such, four EDG's remained OPERABLE during the time that the 'D' EDG was removed from service, the pin bushing problem identified and repairs made. The 'D' EDG had been run successfully for OPERABILITY surveillance testing in accordance with Technical Specification Table 4.8.1.1.2-1 from October 1990 until its removal for this maintenance inspection. Had the piston pin bushing failure resulted in a failure of the 'D' EDG to perform its design function, if it had been called upon to do so, three EDG's would still have remained OPERABLE as required by the SSES Safety Analysis to perform their design function. Based on evaluations performed both by PP&L and the manufacturer, the bushing failure was determined to be an isolated incident and not indicative of any generic problem. A visual inspection of all refurbished pistons on the 'D' EDG did not disclose any other problems. Recent similar inspections of the 'A', 'B' and

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'C' EDG's did not uncover any other bushing failures. Lube oil analyses for 'A', 'B', 'C' and 'E' were all normal. As such, there were no safety consequences or compromise to public health or safety as a result of this event.

CORRECTIVE ACTIONS

Corrective actions included inspections to determine extent of damage and debris distribution, repair work, debris cleanup and retesting/re-inspection. Several components and locations in the lubricating oil system were inspected for both evidence of bronze bushing debris and damage. The following components were inspected:

- Main lube oil and turbo oil filters
- Lube oil suction piping
- Prelube Pump
- Engine Driven Lube Oil Pump
- Lube Oil Heat Exchanger
- Lube Oil Filter
- Lube Oil Strainer
- Crankcase oil supply header
- 7 Right master rod bearing
- 7 Right articulating rod bearing
- 7 Left and 4 Right piston pin bushings
- Several camshaft bearings
- 7 Right, 7 Left and 4 Right heads and rocker assemblies
- Selected head lube oil drain orifices
- Selected rocker arm areas and crevices
- Turbo lube oil piping
- Turbo lube oil air separator

The inspections confirmed no component damage had occurred from the bronze bushing debris.

Repair work consisted of replacement of the 7 Right piston, piston rings, piston pin, master rod bearing and master rod. After manually cleaning the crankcase and lube oil system, a flush was performed using heated 10W weight lube oil. Special 5 micron screen type filters were used for the flush. New lubricating oil, main lube oil filter elements and turbo lube oil filter elements were installed after the flush.

A 12 hour post maintenance run was performed following the repairs and flushing. An underside inspection of all piston pins and bushings performed after the 12 hour run disclosed no further anomalies. Lube oil analysis of samples taken after the 12 hour run and after a 4 hour Operability run confirmed no problems within the engine.



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The manufacturer's inspection procedure for refurbished pistons did not include a pin bushing bore measurement or straightness check. As a result of this bushing failure, however, these checks will now be an acceptance criteria by the manufacturer prior to refurbishing pistons and on the manufacturing of new pistons. All spare refurbished pistons have had their bushings removed and bores checked to be straight.

The refurbished pistons that are currently installed in other diesels have been proven acceptable by successful operation. The assessment of the failure mechanism concludes that failure is rapid if an arched bore condition exists. Lube oil analysis confirmed the failure occurred in the "D" Diesel Generator in the first 12 hours of operation. All of the installed refurbished pistons have undergone more than 50 hours of successful operating time. All engine lube oil analysis are normal indicating no failures exist. Additionally, all refurbished pistons have been visually inspected from the underside after a minimum of 12 hours operating time.

To aid in earlier detection of engine material degradation or failures, PP&L will now perform a lubricating oil sample and analysis following all EDG runs. A new enhanced main lube oil filter design is also being evaluated to further minimize the chances of foreign debris migrating to critical parts of the engine.

ADDITIONAL INFORMATION

Per discussions with NRC NRR personnel, PP&L agreed to review the findings from a 1985 Transamerica Delaval, Inc. (TDI) Connecting Rod/Rod-Eye Bushing report. The review by PP&L's Nuclear Plant Engineering Section concluded that there were no similarities between the TDI failures and the failure of the 7R piston pin bushing of Susquehanna's 'D' Diesel Generator. The details of this assessment were provided to Mr. J. Rajan of NRC/NRR via telecon on January 24, 1991.

Failed Component Identification: None listed in IEEE Std. 803A-1983.
Manufacturer: Cooper Energy Services

Previous Similar Events: None.