Entergy

Entergy Operations, Inc.
1448 S.R. 333
Russellville, AR 72802
Tel 501 858 5000

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Subject: Arkansas Nuclear One - Unit - 1
Docket No. 50-313
License No. DPR-51
Licensee Event Report 50-313/2000-002-01

Gentlemen:

Enclosed is a supplement to the subject report concerning the Low Pressure Injection/Decay Heat Removal pumps. This supplement provides the results of the root cause investigation and an evaluation of the safety significance of the event. Since the evaluation resulted in a conclusion that there was a reasonable expectation that the pumps were capable of performing their intended safety function and therefore were operable, this report is being submitted as a Voluntary Report.

Very truly yours,

Jimmy D. Vandergrift
Director, Nuclear Safety Assurance

JDV/tfs

enclosure

IE22

cc: Mr. Ellis W. Merschoff
Regional Administrator
U. S. Nuclear Regulatory Commission
Region IV
611 Ryan Plaza Drive, Suite 400
Arlington, TX 76011-8064

NRC Senior Resident Inspector
Arkansas Nuclear One
P.O. Box 310
London, AR 72847

Institute of Nuclear Power Operations
700 Galleria Parkway
Atlanta, GA 30339-5957

NRC FORM 366 (5-92) U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

APPROVED BY OMB NO. 3150-0104
EXPIRES 5/31/95

ESTIMATED BURDEN PER RESPONSE TO COMPLY WITH THIS INFORMATION COLLECTION REQUEST: 50.0 HRS. FORWARD COMMENTS REGARDING BURDEN ESTIMATE TO THE INFORMATION AND RECORDS MANAGEMENT BRANCH (MNBB 7714), U.S. NUCLEAR REGULATORY COMMISSION, WASHINGTON, DC 20555-0001, AND TO THE PAPERWORK REDUCTION PROJECT (3150-0104), OFFICE OF MANAGEMENT AND BUDGET, WASHINGTON, DC 20503.

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
Arkansas Nuclear One - Unit 1	05000313	1 of 7

TITLE (4) Voluntary Report Regarding Original Design Of Low Pressure Injection/Decay Heat Removal Pumps That Inadequately Considered Critical Cooling Water Parameters And Bearing Tolerances

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 NAME	DOCKET NUMBER
02	05	2000	2000	002	01	07	07	2000	FACILITY NAME	DOCKET NUMBER

OPERATING MODE (9)	N	THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR: (Check one or more) (11)							
POWER LEVEL (10)	000		20.402(b)		20.405(c)		50.73(a)(2)(iv)		73.71(b)
			20.405(a)(1)(i)		50.36(c)(1)		50.73(a)(2)(v)		73.71(c)
			20.405(a)(1)(ii)		50.36(c)(2)		50.73(a)(2)(vii)	X	OTHER
			20.405(a)(1)(iii)		50.73(a)(2)(i)		50.73(a)(2)(viii)(A)		Voluntary Report
			20.405(a)(1)(iv)		50.73(a)(2)(ii)		50.73(a)(2)(viii)(B)		
			20.405(a)(1)(v)		50.73(a)(2)(iii)		50.73(a)(2)(x)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
Thomas F. Scott, Nuclear Safety and Licensing Specialist	501-858-4623

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

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX
B	BP	P	B010	Y					

SUPPLEMENTAL REPORT EXPECTED (14)				EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
	YES (If yes, complete EXPECTED SUBMISSION DATE)	X	NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

During a normal plant cooldown, Low Pressure Injection/Decay Heat Removal (LPI/DHR) pump P-34A was started in anticipation of placing the DHR System in service to allow securing the Reactor Coolant Pumps (RCPs) and proceeding to cold shutdown. Approximately one hour later, P-34A was secured and declared inoperable due to high inboard (radial) bearing temperature. P-34B was started and subsequently secured when it too experienced high inboard bearing temperature. Core cooling was maintained using an RCS loop and associated steam generators and RCPs. The root cause of this event was an inadequate original pump design that did not consider the full range of cooling water temperatures that the bearings would encounter and the effect on the critical clearances between the inboard bearing and housing. Contributing factors included changes to bearing housing material and oil viscosity. Corrective actions were completed to restore the pumps to an operable status. Permanent modifications were completed and testing was conducted to verify operability prior to restart from the outage. Subsequent evaluation concluded that, with the existing condition, there was a reasonable expectation the pumps were capable of performing their intended safety function and were therefore operable.

A. Plant Status

At the time this condition was discovered, Arkansas Nuclear One Unit 1 (ANO-1) Reactor Coolant System (RCS)[AB] temperature was approximately 280 degrees and pressure was approximately 240 psig. Reactor Coolant Pumps (RCPs) P-32A and P-32B were running. The unit was proceeding to Cold Shutdown for a maintenance outage.

B. Event Description

On February 5, 2000, at approximately 1138, Low Pressure Injection/Decay Heat Removal (LPI/DHR)[BP] pump P-34A was started in anticipation of placing the DHR System in service to allow securing the running RCPs. At 1230, P-34A was secured and declared inoperable due to high inboard (radial) bearing temperature (approximately 160 degrees). LPI/DHR pump P-34B was started at 1250. It was secured at 1306 and declared inoperable due to high inboard bearing temperature.

The LPI/DHR system is designed to remove decay heat from the core and sensible heat from the RCS during the last stages of cooldown. It also provides a means of automatically injecting borated water into the reactor vessel for cooling the core in the event of a Loss of Coolant Accident. The LPI system operates independent of, and in addition to, the High Pressure Injection (HPI)[BG] System. Normal suction for LPI is from the Borated Water Storage Tank (BWST) with an alternate suction from the Reactor Building sump. This gives the system the ability to provide long-term core cooling after the BWST has been depleted.

ANO Technical Specification (TS) 3.3.1(D) requires that two LPI pumps be operable whenever containment integrity is established as required by TS 3.6.1. TS 3.6.1 requires the Reactor Building to be operable whenever all three of the following conditions exist: a) RCS pressure is 300 psig or greater, b) RCS temperature is 200 degrees or greater, and c) Nuclear fuel is in the core. TS 3.1.1.6 requires that, with the average RCS temperature at or below 280 degrees but the reactor above the refueling shutdown condition, at least two of the coolant loops listed below must be operable: 1) RCS loop "A" and its associated steam generator and at least one associated RCP; 2) RCS loop "B" and its associated steam generator and at least one associated RCP; 3) DHR Loop "A;" 4) DHR Loop "B."

At the time this event occurred, RCS pressure was approximately 240 psig; therefore, LPI was not required to be operable. Additionally, since both RCS loops and their associated steam generators and at least one RCP in each loop were operable, the provisions of TS 3.1.1.6 were met even though both LPI/DHR pumps were declared inoperable.

After being declared inoperable, both LPI/DHR pumps were aligned to the BWST and run with acceptable bearing temperatures. Subsequent troubleshooting efforts identified that an oil viscosity change that was implemented during the previous refueling outage may have contributed to the high bearing temperature problems. The oil in both LPI/DHR pumps was changed back to the lower viscosity oil and testing was conducted to verify operability. P-34A ran with acceptable operating temperatures with suction taken from the RCS; however, P-34B again exhibited high bearing temperature when its suction was taken from the RCS. By 0119 on February 7, P-34A was declared operable for DHR operation.

At 0052 on February 8, P-34A was aligned for decay heat operation and RCS cooldown to Cold Shutdown was commenced. At 0232, the running RCPs were secured. At 0435 on February 8, the unit reached cold shutdown (RCS temperature less than 200 degrees). The RCS loops were maintained operable while repair efforts continued on P-34B.

C. Root Cause

The LPI/DHR pumps are Model KSMK 10x12x21 single stage centrifugal pumps manufactured by B&W Canada LTD (Manufacturer Code B010). The outboard bearing consists of two thrust bearings mounted face to face. The inboard bearing is a single radial bearing. The bearings are oil lubricated and cooled with oil within the bearing housing. Bearing temperatures are monitored by contact resistance temperature detectors (RTDs) on the outer stationary race on both inboard and outboard bearings. Channels within the bearing housings are cooled by Service Water (SW) [BI], which is a raw water cooling system taking suction from Lake Dardanelle or the Emergency Cooling Pond (ECP) [BS]. Service Water temperature can vary from approximately 32 to 121 degrees F. Process fluid can vary from approximately 65 to 280 degrees F. Each end of the pump has a mechanical seal. Service Water is also provided to the seal housings for cooling. Introduction of high temperature process fluids causes an axial growth of both the shaft and casing. Because of the difference in mass, there is a different axial growth rate between the shaft and casing. The shaft axial position is held fixed with the casing at the thrust bearings. Therefore, the pump inboard radial bearing accommodates axial movement of the shaft relative to the casing. The clearances at the inboard bearing must be adequate to allow axial movement between the outer bearing race and bearing housing without excessive axial load being applied to the bearing. The clearance must also be maintained such that the outer race does not spin in the housing. The temperature of the bearing housing and bearing affects the clearance between the inboard bearing outer race and the bearing housing. Bearing temperatures range from standby ambient temperatures to the alarm limit of 160 degrees F. Bearing housing temperatures may be less than bearing temperatures and may approach Service Water temperatures at normal Service Water flows. As the bearing heats, the outer race will expand. With cold cooling water, the bearing housing may cool or may heat up at a slower rate than the bearing. This combination will result in a reduction of the clearance between the housing and the bearing.

The cause evaluation for this condition determined that the original pump design allowed ranges of bearing size and bearing housing bore diameter that, when combined with variations in cooling water temperature, could result in inadequate clearances between the bearing and bearing housing. A combination of these variables could cause the bearing to become bound as it slid in the housing as the shaft expanded resulting in the bearing overheating. The original pump vendor designed the pump such that the extreme of allowed tolerances could result in zero clearance. Also, the original 1971 design specification for the cooling water to the pumps was a maximum of 85 degrees F with no minimum value specified. The SW temperature when the pumps were placed in service in February 2000 was approximately 42 degrees F.

The LPI/DHR pumps originally had cast iron bearing housings. These housings experienced flow reductions due to corrosion. In 1992, a modification was developed to change bearing housing material to stainless steel. During development of this change, it was not recognized that the difference in thermal conductivity of the materials would result in reduction in clearances between the bearing outer race and housing for certain SW temperatures.

In 1987, the oil in both LPI/DH pumps was changed to a lower viscosity to more closely match the specifications contained in the vendor technical manual. In September 1999, the oil was changed back to the higher viscosity that had been used previously. Routine oil analysis had shown wear particles indicating a long-term degradation of the thrust bearings. After discussions with the bearing manufacturer and consideration of recommended lubricants in the pump technical manual, a decision was made to use the higher viscosity oil. This change resulted in higher bearing operating temperatures.

The root cause of this condition is considered inadequate original pump design. The pump and its bearings were not designed to operate over the full range of SW temperatures that can exist at ANO. Information developed during the evaluation indicated that the inadequate original design might have been due to an inadequate understanding by the original pump vendor of design considerations for sliding radial bearings.

Inadequate reviews of the material change of the bearing housings and the oil viscosity increase are considered contributing factors. During either of these changes, there was an opportunity to discover the problems in the original design with bearing clearances not being acceptable over the full operating range of cooling water temperatures.

D. Corrective Actions

After P-34A was restored to an operable status for DHR operation by replacing its oil with a lower viscosity on February 7, 2000, P-34B was disassembled. As-found measurements of P-34B inboard bearing and bearing housing were within original design tolerances but within a range of bearing fits predicted to yield unacceptable clearances for existing operating conditions. The pump was assembled with increased clearances between the bearing and bearing housing. The oil was changed to the lower viscosity. A temporary alteration was

provided to regulate SW flow to the inboard bearing housing for temperature control. Procedure changes and Operator training related to the temporary alteration were completed. After extensive post-modification testing was completed, P-34B was declared operable for DHR operation.

After restoration of P-34B, the SW temporary alteration was installed for P-34A. Calculations were performed to demonstrate that acceptable bearing clearances would be maintained for both pumps under conditions established by the temporary alteration. After satisfactory completion of post-modification testing, P-34A was restored to an operable status for DHR operation. At this point, the plant cooldown for the scheduled outage was completed.

During the outage, a modification package was developed and installed on both pumps. This activity identified and verified proper critical dimensions, returned the inboard bearing housings to the original cast iron material, replaced the inboard bearings with those having larger internal clearances, increased the inside diameter of the inboard bearing housings to the upper half of the tolerance band, and installed provisions for measuring local oil temperature on the inboard bearing housing. An evaluation of lubrication requirements determined that the lower viscosity oil is adequate for the full range of expected operating conditions. Post-modification testing demonstrated operability of both pumps at the high and low ends of the range of potential SW temperatures and provided assurance that the pumps will function as required in any operational mode.

A review of other ANO equipment was performed to determine if any other components cooled by SW could be adversely affected by low SW temperature or could be susceptible to design-related problems with bearings. This review included verification that the proper lubricant is being used in critical safety-related rotating equipment, performance monitoring data does not indicate problems with high bearing temperatures, and no modifications have been performed that could impact operation over the range of temperatures during normal or accident conditions. This review identified concerns involving the ANO-1 Reactor Building Spray (RBS) [BE] pumps and Emergency Feedwater (EFW) [BA] pumps as well as the ANO-2 High Pressure Safety Injection (HPSI) [BQ] pumps. ANO performed initial evaluations prior to startup to verify that there were no current operability concerns for these components. Special tests were also performed on the RBS pumps over the full range of SW temperatures. A further detailed qualifying evaluation of bearing performance over the full range of SW temperatures for the ANO-1 EFW pumps and ANO-2 HPSI pumps is being performed by the pump vendor and is expected to be complete by July 31, 2000.

An operating experience report was issued to the industry on bearing and bearing temperature concerns.

Other long-term corrective actions are being addressed by the ANO corrective action program.

E. Safety Significance

ANO convened an Expert Panel to determine the probability of the LPI/DH pump running through a failure of the inboard radial bearing. Organizations involved in this assessment included ANO Design Engineering, ANO Nuclear Safety Analysis, ANO Operations, the University of Virginia, MPR Associates, and the pump coupling manufacturer. A mechanical analysis of pump components was performed using different loading cases. Empirical evidence from a 1996 failure of an LPI/DH pump inboard bearing was considered. During the 1996 event, bearing temperatures and pump vibrations were normal after the bearing failure, the pump was started and stopped ten times over a two week period and accumulated greater than nine days of run time before the bearing was replaced. Based upon analytical checks and empirical data, adequate clearances and tolerances would be maintained between the pump shaft and mechanical seals in static and dynamic conditions if the bearing failed. The clearance between the rotating shaft and stationary housing was determined to be adequate to prevent interference due to shaft deflection following bearing failure. The panel determined that the shaft can accommodate loading and vibration without the radial bearing, that the motor bearing is capable of operating with the extra load, and that no significant pump degradation would occur. The conclusion of the panel was that the probability of the pump operating without the inboard radial bearing was 97 percent. Although not critical to the fault tree outcome, a hydrodynamic (Lomakin) effect would be expected to provide additional shaft support at the wear rings and add analytical margin while the pump is running.

The risk significance of the LPI/DHR pump inboard bearing being susceptible to binding in the bearing housing was evaluated using the ANO-1 Updated Probabilistic Safety Assessment (PSA) Model. This evaluation did not credit the use of Reactor Building Spray Pumps [BE] or other mitigating actions that are not contained in operating or emergency procedures. The results of this evaluation were that the total Core Damage Frequency (CDF) due to pump failure probability is 9.7E-6 and the total delta CDF is 7.7E-7. The effect of this condition is to increase the Large Early Release Frequency (LERF) by 5.7E-8 per reactor year to a total of 6.8E-7 per reactor year. Since both the CDF and LERF fall within Region III of Regulatory Guide 1.174, the condition was not risk significant.

Safety analyses indicate that only one train of LPI/DH is necessary for core heat removal. If high bearing temperatures were detected during an accident, the Emergency Operating Procedure would not allow less than one LPI/DH pump in operation. This expectation is reinforced in operator training.

ANO has concluded that there was a reasonable expectation that the LPI/DH pumps were capable of performing their intended safety function in the event of an accident. The pumps were degraded but operable. This condition is judged to have minimal actual safety significance.

The conclusion regarding operability does not indicate that degradation of the pumps is not considered to be a serious matter. Even with the reasonable expectation of the pumps being able to perform their required safety function, it is recognized that the pumps were neither intentionally designed nor tested to ensure their functionality under the degraded conditions. The operability conclusion was based on a reasonable commitment of time and resources to address past operability. A much more rigorous effort would be required to establish full qualification.

F. Basis for Reportability

This condition was reported to the NRC Operations Center at 1730 EST on February 5, 2000, in accordance with 10CFR50.72(b)(2)(i).

The original evaluation determined that inadequate design considerations resulted in both LPI/DHR pumps being potentially incapable of performing their design function of providing cooling to the core post-LOCA following depletion of the BWST. This resulted in the condition being reported pursuant to 10CFR50.73(a)(2)(v), 10CFR50.73(a)(2)(vii), and 10CFR50.73(a)(2)(ii)(B). With one or both trains of LPI potentially inoperable longer than allowed by Technical Specifications, this condition was also considered reportable in accordance with 10CFR50.73(a)(2)(i)(B). Based on the subsequent evaluation concluding that the condition did not result in the LPI/DH pumps being inoperable, there are no applicable reporting requirements. This report is being submitted as a Voluntary Report in recognition of the potential serious nature of this condition.

G. Additional Information

There have been no previous similar events reported by ANO as Licensee Event Reports. A review of operating history for the DHR/LPI pumps determined that the inboard bearing of P-34B failed in September 1996. The root cause was determined to be inadequate manufacturer fabrication when the bearing housing was found to be undersized and oblong. While oil viscosity or SW temperature were not factors, information developed during the evaluation of the February 2000 event indicates that the 1996 bearing failure could constitute a previous similar event because of the inadequate specification of the original design allowable clearances.

Energy Industry Identification System (EIIS) codes are identified in the text as [XX].