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Subject: Arkansas Nuclear One - Units 1 and 2
Docket Nos. 50-313 and 50-368
License Nos. DPR-51 and NPF-6
Follow-up to May 8, 2000 Unit 1 Low Pressure Injection /Decay Heat Removal Pump Pre-decisional Enforcement Conference

Gentlemen:

A pre-decisional enforcement conference was held on May 8, 2000, to discuss apparent violations identified in NRC Special Inspection Report 50-313/00-04; 50-368/00-04. As discussed during the conference, Arkansas Nuclear One (ANO) committed to provide follow-up discussions on Low Pressure Injection (LPI)/ Decay Heat Removal (DHR) pump shaft deflection during radial bearing failure and how the mechanical seals could be affected by the deflection, additional details concerning the 1996 failure of the "B" LPI/DHR pump inboard radial bearing, and the sensitivity of using the expert panel results in the risk significance determination. ANO also committed to provide additional discussion concerning the Lomakin effect. This information is provided in Attachment 1.

A review of the attached information supports the conclusion ANO presented at the pre-decisional enforcement conference. Given conditions that would restrict axial movement of the inboard radial bearing, the bearing may fail, but its failure will not prevent the LPI/DHR pumps from performing their safety function. Therefore, as concluded in the pre-decisional enforcement conference, the LPI/DHR pumps were operable during periods of low service water temperature. This conclusion is based upon detailed analytical evaluations, professional opinions of experts in the field of rotating equipment and failure analysis, and empirical evidence from the 1996 bearing failure event. If you have any questions or comments, please contact me.

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Very truly yours,

Craig G. Anderson
Vice-President, ANO

CGA/SLP
Attachment

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Attachment 1
Requested Information

1. Discuss how the mechanical seal function is affected by the shaft deflection resulting from radial bearing failure.

The manufacturer of the LPI/DHR pump mechanical seals was contacted. The seals can function within the design limits with an angular offset of 4 mils (seal run-out). Seal run-out is the relative squareness between the seal mating pair that is created by the slope of the shaft at the seal location. The shaft's deflection affect on both inboard and outboard seals was evaluated against the allowed criteria. The outboard seal was the most limiting with a seal face run-out of 2.8 mils compared to the allowable of 4 mils.

The deflection of the shaft at the seal location calculated analytically was reviewed by the manufacturer and their position is that they expect the seal to accept lateral deflection with no adverse affects. The minimum radial clearance at the seal is 30.5 mils. The expected dynamic deflection, with a failed radial bearing, is less than a third of this clearance. This indicates that the shaft does not interfere with a seal in the event of a failed radial bearing.

The manufacturer also reviewed the position of the shaft relative to the mechanical seals in the static condition. It was determined that in the static condition, adequate clearance would remain between the shaft and the seals to ensure that there would be no contact between the surfaces and no seal damage would result in the static condition.

At the conference, ANO discussed seal leakage when the radial bearing on the pump failed in 1996. The data from the 1996 bearing failure was reviewed, and it was determined that minimal seal leakage was present prior to the bearing failure. After the radial bearing on the pump failed, no increase in seal leakage was noted. The seals continued to perform acceptably when the pump accumulated nine days of run time, including multiple starts and stops.

Based on analytical checks and empirical data presented, without the radial bearing, adequate clearances and tolerances remain in the static and dynamic condition between the shaft and the mechanical seals. Therefore, the LPI/DHR pump seals would remain functional considering radial bearing failure.

2. Illustrate the DHR/LPI pump shaft deflection as a result of the radial bearing failure and illustrate the margin of allowable tolerances at the various rotating assembly locations.

The deflection versus the clearance between the rotating shaft and the stationary housing is illustrated in Table 1 below. There is considerable margin at each point before interference is incurred while the pump is running. When the pump stops the impeller wear rings will rest on the housing wear rings or interference could occur at the throttle bushing if the wear rings are worn to their maximum wear point. Upon starting the pump, almost instantaneously, the coupling centers the shaft. This centering effect lifts the shaft off of the wear rings and the shaft runs without contact. It is concluded that there is considerable margin with regard to shaft interference and that the pump will perform its function without the radial bearing.

Table 1
LPI/DHR Pump
Dynamic Shaft Deflection with a Failed Radial Bearing

Component	Clearances	Displacement Crediting Lomakin Effect	Displacement Without Crediting Lomakin Effect
Failed Radial Bearing	N/A	0.0072"	0.0095"
Inboard Shaft Seal	0.0305"	0.0075"	0.0100"
Inboard Throttle Bushing	0.0165"	0.0080"	0.0105"
Wear Rings	0.0145"	0.0070"	0.0090"
Outboard Throttle Bushing	0.0165"	0.0060"	0.0075"
Outboard Shaft Seal	0.0305"	0.0035"	0.0042"

3. Discuss the Lomakin effect as it pertains to the Fault/Decision tree presentation.

The Lomakin hydraulic force was discussed during the conference. However, the conclusion that the DHR/LPI pump would have been capable of performing its specified function was not dependent upon crediting this lift force. During the presentation it was noted that analysis established that the coupling and thrust bearing loads would increase but would be within the design limits without the Lomakin force. The coupling load would increase from 237 pounds to 328 pounds and the thrust bearing load would increase from 359 pounds to 469 pounds, compared to the allowed limits of 400 pounds (based on allowed coupling deflection) and 20,000 pounds respectively. Therefore, based on the above discussion, the fault/decision tree outcome regarding the "coupling capability" is not dependent on the contribution of the Lomakin effect. The Lomakin effect simply provides additional margin to the supporting evidence of functionality.

With regard to the applicability of the hydrodynamic fluid force (Lomakin effect) discussed in Karrasik's Pump Handbook, the force is credited for its additional support of pump shafts in the dynamic case. Its effect on the pump shaft is described in the handbook as "essentially transforms the rotor from one supported at two bearings external to the pump to one with several additional internal bearings lubricated by the liquid pumped." The author describes the application of this effect as controversial when applied to pump designs where multi-stage, long slender shaft designs are intentionally allowed to rest on the wear rings for the design static case for these pumps.

The LPI/DHR pump is a single stage pump with a stiff shaft and the faulted design assessment crediting Lomakin for a 30 day mission is a reasonable application based on this design configuration. Regardless, the Lomakin effect is presented as margin supporting the operability position and is not critical to the fault/decision tree outcome.

4. Discuss the fault/decision tree areas of conservatism in regard to the coupling failure mechanism and the bearing failure mechanism, include other analytical margins in the analysis.

During the conference two areas of conservatism were discussed in the fault/decision tree portion of the presentation. Since some of the analyses were not complete at the time the expert panel developed the fault/decision tree, additional conservatism was added in the categories of coupling capability and motor bearing and outboard pump bearing load capability. These failure mechanisms were assigned relative failure values of .02 and .01. As discussed in item 3, the completed analysis now substantiates both values as conservative since both components have been analyzed as capable of carrying the calculated loads without crediting the Lomakin effect. Therefore, as discussed during the conference, the failure probability of 0.03 assigned by the expert panel is considered conservative and a value closer to nominal would be appropriate. A footnote was added to the fault/decision tree for clarification, this modified version is provided in Attachment 2.

5. Discuss the 1996 empirical results and how these results support the analytical results presented. In particular discuss the 10 mil potential shaft run-out at the radial bearing when the shaft was decoupled and relate whether or not this has any additional impact on the shaft deflections presented as a result of the radial bearing failure.

Following the 1996 radial bearing failure, there were no excessive vibrations, noise, leakage or other indications that the radial bearing on the pump had failed. The pump ran with no increase in seal leakage for nine days accumulated run time, including multiple starts and stops. After discovery of the radial bearing failure, the de-coupled shaft run-out was checked at four locations while the shaft was still in the pump housing. This method for measuring shaft run-out was inconclusive for determining if any bowing of the shaft occurred. The measurements were taken for information only and the method and points of reference along the shaft are not adequately recorded. The only true method to determine if a shaft has any run-out is to remove it from the assembly, support it on V blocks and take independent shaft measurements at multiple locations.

Even if there were some bowing of the shaft, the effect of a bowed shaft would be increased vibration and an increase misalignment at the shaft seals. The vibration analysis did not explicitly consider bow, but rather considered a postulated imbalance due to undetermined causes. The standard vibration imbalance criteria is 8W/N (W = weight of the rotor assemble, N = rpm); however, for this analysis, 32 W/N was used providing a margin of 400% for the possible imbalance. The results showed a vertical displacement of 0.26 mils as compared to an allowable displacement of 1.6 mils. Therefore, the vibration response has approximately 800% margin. The vibration response to the imbalance assumed in the analysis indicates that vibration due to a bow would only cause moderate increases in vibration.

The 1996 data provides further confirmation of performance and can be used to assess satisfactory pump operation. Both seals operated acceptably in 1996, this indicates that even if the bearing failure introduces some bow, the pump and shaft seals are able to accommodate the run-out and continue to function acceptably.

In summary, based on the method used for measuring shaft run-out, there is no evidence to conclusively determine if any bowing of the shaft occurred following the 1996 failure of the radial bearing. However, the analysis margins and the 1996 data can be used as a sound basis that provides reasonable assurance for operability.

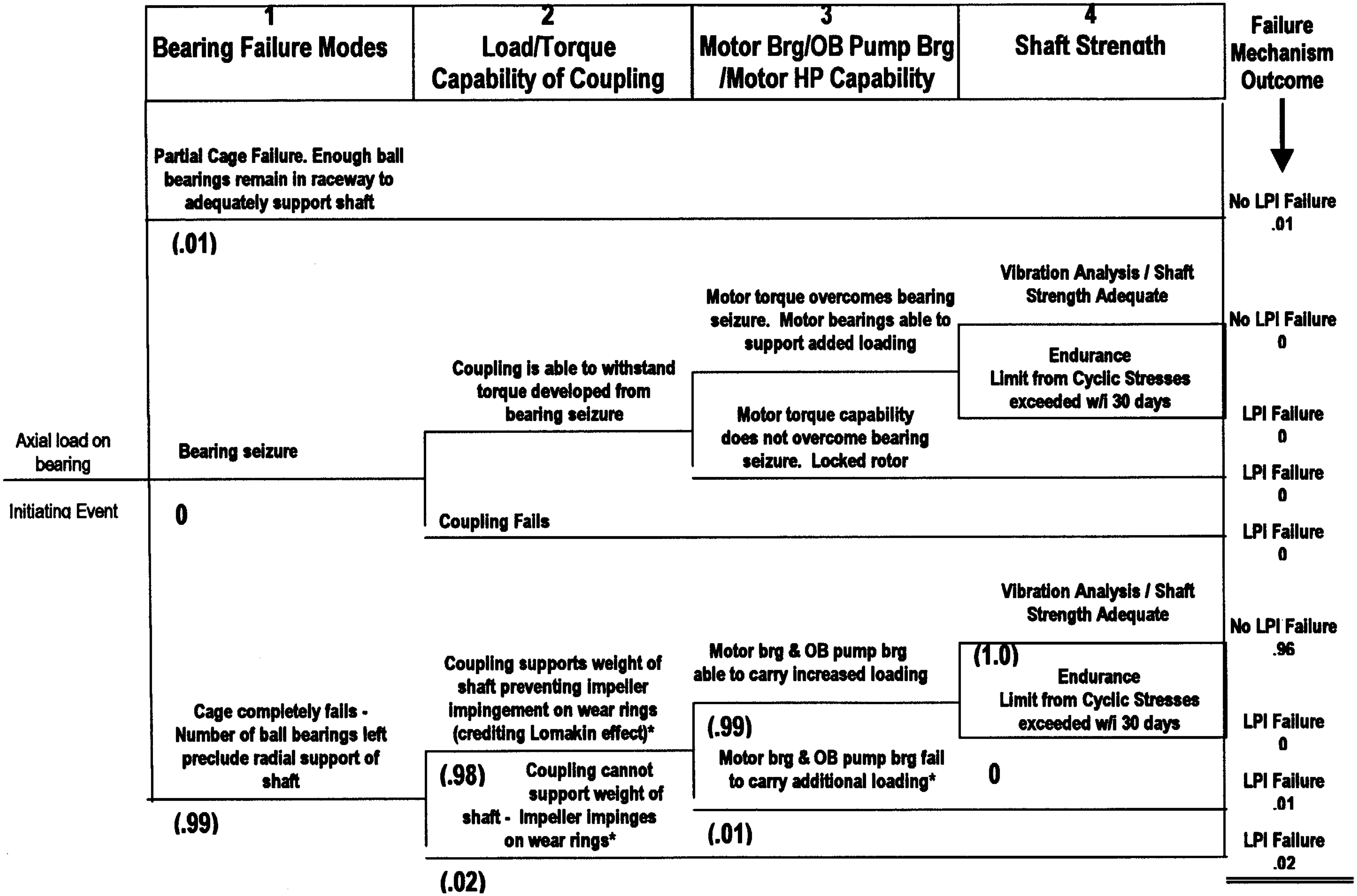
6. Discuss the sensitivity of using the expert panel results in the risk significance determination.

Sensitivity studies using the ANO-1 Probabilistic Safety Analysis (PSA) model without crediting Reactor Building Spray for recovery were performed. As discussed in item 4, the expected failure probability is closer to nominal; however, a conservative 0.03 failure rate has been assumed. Below is a table for the change in core damage frequency (CDF) vs. increases in assumed LPI/DHR pump failure rates.

Table 2
Δ CDF vs. LPI/DHR Failure Probability

LPI/DHR Failure Probability	ΔCDF per Reactor Year
0.05	1.65 E-06
0.10	3.94 E-06
0.25	1.734 E-05
0.50	5.895 E-05

Fault/Decision Tree



LPI Failure = .03
No LPI Failure = 0.97

*The fault tree represents the results of the expert panel prior to completion of some of the analysis. Therefore, additional conservatism was given in the categories of coupling capability and motor bearing and outboard pump bearing load capability. These failure mechanisms were assigned relative failure values of 0.02 and 0.01. The completed analysis now substantiates both values as conservative since both components have been analyzed as capable of carrying the calculated loads without crediting the Lomakin effect.