INTRA-COMPANY MEMORANDUM

FirstEnergy

TO J. W. Rogers, Manager - Plant Engineering

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MAIL STOP 1056

SUBJECT Reactor Coolant Pump Issues

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NPE-02-00227

Attached is a white paper concerning Reactor Coolant Pumps issues collected from CRs, OE from Industry, and Flowserve (vendor). Based on the evaluation of the information the following is recommended.

- Replace pump cover gaskets on all 4 pumps with new inconel gaskets. Clean, inspect, and repair gasket area's.
- Remove, inspect, and refurbish as required all 4 rotating elements (impellers).
- Inspect pump covers for cracking and repair/replace as required.
- Refurbish N9000 seals per current schedule.
- Replace two RCP motors.

JJB/JLT/tro

Attachment

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1.0 Issues Summary

Multiple issues relative to the condition of the Reactor Coolant Pumps (RCPs) have led to development of an overview of the work required to improve the RCPs material condition. Resolving these issues will require motor removal and disassembly of the pump for inspections and replacement of components.

All four RCPs have had indications of pump casing gasket leakage at the inner gasket. Two of the RCPs have had indication of leakage past both inner and outer gaskets. Re-tensioning of the cover bolts has not completely stopped the leakage.

Flowserve has identified the potential for cracks forming in the impeller vanes. The cracks are caused by inadequate heat treatment of repairs during manufacturing and are propagated by stop/starts of the pumps. Investigation has found that all four of the installed impellers have had weld repairs without heat treatment.

Flowserve has identified the potential of through wall cracking in the thermal barrier region of the RCP pump covers. A preliminary investigation has indicated that Davis-Besse has limited exposure for this issue.

RCP shaft bowing was also investigated but not believed to be an issue at this time.

RCP motor replacement is an ongoing Preventive Maintenance Activity.

2.0 Conclusions

Reactor coolant leakage from the RCP cover gasket area has been a continuing issue. Two of the RCPs have had leakage past both gasket areas and boron deposits on the pump casing bolts. All four of the RCPs have had leakage indications for the inner seals. Flowserve does not recommend operating for extended periods (multiple cycles) with the inner seal leaking thus relying solely on the outer seal.

Retensioning of the studs on all RCPs was performed in 10 RFO when leakage was found. Primary leakage was found on the inner seal during 11RFO and we have operated with knowleakage on the inner seal since then. Industry experience has shown that re-tensioning the studs a second time has not completely prevented leakage from propagating past both gasket areas causing boric acid to be deposited on the bolting hardware and surrounding areas.

To adequately repair the gasket joint on the RCP requires disassembly of the pump. Due the magnitude of the work, the rotating element, pump cover, and motor issues should be addressed at the same time.

3.0 Plant Engineerings Recommendations

3.1 Replace pump cover gaskets on all 4 pumps with the new Inconel/graphite seals. Clean, inspect, and repair gasket area's.
3.2 Remove, inspect, and refurbish all 4 rotating elements (impellers).
3.3 Inspect pump covers for cracking and repair/replace as required.
3.4 Refurbish N9000 seals per current schedule.
3.5 Replace two RCP motors.

Discussion:

1.0 Reactor Coolant Pump Casing Gasket Leaks

1.1 Discussion

The reactor coolant pumps at Davis Besse are designed with a double gasket for closure of the main case-to-cover joint. The annulus between the two flexitallic-style gaskets are connected through a high-pressure line to an isolation valve. The purpose of this inter-gasket leakoff line is to capture any leakage past the inner gasket and to allow monitoring of potential leakage.

Davis Besse has detected leakage from all four RCP inner gasket area and in the case of RCP 1-1 and 1-2 leakage has been detected pass both gaskets. Retensioning of the case studs has not completely restored the joint and the inner gasket area continue to leak. Additional information on Davis Besse history is described in the next section.

Based on in put from Flowserve, once the inner gasket begins to experience leakage, there is little chance of restoring full integrity of the case to cover joint without pump disassembly. There have been attempts to eliminate leakage by re-tensioning the case studs. Retensioning of case studs while the motor is installed is very difficult and time-consuming and from experience is marginally effective. Even in cases where the stud preload has been lower than required, retensioning was not successful in stopping the leakage. Once there has been degradation of the gasket, the sealing ability is compromised and there will most likely be continued leakage problems. Further Retensioning is ineffective because the seal is fully crushed.

OE 12074, TMI 1, had indications of an inter-gasket leak 1993, and in 1999 found approximately 1000 pounds of boric acid on a RC-P-1P. 14 of the 24 RCP stud bolts were covered with boron, causing severe wastage on several stud bolts. TMI concluded that the event was not significant because the specific leak rate was low and the stud strength remained above the industry minimum. The event was noteworthy because inspection methods were ineffective and suspected leakage continued until stud damage occurred.

SOER 81-012 described three facilities, Fort Calhoun, Oconee 2, and Oconee 3 that did not monitor leakage past the first sealing surface until leakage occurred out of the pump cover damaging studs and surrounding equipment. The SOER recommends keeping the leak indication lines in service.

1.2 Davis Besse History

In 1986 all four RCPs were disassembled and the rotating elements were replaced. The gaskets were replaced at that time.

During 10 RFO, PCAQR 96-0650 was intimated identifing leakage at the pump casing joint and boric acid on the following RCP stud bolts:
RCP 1-1: Studs 5, 7, 9, 10, 11, and 12
RCP 1-2: Studs 2
The cause was contributed to pump bolt load relaxation. The pump cover bolts were re-tensioned on all four RCP's. It should be noted that the vendor recommends stud

re-tensioning after gasket replacement and the pump has experienced thermal cycles. This re-tensioning did not occur after the 1986 replacement until 10 RFO and leakage developed.

Leakage has been reported from the inner gasket for all 4 RCPs in 11 RFO by OP-06900 section 4.104.

CR 2000-0869, 12 RFO, flange leakage at the bolted connection for RCP 1-1. Boric acid was found on 3 of the RCP studs.

12 RFO, DB-PF-03035 indicated leakage from the inner gasket area for RCP 1-1, 1-2, and 2-1. No external leakage was indicated. The leakage test on RCP 2-2 was indeterminate.

CR 02-01523, 13 RFO, DB-PF-03035 indicates leakage from the inner gasket area for RCP 1-1 and 1-2. No external leakage was found. RCP 2-1 and 2-2 Leak tests were not performed. Work orders have been generated to retension all four pump covers.

1.3 Conclusions

Over the past six years, leakage from the RCP cover gaskets has been an issue. In 10 RFO two of the RCPs had leakage pass both gaskets and left boron on carbon steel bolting hardware and the surrounding area. At that time the cover studs were re-tensioned on all four pumps. The next outage, 11 RFO, showed all four pumps had leakage at the inner gasket. Again in 12 RFO, RCP 1-1 had leakage past both gaskets and boron deposits on the carbon steel bolting hardware. Two other RCPs had indications of leakage from the inner gasket. In 13 RFO, RCP 1-1 and 1-2 showed leakage at the inner gasket, RCP 2-1 and 2-2 Leak tests were not performed.

Industry experience has been similar to Davis-Besse, that re-tensioning of the cover gaskets has limited short term success and inner gasket leakage leads to outer gasket leakage. Outer gasket degradation leads to reactor coolant leakage and boron corrosion on the cover studs and surrounding equipment.

1.4 Recommendations

Replace the gaskets on all four RCPs.

1.5 Reference

1.5.1 SOER 81-12, Reactor Coolant Pump Closure Stud Corrosion, Fort Calhoun, Oconee 2, Oconee 3.
1.5.2 OE 3057, Reactor Coolant Pump Flange Leakage, 11/88, Trojan
1.5.3 OE 9893, Primary Coolant Pump Leakage at Mechanical Joint, 12/98, Palisades
1.5.4 OE 12074, Boric Acid Corrosion of Carbon Steel Components at the Reactor Coolant System Pressure Boundary at Three Mile Island I. 09/99
1.5.5 CR 02-01523, RCP 1 and 2 leakage
1.5.6 CR 02-02119, Cover Gasket Leak-off Valve
1.5.7 CR 2000-0869, RCP 1-1 flange leakage at the bolted connection.
1.5.8 PCAQR 96-0650, RCP 1-1 evidence of leakage and boric acid on studs.
1.5.9 Flowserve Letter dated July 2, 2002. To Andrew Siemaszko from Gerry Lenzen, Section Head, Primary Pumps.

2.0 Impeller Cracks

2.1 Discussion:

OE13604, Palisades, Byron Jackson/Flowserve: Three cracks were found in a primary coolant pump impeller that was removed for refurbishment during the 2001 refueling outage. The three cracks were similar in nature; each started on a separate impeller vane at the suction side of the vane tip near the hub and then transverses in the vane in a linear fashion. Prior to the removal of the pump, the pump exhibited no symptoms that would indicate the presents of the cracks.

The root cause concluded that a combination of increased residual stresses, caused by a lack of the proper post weld heat treatment at the manufacturing facility, and high stress risers, due to poor fabrication practices, allowed the stresses associated with the starting and stopping of the pump to initiate fatigue-type cracks on the impeller vanes.

Based on Flowserve's evaluation, the cracks initiate perpendicular to the vane leading edge and completely penetrate the vane. Most of the cracks have propagated back into the vane and appear to self-arrest in the thicker vane cross-section. In a few cases the crack propagated in a semi-circular direction. In one case the semi-circular section was lost from the impeller. A piece approximately 3" by 6" was found in the reactor vessel. No evidence of ISCC attack has been observed. The problem was caused by lack of post weld heat treatment for repairs that were made during post manufacturing.

A means for external monitoring and detection of this condition does not exist. Impeller cracking can only be determined by removal of the impeller from the pump, chemical decontamination, and inspection by visual and liquid penetrate examination techniques. The cracks are not detectable without removal of the oxide layer from the impeller by chemical decontamination.

Flowserve recommends that pump impellers in excess of 175,000 hours of service (~20 years of running service) be removed and inspected for cracking to preclude in-service failure. However, they have found cracking as early as 13 years. Davis-Besse has replaced all four reactor coolant pump rotating elements in 1986 as due to issues with the RCP shaft cracking. Preliminary estimate of the operation time for these impellers is estimate at ~103,000 hours (~12 years).

Review of the Acceptance Data Package for the 4 rotating elements that were installed in 1986. The Data Packages shows that all 4 impellers had weld repairs performed without post-heat treatment. It is preferred that the currently install impellers should be refurbish due to less starts on these than the current spares.

2.2 Conclusion

The current rotating elements have the potential of forming cracks. Based on the vendor estimated approximately 20 years of service prior to the cracking to become evident. The installed rotating elements have approximately 12 years of service. This issue is not an immediate concern.

2.3 Recommendations

The inspection of the rotating elements should be performed with the gasket replacement effort.

2.4 Reference:

2.4.1 OE13604, Cracks Identified in Primary Coolant Pump Impellers.
2.4.2 CR 02-02091, RCP Impeller Cracking in the Industry.
2.4.3 FLOWSERVE Tech Note No. 0203-80-028

3.0 Pump Covers Heat Exchanger Leakage

3.1 Discussion

Flowserve has issued a Technical Service Bulletin on RCP heat exchanger leakage. Thermal cracking in the cover/heat exchanger bore has breached the drilled hole heat exchanger allowing primary coolant leakage into the CCW system at two plants.

The heat exchanger in the RCP pump cover has drilled holes into the cover with numerous inter-connected holes around the cover bore. There is mixing of cool water from the seal region and the reactor coolant. This induces thermal cracking in this area. Based on Flowserve's evaluation there is a potential for axial crack propagation resulting in a breach of the drilled hole heat exchanger.

Flowserve recommends inspection of the pump cover during the 10-year in-service inspection. In the event of leakage, the CCW should be isolated and the cover replaced. Per the bulletin a new design cover is available to eliminate the thermal fatigue cracking. At one utility, the RCP cover heat exchanger was "plugged" to allow CCW flow to the seal package and remove the intersystem leakage.

Per discussion with Flowserve, the design of the Davis Besse pump cover has a low probably of this type of failure. Due to the nature of this cracking, there is always a potential of the small surface cracking becoming through wall during thermal transits.

3.2 Conclusions

Davis-Besse pump cover design has a low probability for this type of failure.

3.3 Recommendations

With the inspection of the impellers, inspect the pump covers.

3.4 Reference

3.4.1 Flowserve Tech Note 0203-80-027, Reactor Coolant and Reactor Recirculation Pump Heat Exchanger Leakage.
3.4.2 LER 302-010003 Primary Side to NSCCC at Crystal River 3.

4.0 Bowed Shafts

4.1 Discussion

RCP from several plants have been inspected during pump refurbishment activities and found to have shaft bowing in excess of acceptable limits. Shaft bowing of up to 0.020 inch TIR has been found. The design specification for the runout of a Byron Jackson reactor coolant pump shaft is 0.002 inches TIR. Misalignment causes the rotating assembly to have increased runouts resulting in higher vibration readings and increased radial forces on the pump shaft. Flowserve recommends that for RCP's that have increasing vibration readings over time should be inspected for shaft bowing.

None of the RCP's has demonstrated a significant increase in vibration over the last cycle.

4.2 Conclusion

Shaft bowing is not an issue at Davis-Besse. This condition is detectable by current instrumentation.

4.3 Recommendations

No action is required for this issue.

4.4 References

4.4.1 E-mail from Pat Prom, Flowserve, to James L. Tabbert, FENOC. Subject: Byron Jackson Reactor Coolant Pumps.

4.4.2 Draft Technote, Flowserve NO 0206-80-029, Reactor Coolant Pump Shaft Bowing.

5.0 RCP Motor Replacement

5.1 This is an ongoing Preventive Maintenance Activity, which should be performed if RCP work is performed.