August 24, 2001

EA-01-206

Mr. Charles H. Cruse
Vice President
Constellation Nuclear
Calvert Cliffs Nuclear Power Plant, Inc.
1650 Calvert Cliffs Parkway
Lusby, MD 20657-4702

SUBJECT: CALVERT CLIFFS UNIT 1 - NRC INSPECTION REPORT 50-317/01-009

Dear Mr. Cruse:

On July 13, 2001, the NRC completed a special inspection at the Calvert Cliffs Nuclear Power Plant, Unit 1, to evaluate the failure of the No. 11 auxiliary feedwater pump turbine bearing that occurred on May 16, 2001. The special inspection was conducted after your staff had the opportunity to complete its investigation and issue the associated root cause analysis report. The enclosed report documents the results of the inspection, which were discussed with you, Mr. Katz, and other members of your staff during an exit meeting on July 23, 2001.

Based on the results of this inspection, one preliminary finding of substantial safety significance (Yellow) was identified regarding inadequate adherence to maintenance instructions during reassembly of the turbine bearing. As a result, excessive sealant was applied to the bearing housing, which contaminated the bearing oil and most likely entered the bearing, and resulted in loss of lubrication and subsequent bearing failure. Preliminarily, this inspection finding appears to be an apparent violation of 10 CFR 50, Appendix B, Criterion V, “Instructions, Procedures and Drawings,” and is being considered for escalated enforcement action in accordance with the “General Statement of Policy and Procedure for NRC Enforcement Action” (Enforcement Policy), NUREG-1600. The current Enforcement Policy is accessible from the NRC web site at http://www.nrc.gov.

While your staff’s investigation into the physical causes of the bearing failure was generally adequate, the NRC observed some weaknesses. The quarantine of material found in the failed bearing and sump oil was less than effective, and the potential for foreign material to enter the bearing from make-up oil added during daily rounds was not investigated until questioned during the inspection. The NRC also determined that the conclusion reached by your staff, that inadequate vendor technical manual direction led to the application of excessive sealant, was not well supported by the results of your investigation. The NRC also found that you missed some opportunities to identify this problem prior to the bearing failure. While these observations do not change the conclusions regarding the physical cause of the bearing failure, they are considered to be examples of weakness in the implementation of your corrective action program.

We believe we have sufficient information to make our final risk determination for the performance issue regarding inadequate adherence to maintenance instructions during reassembly of the turbine bearing. However, you have the opportunity to either request a regulatory conference to discuss your evaluation and any differences with the NRC evaluation, or to send us your position in writing within 30 days. Please contact David Lew at (610) 337-5120 within 7 days of the date of this letter to inform the NRC of your intentions. If we have not heard from you within 10 days, we will continue with our significance determination and enforcement decision, and you will be advised by separate correspondence of the results of our deliberations on this matter. Since the NRC has not made a final determination in this matter, no Notice of Violation is being issued at this time. In addition, please be advised that the characterization of the apparent violation described in the enclosed report may change as a result of further reviews.

During the inspection, two issues of very low safety significance (Green) were identified regarding storage of lubricating oil and acceptance criteria for equipment reassembly. These two issues were also determined to be violations of NRC requirements. However, because of their very low safety significance and because the issues have been addressed and entered into your corrective action program, the NRC is treating these issues as Non-Cited Violations, in accordance with Section VI.A.1 of the NRC's Enforcement Policy. If you deny these non-cited violations, you should provide a response with the basis for your denial, within 30 days of the date of this inspection report, to the Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington DC 20555-001; with copies to the Regional Administrator, Region I; the Director, Office of Enforcement; and the NRC Resident Inspector at the Calvert Cliffs facility.

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter and its enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's document system (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/NRC/ADAMS/index.html (the Public Electronic Reading Room).

Sincerely,

**/RA/**

Wayne D. Lanning, Director
Division of Reactor Safety

Docket No. 50-317
License Nos. DPR-53

Enclosure: NRC Inspection Report No. 50-317/01-009

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REGION I

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| Docket No: | 50-317 |
| License No: | DPR-53 |
| Report No: | 50-317/01-009 |
| Licensee: | Calvert Cliffs Nuclear Power Plant, Inc. |
| Facility: | Calvert Cliffs, Unit 1 |
| Location: | Calvert Cliffs Nuclear Power Plant, Unit 1 |
| Dates: | June 27-28, 2001 and July 9-13, 2001 |
| Inspectors: | Mel Gray, Reactor Inspector<br>David Beaulieu, Senior Resident Inspector<br>James Trapp, Senior Reactor Analyst (in office support) |
| Approved by: | David C. Lew, Chief<br>Performance Evaluation Branch<br>Division of Reactor Safety |

## SUMMARY OF FINDINGS

Inspection Report 05000317/2001-009; on 6/27/2001- 7/13/2001; Calvert Cliffs Nuclear Power Plant, Inc., Calvert Cliffs Nuclear Power Plant, Unit 1; Event Follow-up. Special Inspection, turbine-driven auxiliary feedwater pump bearing failure.

The inspection was conducted by a regional inspector and a senior resident inspector, with in office support from a regional senior risk analyst. The inspectors preliminarily identified one finding of substantial safety significance (Yellow) that is also an apparent violation of NRC requirements. The NRC will make a final determination of significance in the future. The inspection also identified two findings of very low safety significance (Green) which were also violations of NRC requirements. These two findings were classified as non-cited violations. The significance of issues identified during the inspection is indicated by their color (Green, White, Yellow, Red) using Inspection Manual Chapter (IMC) 0609 "Significance Determination Process" (SDP). Findings for which the SDP does not apply are indicated by "No Color" or by the severity level of the applicable violation. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described at its Reactor Oversight Process website at http://www.nrc.gov/NRR/OVERSIGHT/index.html.

Inspector Identified Findings

Cornerstone: Mitigating Systems

- **Preliminarily Yellow.** The inspectors identified an apparent violation of 10 CFR 50, Appendix B, Criterion V, which requires, in part, that activities affecting quality shall be accomplished in accordance with documented instructions, procedures, or drawings. Contrary to this, on March 25, 2000, maintenance order instructions regarding the application of sealant to the 11 AFW pump turbine outboard bearing housing were not followed in that excessive sealant was applied, which most likely resulted in the bearing failure on May 16, 2001.

  This preliminary finding had a credible impact on safety, because the ability of a turbine-driven pump to perform its safety function was affected. This issue affects the mitigating cornerstone since AFW pumps supply feedwater to the steam generators to remove decay heat removal when main feedwater is unavailable. Using an SDP Phase 3 assessment, the issue has been preliminarily characterized to have substantial safety significance (Yellow) based on the equipment function of removing decay heat and the length of time the excessive sealant was applied. **(AV 50-317/01-009-02; EA 01-206)**

  While the licensee's investigation into the physical causes of the bearing failure was generally adequate, some weaknesses were observed. While these observations do not change the conclusions regarding the physical cause of the bearing failure, they are considered to be examples of weakness in the implementation of the corrective action program: (1) The quarantine of material found in the failed bearing and sump oil was less than effective, resulting in limited opportunity for confirmatory chemical analyses; (2) The potential for foreign material to enter the bearing from make-up oil added during daily operator rounds was not investigated until questioned during the inspection; (3) The licensee's conclusion that inadequate vendor technical manual direction led to the

application of excessive sealant was not well supported by the results of the investigation; (4) Some missed opportunities to identify this problem prior to the bearing failure were identified.

- **Green.** The inspectors identified a Non-Cited Violation for failure to include appropriate quantitative and qualitative acceptance criteria in work instructions to ensure auxiliary feedwater pump turbine bearing reassembly was satisfactorily accomplished. Specifically, the maintenance order instructions for bearing reassembly after turbine overspeed tests did not include acceptance criteria for critical tolerances. This is a violation of 10 CFR 50 Appendix B, Criterion V, which requires, in part, that activities affecting quality shall be prescribed by documented instructions, and these instructions shall include appropriate quantitative and qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished.

  The finding had a credible impact on safety, since maintaining turbine bearings within critical tolerances is required to ensure reliable operation of the turbine-driven AFW pumps. This issue affects the mitigating cornerstone since AFW pumps supply feedwater to the steam generators to remove decay heat when main feedwater is unavailable. However, since bearing inspections of the 11 AFW pump turbine and turbine vibration trending do not indicate the bearing failed as a result of out of an out of tolerance condition, and the performance of the turbine bearings for the 12, 21 and 22 AFW pump turbines is satisfactory, this issue has been determined to have very low safety significance in accordance with the NRC SDP Phase 1 assessment. **(NCV 50-317/01-009-03)**

- **Green.** The inspectors identified a Non-cited Violation for failure to establish measures to prevent damage or deterioration of make-up oil to safety related equipment. The inspectors observed visual debris in oil containers stored by operations personnel for make-up to safety related equipment. This is a violation of 10 CFR50 Appendix B, Criterion XIII, which requires, in part, measures be established to control the handling and storage of material to prevent damage or deterioration.

  This finding had a credible impact on safety, since visual debris in oil containers could have been transported into oil sumps and reservoirs associated with safety related equipment and degraded equipment performance. The issue affects the mitigating systems cornerstone since safety related mitigating equipment could be affected. However, since the debris was noted to be minor and localized at the bottom of the oil containers, and there is no indication of an actual loss of equipment as a result of contaminated make-up oil, this issue has been determined to have very low safety significance (Green) in accordance with the NRC SDP Phase 1 assessment. **(NCV 50-317/01-009-01)**

## Report Details

### Summary of Plant Event

On May 16, 2001, Calvert Cliffs (CC) Unit 1 operators were completing a periodic surveillance test of the 11 turbine-driven auxiliary feedwater (AFW) pump. The procedure requires the pump be run for ninety minutes. Eighty-eight minutes into the surveillance test, operators observed a rapid increase in the turbine outboard journal bearing temperature. When the temperature exceeded 210°F, operators secured the pump in accordance with procedural guidance to terminate the bearing temperature increase.

Operators declared the 11 AFW pump inoperable and entered the applicable technical specification action statement. Operators initiated a corrective action program incident report to investigate the cause of the bearing failure and issued a high priority maintenance order (MO) to disassemble and inspect the turbine inboard and outboard journal bearings. Upon outboard bearing disassembly on May 17, personnel observed a black residue in the lower half of the bearing that appeared to be different from bearing lubricating oil. CC personnel noted the black residue was similar in color, odor and texture to the sealant (permatex#2) applied to the adjacent bearing housing split joint. The sealant is applied to prevent lubricating oil leaks through the joint between the bearing housing and bearing cap. The turbine design does not include a gasket in this joint.

Personnel observed a thick film of sealant had been applied to the bearing housing split surfaces and that some sealant had been extruded onto the walls of the bearing oil sump. Additionally, the personnel noted in the MO some visual evidence of material in the oil reservoir. CC personnel preliminarily concluded sealant may have been extruded out the outboard bearing housing joint onto the sump oil wall, become entrained in sump oil, and was transported into the bearing via the rotating oil ring. Actions were taken to flush, drain and refill the bearing oil sumps, remove the excess sealant from the housing surfaces, re-machine the outboard bearing babbitt surface, and reassemble the pump. The 11 AFW pump was successfully tested and returned to service on May 18, 2001.

Based on the potential safety significance of the problem, CC personnel inspected the 12, 21 and 22 AFW pump turbine bearing housings and sumps to determine the potential for sealant intrusion into the bearings. CC personnel disassembled and inspected the inboard and outboard turbine bearing housings for the other turbine-driven AFW pumps. Visual observation of the bearing housing and sump wall surfaces indicated that less sealant had been applied to these components, and there was not evidence of significant sealant extrusion onto the sump walls. Personnel drained, flushed, and refilled the oil sumps and returned these AFW pumps to service.

The licensee formed a multi-disciplined team to investigate the event, determine the causes, address the extent of the problem, and develop corrective actions to prevent recurrence. The investigation team activities included interviews with cognizant maintenance personnel, retrieval and review of the operating and maintenance history of the AFW pumps, and various mock-up tests to investigate the potential for transport of sealant into the bearings. The team supplemented its investigation with independent reviews by engineering consultants and turbine experts.

The Calvert Cliffs investigation team root cause analysis report was approved on June 22, 2001. The report concluded that the 11 AFW pump turbine bearing failed due to interruption of lubrication to the bearing. Bearing lubrication was interrupted most likely as a result of sealant intrusion into the bearing. The analysis concluded the sealant had been applied to the bearing housing in accordance with the vendor manual to a thickness of .015 inches, but the thickness proved to be excessive. Consequently the vendor manual direction was considered to be inadequate. Corrective actions to prevent recurrence included revising the vendor manual to provide enhanced direction.

## 4. OTHER ACTIVITIES [OA]

### 4OA3 Event Follow-up (93812)

#### .1 Sequence of Events

a. Inspection Scope

The inspector used an events and causal analysis approach to develop an understanding of the circumstances surrounding the 11 AFW pump bearing failure. A chronology of events leading up to the bearing failure was developed and is included in Attachment 3.

b. Issues and Findings

There were no issues or findings identified in developing the chronology of events leading to the bearing failure.

#### .2 Bearing Failure Investigation

a. Inspection Scope

The inspectors reviewed the licensee's investigation to determine whether it was of appropriate scope and detail to identify the probable causes of the bearing failure. To assess the adequacy of the licensee's investigation, the inspectors independently reviewed maintenance and operating documents associated with the auxiliary feedwater pumps, interviewed cognizant engineering, maintenance, and operations personnel, and walked down the auxiliary feedwater pump equipment.

b. Issues and Findings

The inspectors determined that the licensee's investigation into the bearing failure were generally of adequate scope and detail to determine the bearing failure was due to interruption of lubrication. Lubrication was interrupted by a foreign material, most likely sealant, that had been applied in excessive quantities to the bearing housing. Nevertheless, the inspectors identified weaknesses in the licensee's investigation in regard to considering all potential sources of foreign material into the bearing and quarantine of evidence. While these weaknesses do not change the conclusions of the investigation that the likely physical cause of the bearing failure was sealant intrusion,

they are considered to be examples of weaknesses in corrective action program implementation.

The licensee's investigation began with visual inspections and photographs of the as found condition of the failed 11 AFW turbine bearing. When the bearing was disassembled, a black pasty substance was identified in the lower half of the bearing. Maintenance and engineering personnel observed that the substance was similar in color, odor and texture to the permatex sealant applied to the adjacent bearing housing.

The licensee interviewed maintenance personnel responsible for AFW pump work. The mechanic who reassembled the 11 AFW pump turbine bearings in March 2000 confirmed that he performed similar work on the 12 AFW pump in April 2000, and the 21 and 22 pumps the following year. The mechanic stated that a vendor representative had observed the reassembly of 12 AFW bearings in April 2000 and commented that too much sealant was being applied to the bearing housing. Consequently, the mechanic applied significantly less sealant to the 12 AFW pump and to the 21 and 22 AFW bearing housings the next year. However, no action was taken to review the work performed the previous month on the 11 AFW pump turbine bearings. This is consistent with the results of the AFW bearing housing inspections that showed that the 11 AFW turbine housing had more sealant applied than the other pumps.

The licensee removed some of the substance from the bearing and provided it to chemistry personnel for analysis. The licensee also drained the contents of the 11 AFW pump turbine oil sump for analysis. Chemistry personnel filtered and collected material from the sump oil. Chemistry personnel compared the material from the bearing to the material filtered from the sump oil using Fourier Transform Infrared Radiography (FTIR) and concluded both materials were the same. Considering that permatex sealant was a likely cause of the problem, FTIR scans of the bearing substance were compared to FTIR scans of fresh samples of lubricating oil (Texaco R&O 46) and sealant (Permatex#2). Based on these scans, the licensee concluded that the residue found in the bearing was not sump oil. Furthermore, while not conclusive, the licensee determined the FTIR scans of the material found in the bearing and fresh Permatex were sufficiently similar such that they concluded, with a high degree of confidence, the material found in the bearing and filtered from the bearing oil was likely sealant.

The turbine-driven AFW pumps are designed with oil rings to pump oil from the sump into the bearings. Using a mock-up of the system, the licensee investigated the potential for the sealant to be dislodged and transported via the oil rings into the bearing. Testing sponsored by the licensee determined that while larger particles will sink to the sump bottom, fine particles of sealant may remain on the sump oil surface and adhere to the oil rings, and this material may be transported into the bearing. Since journal bearing clearances are very small, the licensee concluded sealant particles could interrupt oil lubrication within the bearing. Based on this overall evidence, the licensee concluded sealant intrusion most likely caused the bearing failure.

The licensee engaged an independent engineering firm to review the evidence and ensure adequate consideration was given to other plausible causes. Potential oil degradation due to higher than normal temperatures, bearing configuration issues, and sump oil conditions were considered. Consistent with the licensee's investigation, the

conclusion was reached that foreign material intrusion into the bearing most likely caused the bearing failure.

The inspectors reviewed the photographs of the as-found condition of the bearing, pump and turbine vibration trends, oil sample analysis results, results of the mock-up tests, and chemical analysis of the black material found in the bearing and sump oil. The inspectors reviewed the independent engineering consultant report and conclusions, and interviewed cognizant engineering, maintenance, and chemistry personnel to understand their observations and the basis for their conclusions. While the inspectors noted the investigation results, considered together, support the conclusion that sealant intrusion into the bearing was the most likely cause of the bearing failure, the inspectors questioned whether the investigation had adequately considered the potential for foreign material to enter the bearing via periodic oil additions to the sump.

The inspectors determined that maintenance personnel sampled the AFW bearing oil every six months. This required that make-up oil be added to replace the sample volume. Completed MO instructions documented that the correct lubricating oil was transferred from the bulk oil storage barrels into clean plastic bottles drawn from stock. The inspectors walked down the bulk storage area and concluded oil cleanliness control was adequate.

As a result of questions regarding make-up oil additions, the inspectors confirmed that operations personnel also add oil as required to equipment during daily rounds. Operators document addition of oil to equipment in “oil addition tracking sheets.” Make-up oil is maintained in containers stored in lockers throughout the plant and operators periodically transfer oil from the bulk oil storage barrels into the containers stored locally. The inspectors observed the contents of containers containing R&O 46 oil in lockers in the turbine building that would likely be used to make-up oil to the AFW pump bearings. In some of these containers debris was identified in the bottom. As a result, the licensee quarantined these containers and examined the contents of oil lockers throughout the plant. The licensee also identified further instances of minor sludge and container deficiencies.

The inspectors reviewed oil addition tracking sheets available back to August 2000 and determined that there was not a record of make-up oil to the 11 AFW turbine bearings. Additionally, a review of maintenance orders back to 1998 did not identify a record of oil leaks from the 11 AFW pump turbine bearings. Furthermore, the licensee had representative samples from the oil containers tested. The results did not identify foreign material similar to that found in the failed 11 AFW bearing and associated oil sump. Consequently, the inspectors determined it was less likely that the 11 AFW turbine bearing failure on May 16, 2001 was caused by foreign material introduced via make-up oil added by operations personnel to the bearing sump than by the application of excessive sealant.

The failure to establish measures to prevent damage or deterioration of oil that is used for make-up to safety related equipment is a violation of 10 CFR50 Appendix B, Criterion XIII, which requires, in part, measures be established to control the handling and storage of material to prevent damage or deterioration. This issue had a credible impact on safety since visual debris in oil containers maintained by operators could have

been transported into oil sumps and reservoirs associated with safety related equipment and degraded equipment performance. The issue affects the mitigating systems cornerstone since safety related mitigating equipment could be affected. However, since the debris was noted to be minor and localized at the bottom of the oil containers, and there is no indication of an actual loss of equipment as a result of contaminated make-up oil, this issue has been determined to have very low safety significance (Green) in accordance with the NRC SDP Phase 1 assessment. This violation is being treated as a non-cited violation (NCV) consistent with Section VI.A of the NRC Enforcement Policy, issued May 1, 2000 (65FR25368). **(NCV 50-317/01-009-01)** The licensee initiated incident report (IR) IR3-059-095 to address the problem in their corrective action program.

In returning the 11 AFW pump to service, the licensee restored the smoothness of the outboard turbine bearing babbitt surface. The licensee provided the shavings from the babbitt to an independent consulting firm to analyze for the presence of foreign material. The analyses of this material was inconclusive in regard to the presence of permatex sealant, since apparently the black residue had been wiped off the bearing babbitt prior to machining. Since the licensee's analysis used an FTIR scan, which is a non-destructive test, the inspectors questioned whether the substance found in the bearing and filtered from the sump oil was available. As a result of inspector questioning of personnel from various departments, the licensee retrieved two unlabeled swatches of cloth with a few minute flakes of black material, apparently removed from the failed bearing and filtered from the sump oil respectively. The licensee had this material analyzed after the inspection. Preliminary FTIR scan results indicated that the material filtered from the sump oil was likely permatex sealant. The test results of the material from the bearing were inconclusive in regard to the presence of sealant.

The inspectors concluded quarantine of material from the bearing and sump oil was weak in the licensee's investigation. As a result there was limited material available for confirmatory analyses. The inspectors also noted that the oil from the 12, 21, and 22 AFW pump turbine bearing sumps had not been retained for analysis. The inspectors observed the analysis results of these oil sumps could have been compared and contrasted to the sump oil from the failed bearing to further corroborate the extent of the problem.

.3 Root Cause Evaluation

a. Inspection Scope

The inspectors reviewed the licensee's root cause evaluation of the causal factors that resulted in excessive sealant being applied to the 11 AFW turbine housing, likely causing the bearing failure on May 16, 2001. The inspectors also reviewed the licensee's operability assessments and consideration of the extent of the problem.

b. Issues and Findings

The licensee's root cause evaluation concluded that the vendor technical manual guidance was not adequate to ensure sealant material was applied in proper amounts.

This was identified as the single causal factor leading to excessive sealant application. However, the inspectors determined the licensee's identified causal factor was not supported by the investigation results. The inspectors concluded the bearing failure was caused by inadequate adherence to maintenance instructions during reassembly of the bearing, which resulted in the application of excessive sealant.

The maintenance order used by the mechanic for reassembly of the bearing in March 2000 referenced portions of the vendor technical manual. The vendor manual directs that permatex sealant applied to the bearing housings be limited to a maximum thickness of 0.015 inches. The vendor manual further cautions that sealant should be limited to a thin film to prevent anything blocking bearing oil flow. However, photographs of the as found condition of the bearing in May 2001 show a significant flow of sealant down the bearing housing sump walls, much more than would be expected if a coat on the order of .015 inches maximum was applied. Additionally, the maintenance orders documenting the as found condition of the bearing housing in May 2001 characterize the sealant as being applied in a "thick film." Furthermore, the vendor representative observing reassembly of the 12 AFW pump turbine bearings in April 2000 stated that too much sealant was being applied. These results support the conclusion that sealant was applied in excess of the vendor manual quantitative and qualitative direction as referenced in the maintenance order instructions.

The inspectors also reviewed training records of personnel involved in AFW turbine bearing reassembly and confirmed that training was provided in December 1998 on the application of lubricants and sealants. The inspectors confirmed that the training included examples of past instances where sealant was applied in excessive quantities causing equipment problems.

10 CFR 50, Appendix B, Criterion V, requires, in part, that activities affecting quality shall be accomplished in accordance with documented instructions, procedures, or drawings. Contrary to this, on March 25, 2000, maintenance order instructions regarding the application of sealant to the 11 AFW pump turbine outboard bearing housing were not followed in that excessive sealant was applied, which most likely resulted in the bearing failure on May 16, 2001. This issue affects the mitigating cornerstone since AFW pumps supply feedwater to the steam generators to remove decay heat when main feedwater is unavailable. As discussed in Section 4OA3.4 of this report, this issue has been assessed using the reactor safety Significance Determination Process (SDP) for At-Power Situations. The issue has been preliminarily characterized to have substantial safety significance (Yellow) based on the equipment function in removing decay heat and the length of time the excessive sealant was applied. This result is consistent with the risk assessment performed by the licensee and documented to the NRC in license event report (LER) 50-317/01-001-00 dated July 13, 2001. In accordance with NRC Enforcement Policy and the reactor safety SDP, this issue is considered to be an apparent violation of TS 5.4.2. **(AV 50-317/01-009-02; EA 01-206)**

.4 Prior Opportunities for Identification

a. Inspection Scope

The inspectors reviewed the licensee's root cause evaluation to determine whether the licensee identified how long the causal factors existed that led to the bearing failure and whether there were prior opportunities for identification of the problem.

b. Issues and Findings

The licensee's investigation identified an excessive amount of sealant was applied to the 11 AFW turbine bearing housing in March 2000. The licensee's root cause evaluation appropriately identified two prior opportunities for identification of this issue.

In a review of the AFW system history, the licensee identified that a root cause analysis completed in 1996 for a bearing failure on the 11 AFW turbine identified the primary cause to be an unbalanced turbine rotor. Subsequently the turbine rotors of all AFW pumps were dynamically balanced. The causal analysis was sufficiently broad in scope to identify and address other plausible causes of the turbine bearing failure in 1996. The report stated that sealant (RTV used at that time) intrusion into the bearing was plausible since copious quantities of RTV were found to be extruded into the bearing housing when the bearing caps were removed. The corrective action at that time was to allow the use of permatex as a sealant. This corrective action did not prevent sealant intrusion into the bearing in May 2001. A second opportunity to identify this problem occurred in April 2000 when the vendor verbally informed the mechanic, during reassembly of the 12 AFW turbine, that too much sealant was being applied to the bearing housing. The opportunity was missed when this issue was not entered into the corrective action program for evaluation.

The inspectors identified an additional opportunity to identify this problem. On September 14, 2000, the 11 AFW pump was in service to provide feedwater flow following an automatic reactor trip. After approximately two hours of run time, the outboard turbine bearing temperature reached a temperature of 196°F. The plant computer point readout for this bearing changes color at 195°F (warning) to inform operators of a potentially abnormal condition. The plant computer point again changes color at 200°F (alert) and 205°F (critical) to alert operators of an equipment problem. As a result of concerns about the bearing temperature, operators secured the 11 AFW pump and initiated IR3-042-199 to evaluate the issue. Engineering personnel canceled the IR based on temperatures not being significantly different than those observed since 1996.

The inspectors confirmed that the 11 AFW pump outboard turbine bearing steady state temperature generally ran in the low 190°F range. Although within the vendor manual recommended limit of 210°F, this bearing temperature was marginally higher than in the past and higher than the other AFW outboard turbine bearings, whose temperature was typically between 175 to 185°F. The inspectors noted that the 11 AFW oil sample analyses from May 2000 and November 2000 indicated increased oil viscosity in the outboard turbine oil sump. Some increase in viscosity over time is expected, however, increasing viscosity will tend to increase the bearing running temperature due to increasing oil flow friction.

The inspectors concluded the higher than normal bearing temperature on the 11 AFW turbine bearing did not likely cause the bearing failure in May 2001, since bearing

inspection results during previous years of running with temperatures in the low 190°F range were satisfactory. However, considering concerns with the turbine temperature led operations personnel to secure the pump, and the trending information indicating that running temperatures were higher, and oil condition was marginal, the inspectors concluded the engineering response to maintain normal trending to be a missed opportunity to investigate the bearing sump oil condition and potentially identify sealant intrusion into the oil sump.

.5 Corrective Actions

a. Inspection Scope

The inspectors reviewed the corrective actions identified in the licensee's root cause evaluation report to determine whether they addressed the causal factors. Additionally the inspectors reviewed whether the corrective actions have been prioritized with consideration of the risk significance.

b. Issues and Findings

The inspectors reviewed the licensee's immediate corrective actions to restore the 11 AFW pump to operability and address the extent of the problem and found them to be adequate. The 11 AFW pump turbine bearings were restored to within specifications and the pump tested with satisfactory results. The 12, 21 and 22 AFW pump turbine bearing housings and sumps were inspected to determine the potential for sealant intrusion into the bearings. Visual inspections indicated that less sealant had been applied to these components, and there was not evidence of sealant flow down the sump walls. The bearing oil sumps for all turbine-driven AFW pumps were drained, flushed, and refilled with new oil.

With regard to corrective actions to address the causal factors that led to the bearing failure, although the inspectors disagreed with the causal factor identified by the licensee for excessive sealant application, namely inadequate vendor manual direction, the licensee's intended corrective actions were sufficiently broad to accommodate the procedural adherence issue identified by the inspectors. The licensee tracked corrective actions to review and revise turbine overhaul procedures and instructions as required and to conduct additional training with maintenance personnel on the lessons learned from this event. The licensee's corrective actions also addressed the extent of the problem in that an action item was identified to review other equipment procedures that involve application of sealant.

Additionally, the inspectors observed that the corrective actions completed or intended by the licensee were appropriately broad to compensate for uncertainty in the identified cause of the bearing failure. While the licensee's investigation identified excessive sealant application as the likely cause of the bearing failure, the corrective actions address the potential for foreign material intrusion into the bearing during other activities. In discussing the procedure and instruction review underway, the inspectors determined the licensee was in the process of reviewing the periodic maintenance orders and procedures for AFW oil sampling, AFW bearing inspection, and AFW turbine overhaul against vendor manual technical guidance.

As part of their investigation, the licensee determined that the MO instructions did not implement some vendor manual recommendations. The vendor manual recommended that the sump oil be changed out each time the bearing was disassembled; however, the MO instructions did not require this. The vendor manual also recommended that oil be filtered through a 5 micron filter prior to being added to the oil sump; however, the make-up oil was not filtered to this degree. The vendor manual recommended that the oil rings be checked for roundness; however, the MO instructions do not include this check.

During the inspection the inspectors identified an additional deficiency in the MO instructions for bearing inspection and reassembly after turbine overspeed tests. The MO instructions and the vendor manual pages referenced in the instructions did not include critical dimensions for bearing diametrical clearance and total shaft run-out. Additionally, criteria for trueness of the bearing surface was not included. The inspectors noted that while the licensee's MO instructions for bearing inspection, currently performed every four years, did not include acceptance criteria for these dimensions, the licensee's turbine overhaul procedures, currently performed every ten years, include appropriate acceptance criteria for these dimensions and require the as found and as left dimensions be recorded.

10 CFR 50 Appendix B, Criterion V requires, in part, that activities affecting quality shall be prescribed by documented instructions, and these instructions shall include appropriate quantitative and qualitative acceptance criteria for determining that important activities have been satisfactorily accomplished. Contrary to this requirement, the MO instruction for the 11, 12, 21 and 22 periodic bearing inspections did not include acceptance criteria for critical bearing tolerances. This issue had a credible impact on safety, since maintaining turbine bearings within critical tolerances is required to ensure reliable operation of the turbine-driven AFW pumps. This issue affects the mitigating cornerstone since AFW pumps supply feedwater to the steam generators to remove decay heat when main feedwater is unavailable. However, since bearing inspections of the 11 AFW pump turbine and turbine vibration trending do not indicate the bearing failed as a result of an out of tolerance condition, and the performance of the turbine bearings for the 12, 21 and 22 AFW pump turbines is satisfactory, this issue has been determined to have very low safety significance (Green) in accordance with the NRC SDP Phase 1 assessment. This violation is being treated as a non-cited violation (NCV) consistent with Section VI.A of the NRC Enforcement Policy, issued May 1, 2000 (65FR25368). **(NCV 50-317/01-009-03)** The licensee initiated IR3-041-445 to address this problem in their corrective action program.

The inspectors reviewed the 11 AFW pump surveillance test results after the bearing failure. The inspectors observed that the outboard turbine bearing steady state temperature was approximately 175°F, which is significantly less than previous steady state temperatures. The licensee indicated that the outboard bearing running temperature decreased, most likely as a result of increasing the bearing diametrical clearance, from .008 inches to .009 inches. Both are within the tolerance accepted by the manufacturer. The inspectors concluded this corrective action was appropriate since the 11 AFW turbine outboard bearing running temperature was now in line with the other AFW turbine outboard bearing temperatures. As an enhancement, the

licensee initiated incident report IR3-059-087 to consider whether another grade of oil would provide improved performance in regard to lowering bearing temperatures.

Finally, the inspectors noted that, based on past AFW bearing failures, the licensee initiated a corrective action to perform a "collective significance evaluation" of issues that, although not identified to be the cause of the most recent bearing failure, have been problems in the past. The inspectors determined that a team of licensee personnel had been formed to complete this evaluation. Considering the number of problems the licensee has experienced with these bearings, the inspectors concluded this corrective action was appropriate.

.6 NRC Risk Assessment of the Turbine-Driven Auxiliary Pump Bearing Failure

a. Inspection Scope

Considering the results of this inspection, the inspectors worked with the regional senior risk analyst (SRA) to independently assess the risk significance of the 11 AFW pump turbine bearing failure on May 16, 2001. The inspectors also reviewed the licensee's assessment of the risk as summarized in Licensee Event Report (LER) 50-317/01-001 dated July 13, 2001.

b. Issues and Findings

The inspectors used the NRC Significance Determination Process (SDP), described in NRC Inspection Manual Chapter (IMC) 0609, to evaluate the risk associated with the bearing failure. This issue had a credible impact on safety, because the ability of a turbine-driven AFW pump to perform its safety function was affected. This issue affects the mitigating systems cornerstone since AFW pumps supply feedwater to the steam generators to remove decay heat when main feedwater and condensate are unavailable. Using the SDP Phase 1 screening worksheet, the inspectors determined the risk associated with the issue should be assessed with the SDP Phase 2 worksheets specific to Calvert Cliffs, i.e., more than very low safety significance, since the bearing failure resulted in the loss of a turbine-driven AFW pump for greater than the technical specification allowed outage time.

At the time of the inspection, the Calvert Cliffs SDP Phase 2 worksheets were undergoing revision to better reflect plant operation; therefore they were not available. Consequently, the inspectors performed a risk assessment of the bearing failure using an SDP Phase 3 analysis. The inspectors used the "Standardized Plant Analysis Risk (SPAR) Model for Calvert Cliffs" to assess the bearing failure in terms of increase in core damage frequency (delta-CDF).

The Calvert Cliffs auxiliary feedwater system is a dual train system that includes two turbine-driven pumps and one motor driven pump. One train uses the motor-driven pump while the other includes the two turbine-driven pumps. Cross-tie piping is installed between Unit 1 and Unit 2 to allow the motor driven pump in one unit to supply feedwater to the AFW system in the other unit. During automatic AFW initiation, one turbine-driven pump starts and the single motor driven pump starts. Either pump is

capable of supplying sufficient feedwater flow to the steam generators to remove decay heat and cool down the primary reactor coolant system.

An excessive amount of sealant was applied to the 11 AFW pump turbine bearing housing on March 25, 2000. Subsequently, the 11 AFW pump turbine bearing failed after 10.5 hours of cumulative operation. The Calvert Cliffs Individual Plant Examination (IPE) assumes the AFW pump is capable of providing flow for 24 hours following system initiation. Since the 11 AFW bearing failed after 10.5 hours of operation, the inspectors concluded the 11 AFW pump was not capable of performing its function for its mission time from March 25, 2000 until May 16, 2001. In running the SPAR model, the 11 AFW pump was assumed to be unavailable for a period of 365 days. Additionally, the pump bearing failure was assumed to be non-recoverable since repairs would have required significant equipment disassembly, inspection, and repair under high stress conditions, and these actions are not credited in the model.

The SPAR Model indicated that, as a result of excessive sealant application to the 11 AFW pump turbine bearing housing, there was an increase in CDF, or delta-CDF, of 8.2E-6. The primary sequences of events involved a loss of offsite power event followed by diesel generator failures, which resulted in a loss of capability to remove core decay heat either by feedwater or by once through cooling of the primary system. The SPAR model includes internal event initiators only and does not model plant risk resulting from external events (seismic, fire, flood, etc). The licensee's PRA model includes both internal and external event initiators. The external event contribution to risk resulted in the licensee's delta-CDF being greater than that calculated by the NRC's SPAR model.

The licensee modeled the bearing failure using their current Probabilistic Risk Assessment (PRA), which includes both internal and external events. As indicated in the LER submitted for this event, the baseline annual CDF for Calvert Cliffs is 1.1E-4. The licensee assumed only the 11 AFW pump was affected, and assumed the excessive sealant was applied from March 25, 2000 to May 16, 2001. During this time the plant was in operating mode 1 or 2 for 387 days. The licensee used their PRA model to perform a base calculation assuming the 11 AFW pump was inoperable for 387 days. This resulted in a delta-CDF of 4E-5. The licensee reran the model assuming the 11 AFW pump probability of failure would be once per 10.5 hours of operation. The licensee also assumed some probability for successful operator actions to recover the 11 AFW pump. These actions are not modeled in the current Calvert Cliff PRA. This resulted in a delta-CDF of 2E-5. While the licensee's basis for the recovery of the 11 AFW pump was not evident to the inspectors, this assumption was not pursued further since both licensee results were in a delta-CDF range of 1E-5 to 1E-4.

The NRC noted that, based on the SPAR model alone, without consideration of plant risk due to external initiating events, the calculated delta-CDF was 8.2E-6, which is in the upper range of 1E-6 to 1E-5. However, the NRC does consider that the external contribution to risk sequences associated with AFW failure to be significant. Considering the licensee model results, which appropriately include the risk due to external initiating events, the calculated delta-CDF was 2E-5, which is in the range of 1E-5 to 1E-4. The NRC concluded the SPAR model and licensee PRA model results were consistent when the plant risk due to external initiating events is considered.

Therefore, the inspectors concluded the AFW bearing failure resulted in a delta-CDF in the range of 1E-5 to 1E-4. Findings in this range are considered to be yellow using the SDP. Consequently, the risk associated with excessive sealant application to the 11 AFW pump turbine bearing housing is considered to be of substantial safety significance (Yellow).

## 4OA6 Meetings, Including Exit

### .1 Exit Meeting Summary

On July 23, 2001, the NRC inspectors presented the inspection results to Mr. Charles Cruse, Mr. Peter Katz, and other members of the Calvert Cliffs staff. Mr. David Lew, Chief, Performance Evaluation Branch, NRC Region 1, was also in attendance. No information examined or reviewed during the inspection was considered to be proprietary. The inspectors asked the licensee whether any materials examined during the inspection should be considered proprietary. No proprietary information was identified.

## ATTACHMENT 1

SUPPLEMENTAL INFORMATION

PARTIAL LIST OF PERSONS CONTACTED

Licensee

| | |
|---|---|
| C. Cruse | Vice President |
| P. Katz | Plant General Manager |
| T. Pritchett | Manager, Nuclear Engineering Department |
| M. Navin | Superintendent, Technical Support |
| P. Furio | Nuclear Regulatory Matters |
| J. Spina | Superintendent, Nuclear Maintenance |
| M. Hunter | System Manager |
| T. Grigg | Chemistry Engineer |
| C. Earls | Chemistry Supervisor |
| B. Mrowca | Engineer, Reliability Engineering Unit |
| V. Trojan | Lubrication Engineer |
| C. Boyer | Maintenance Supervisor |

## ITEMS OPENED, CLOSED, AND DISCUSSED

Opened

| | | |
|---|---|---|
| 50-317/01-009-02 | AV | Apparent violation of 10 CFR50 Appendix B, Criterion V, which requires, in part, that activities affecting quality be accomplished in accordance with documented instructions, procedures, or drawings. Failure to follow documented instructions regarding the application of sealant to the 11 AFW pump turbine outboard bearing housing resulted in excessive sealant application, which most likely caused the bearing failure on May 16, 2001. |

Opened and Closed

| | | |
|---|---|---|
| 50-317/01-009-01 | NCV | Failure to establish measures to prevent damage or deterioration of oil used for make-up to safety related equipment. (Section 4OA3.2) |
| 50-317/01-009-03 | NCV | Failure to include acceptance criteria for critical bearing tolerances in work instructions used to reassemble the 11 AFW pump turbine bearings in March 2000. |
| 50-317/01-001 | LER | “Auxiliary Feedwater Pump Turbine Bearing Failure Caused by Sealant Intrusion” |

## LIST OF ACRONYMS USED

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|---|---|
| AFW | Auxiliary Feedwater |
| CC | Calvert Cliffs |
| CDF | Core Damage Frequency |
| FTIR | Fourier Transform Infrared Radiography |
| IMC | Inspection Manual Chapter |
| IR | Incident Report |
| LER | Licensee Event Report |
| MO | Maintenance Order |
| NRC | Nuclear Regulatory Commission |
| NVC | Non-Cited Violation |
| SDP | Significance Determination Process |
| SPAR | Standardized Plant Analysis Risk |
| SRA | Senior Risk Analyst |
| TS | Technical Specifications |

**ATTACHMENT 2**

PARTIAL LIST OF DOCUMENTS REVIEWED

"Causal Analysis entitled "11 AFW Turbine Outboard Bearing Failure," approved June 22, 2001
CC Licensee Event Report 50-317/01-001, dated July 13, 2001
CC Maintenance "Oil Issue Log" from April 1999 through June 2001.
CC Operations Administrative Policy 90-5, "Equipment Oil Control," December 13, 1995.
CC Operations Department "Oil Addition Tracking Sheets, August 2000 through March 2001.
CC Procedure FTM-3B, "Rotating Equipment Alignment," Revision 4.
CC Procedure MN-1-109, "Foreign Material Exclusion," Revision 9.
CC Procedure TURB-01, "Auxiliary Feedwater Pump Turbine Overhaul, Revision 6.
CC Operating Instruction OI-32A, Auxiliary Feedwater System, Revision 14.
CC Root Cause Analysis PD199600022, 11 AFW Pump Bearing Failure, March 11, 1997
CC Lesson Plan MM-CMAINTC01.2-0, "Sealants and Lubricants," November 12, 1998
CC Training Record MM-CMAINTC01.2, "Sealants and Lubricants"
CC Fourier Transform Infrared Radiography Scans Provided by CC Chemistry Department
ESP#ES199601662, Engineering Evaluation to Allow Use of New Design Babbitt Bearings, August 29, 1996
"Independent Review of the Temperature Excursion in the No. 11 AFW Pump Turbine Bearing, MPR-2289, revision 0, June 29, 2001
Oil Analysis Results from Analysts, Inc. for 11 AFW turbine.
Operability Determination, NO-1-106, serial number 01-010, dated May 18, 2001
Vendor Technical Manual 12083-010 for Terry Turbine AFW Pump
Vendor Drawing 12083-015, sheets 1 and 2, "Turbine Section"
Fax dated July 25, 2001, Sample Results From Oil Cans, Analysts, Inc.
Fax dated August 9, 2001, "Auxiliary Pump #11 Bearing," Preliminary Report of filter residue paper.

Maintenance Orders

MO#1199704147
MO#1199804675
MO#1199804676
MO#1200003857
MO#1200004525
MO#1200102533
MO#1200102563
MO#2200101993
MO#2200101994

Incident Reports

IR1-046-727
IR3-040-102
IR3-041-139
IR3-041-445
IR3-042-199
IR3-059-087
IR3-059-095
IR3-084-380

**ATTACHMENT 3**

TURBINE-DRIVEN AUXILIARY FEEDWATER PUMP BEARING FAILURE
CHRONOLOGY OF EVENTS

| Date | Event |
|---|---|
| 8/26/96 | 11 AFW pump outboard bearing fail. Cause determined to be imbalanced turbine rotor. Rotor balances completed over the next several years on all turbine-driven AFW pumps. |
| 8/29/96 | During rebuild of 11 AFW turbine bearings, material changes implemented via engineering services package (ESP) #ES199601662 to install tin based babbitted bearings in place of lead based babbitted bearings. During post maintenance testing maximum outboard bearing temperature noted to be 194°F. |
| 5/97 | Bearing water intrusion identified in 11 AFW outboard bearing oil sump. Bearing oil cooler replaced in kind via MO#1199606300. |
| 4/30/98 | During refueling outage, 11 AFW pump turbine overspeed test completed, followed by bearing inspection. Maintenance order indicates bearing sump drained, flushed and refilled with Texaco R&O 46 oil. This is the last record of the 11 AFW turbine bearing sump drain and refill prior to May 16, 2001, bearing failure. (Reference MO#1199704147) |
| 9/15/99 | 11 AFW oil sample taken. Results in specification. |
| 9/22/99 | Following CC Unit 1 manual reactor trip, 11 AFW pump operated to provide feedwater to steam generators for approximately six hours. Bearing steady state temperature recorded at approximately 200°F. |
| 11/11/99 | 11 AFW pump surveillance test completed. Steady state outboard turbine bearing temperature recorded to be 188°F. |
| 11/11/99 | 11 AFW turbine outboard bearing oil sump sample taken. Results in specification. |
| 3/25/00 | During refueling outage, 11 AFW pump turbine overspeed test completed, followed by bearing inspection. As found condition determined to be satisfactory. Mechanic applies sealant to bearing housing. (Reference MO#1199804675) Post maintenance test run notes bearing temperatures satisfactory. |
| 4/11/00 | During refueling outage, 12 AFW pump turbine bearings reassembled after overspeed test. Vendor representative present. Vendor observes mechanic reassembling of 12 AFW pump turbine outboard bearing and informs mechanic too much sealant is being applied bearing housing joint. Mechanic applies less sealant. (Reference MO#1199804676) |
| 5/15/00 | 11 AFW pump surveillance test completed. Steady state outboard turbine bearing temperature recorded to be 186°F. |
| 5/15/00 | 11 AFW turbine outboard bearing oil sump sample taken. Results indicate increasing oil viscosity in abnormal range. |

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| 8/9/00 | 11 AFW pump surveillance test completed. Steady state outboard turbine bearing temperature recorded to be 194°F. |
| 9/10/00 | Following CC Unit 1 automatic reactor trip, 11 AFW pump operated for approximately two hours to provide feedwater flow to steam generators. When steady state temperature of 196°F reached, operators secured 11 AFW pump due to bearing temperature concerns. Operations initiated IR3-042-199. (Reference LER 317/2000-005) |
| 11/8/00 | 11 AFW pump surveillance test completed. Steady state outboard turbine bearing temperature recorded to be 191°F. |
| 11/8/00 | 11 AFW turbine outboard bearing oil sump sample taken. Results indicate no change in oil viscosity; however viscosity remains high in abnormal range. |
| 2/7/01 | 11 AFW pump surveillance test completed. Steady state outboard turbine bearing temperature recorded to be 186°F. |
| 4/01 | During CC Unit 2 refueling outage, mechanic that reassembled 11 and 12 AFW pump turbine bearings in 2000 reassembled 21 and 22 AFW pump turbine bearings after overspeed test. Based on verbal direction provided by vendor in April 2000, mechanic applied less sealant to bearing housing joint. (Based on mechanic interview in 5/2001) |
| 5/16/01 | 11 AFW pump surveillance test performed. Results unsatisfactory since turbine outboard bearing temperature rises rapidly 88 minutes into test, requiring pump be secured. Highest recorded bearing temperature is 211°F. |
| 5/16/01 | 11 AFW turbine outboard bearing oil sump sample taken after surveillance test. Results indicate no significant change in oil viscosity; however, viscosity remains high in abnormal range. |
| 5/18/01 | Personnel disassemble and inspect 11 AFW pump bearings. Observe thick film of permatex sealant applied to the bearing housing split and some sealant extruded onto the bearing sump walls. Additionally, some visual evidence of material in the bottom of the oil reservoir. Bearing reworked, pump turbine reassembled, oil sumps drained, flushed and refilled. 11 AFW pump successfully tested and returned to operability. |
| 5/19/01 | 12, 21 and 22 AFW pump turbine bearings inspected sequentially to determine the potential for sealant intrusion into the bearings. Visual observations of bearing housing and sump wall surfaces indicate less sealant applied to these components and there is not evidence of sealant flow down the sump walls. Oil sumps drained, flushed, and refilled and AFW pumps and returned them to service. |
| 5/21/01 | Further analysis of oil from 11 AFW pump turbine outboard bearing sump on May 16 indicates oil contained fine ferrous particles, indicative of short lived condition where rubbing/loss of lubrication occurred. |
| 5/21/01 | CC management forms multi-discipline team to investigate the event, determine causes, address the extent of the problem, and develop corrective actions to prevent recurrence. |

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| 6/22/01 | CC root cause analysis report issued. |
| 6/27-7/13/01 | NRC special inspection. |