UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
612 EAST LAMAR BLVD, SUITE 400
ARLINGTON, TEXAS 76011-4125

August 12, 2010

Mr.David J. Bannister, Vice President
and Chief Nuclear Officer
Omaha Public Power District
Fort Calhoun Station FC-2-4
P.O. Box 550
Fort Calhoun, NE 68023-0550

Subject: FORT CALHOUN PLANT - NRC SPECIAL INSPECTION REPORT 05000285/2010006

Dear Mr. Bannister:

On June 30, 2010, the U.S. Nuclear Regulatory Commission (NRC) completed a special inspection at your Fort Calhoun Station to evaluate the facts and circumstances surrounding the failure to start of the turbine-driven auxiliary feedwater pump, FW-10 due to an inadequately protected reset lever. Based upon the risk and deterministic criteria specified in NRC Management Directive 8.3, "NRC Incident Investigation Program," including possible generic implications, the NRC initiated a special inspection in accordance with Inspection Procedure 93812, "Special Inspection." The basis for initiating the special inspection and the focus areas for review are detailed in the Special Inspection Charter (Attachment 2). The determination that the inspection would be conducted was made by the NRC on March 11, 2010, and the on-site inspection started on March 22, 2010. The enclosed report documents the inspection findings that were discussed on June 30, 2010, with Mr. Jeff Reinhart, Site Vice President and other members of your staff.

The inspection examined activities conducted under your license as they relate to safety and compliance with the Commission's rules and regulations and with the conditions of your license. The inspectors reviewed selected procedures and records, observed activities, and interviewed plant personnel.

This report documents three self-revealing findings and one NRC-identified finding of very low safety significance (Green). All four of these findings were determined to involve violations of NRC requirements. However, because of their very low safety significance and because they are entered into your corrective action program, the NRC is treating these findings as noncited violations, consistent with Section VI.A.1 of the NRC Enforcement Policy. If you contest the violations or the significance of the noncited violations, you should provide a response within 30 days of the date of this inspection report, with the basis for your denial, to the U.S. Nuclear Regulatory Commission, ATTN: Document Control Desk, Washington, D.C. 20555-0001, with copies to the Regional Administrator, U.S. Nuclear Regulatory Commission, Region IV, 612 E. Lamar Blvd, Suite 400, Arlington, Texas, 76011-4125; the Director, Office of Enforcement, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001; and the

NRC Resident Inspector at the Callaway Plant. In addition, if you disagree with the crosscutting aspect assigned to any finding in this report, you should provide a response within 30 days of the date of this inspection report, with the basis for your disagreement, to the Regional Administrator, Region IV, and the NRC Resident Inspector at the Fort Calhoun Station.

In accordance with 10 CFR 2.390 of the NRC's "Rules of Practice," a copy of this letter, and its enclosure, will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records component of NRC's document system (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html (the Public Electronic Reading Room).

Sincerely,

/RA/ RVA for

Jeffrey A. Clark, P.E.
Chief, Project Branch E
Division of Reactor Projects

Docket: 50-285
License: DPR-40

Enclosure: NRC Inspection Report 05000285/2010006
w/Attachments:

Attachment 1: Supplemental Information
Attachment 2: Special Inspection Charter
Attachment 3: Timeline of Activites Relating to 2009 and 2010 TDAFW Pump Failures
Attachment 4: Final Significance Determination Evaluation

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U.S. NUCLEAR REGULATORY COMMISSION
REGION IV

Docket:	05000285
License:	DPR-40
Report:	05000285/2010006
Licensee:	Omaha Public Power District
Facility:	Fort Calhoun Station
Location:	9610 Power Lane Blair, NE 68008
Dates:	March 22 through June 30, 2010
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Approved By:	J. Clark, Chief, P.E., Project Branch E Division of Reactor Projects

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SUMMARY OF FINDINGS

IR 05000285/2010006; 3/22/10 – 6/30/10; Fort Calhoun Station; Special inspection into turbine-driven auxiliary feedwater pump failures to start.

The report covered one week of on-site inspection and in-office review through June 30, 2010. Four resident inspectors performed the inspection with assistance from two region based inspectors including a senior reactor analyst. Four Green noncited violations were identified. The significance of most findings is indicated by their color (Green, White, Yellow, or Red) using Inspection Manual Chapter 0609, "Significance Determination Process." The crosscutting aspect was determined using Inspection Manual Chapter 0310, “Components Within the Cross-Cutting Area.” Findings for which the significance determination process does not apply may be Green or be assigned a severity level after NRC management review. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 4, dated December 2006.

A. NRC-Identified and Self Revealing Findings

Cornerstone: Mitigating Systems

- Green. A self-revealing noncited violation of 10 CFR 50 Appendix B, Criterion XVI, “Corrective Action,” occurred for the licensee’s failure to assure that a condition adverse to quality was corrected. Specifically, five instances were identified where the licensee failed to correct an adverse configuration design which allowed the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip reset lever to be bumped and unlatched which would have prevented the pump from starting when required. The failure to correct this adverse condition resulted in the turbine-driven auxiliary feedwater pump reset lever becoming unlatched and causing the pump to trip off during a surveillance test start attempt on February 17, 2010. The licensee entered this issue in their corrective action program as Condition Report CR-2010-0813.

  The finding is more than minor because it is associated with the equipment performance attribute of the Mitigating Systems Cornerstone, and affected the cornerstone objective of ensuring the availability, reliability, and capability of systems that respond to initiating events. Using Manual Chapter 0609.04, "Phase 1 – Initial Screening and Characterization of Findings," the issue screened as potentially risk significant since the finding represented a loss of system safety function of a single train for greater than the technical specification allowed outage time. The finding required a Phase 2 analysis. When evaluated per Manual Chapter 0609, Appendix A, "Determining the Significance of Reactor Inspection Findings for At-Power Situations," and the Fort Calhoun Phase 2 pre-solved table item, “Turbine-driven Auxiliary Feedwater Pump Fails to Start,” the inspectors determined this finding to be potentially risk significant. A Phase 3 analysis was performed and it was determined that the finding was of very low risk significance. This finding has a crosscutting aspect in the area of problem identification and resolution associated with the corrective action program component because the licensee’s periodic trends and assessments did not recognize the significance of precursor events related to bumping the reset lever and prompt action to prevent further problems with the turbine-driven auxiliary feedwater pump FW-10 [P.1(b)] (Section 1.2.1).

- Green. The team identified a noncited violation of Technical Specification 5.8.1.a regarding the licensee's failure to implement written procedures as recommended in Regulatory Guide 1.33, Revision 2, Appendix A, February 1978. Paragraph 3.l of Appendix A requires procedures for startup, shutdown and operation of the auxiliary feedwater system. Specifically, the licensee had no procedural guidance to verify full engagement of the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip mechanism when latched. This resulted in the licensee's failure to identify the partially latched condition of the exhaust trip mechanism which subsequently vibrated loose during a surveillance test causing a start failure of the pump, on February 17, 2010. The licensee entered this deficiency in their corrective action program as Condition Report CR 2010-0813.

  This finding is greater than minor because it was associated with the Mitigating Systems Cornerstone attribute of procedural quality and it affected the cornerstone objective to ensure the availability, reliability, and capability of systems that respond to initiating events to prevent undesirable consequences. Using Manual Chapter 0609.04, "Phase 1 – Initial Screening and Characterization of Findings," the issue screened as very low safety significance because it was not a design or qualification deficiency that resulted in a loss of operability or functionality, did not create a loss of system safety function of a single train for greater than the technical specification allowed outage time and did not affect seismic, flooding, or severe weather initiating events. The finding has a crosscutting aspect in the area of problem identification and resolution associated with operating experience because the licensee failed to implement and institutionalize operating experience through changes to station operating procedures when they failed to incorporate industry information to verify the turbine-driven auxiliary feedwater pump is fully latched [P.2(b)] (Section 1.2.2).

- Green. A self-revealing noncited violation of Technical Specification 5.8.1.a was identified regarding the licensee's failure to implement and maintain the applicable procedures recommended in Regulatory Guide 1.33, Revision 2, Appendix A, February 1978. Paragraph 9.a of Appendix A requires that such maintenance that can affect the performance of safety-related equipment be properly preplanned and performed in accordance with documented instructions. Specifically, the licensee failed to have an adequate procedure for ensuring air was vented from the auxiliary feedwater pump control oil system following maintenance. As a result, the turbine-driven auxiliary feedwater pump failed to start during the February 26, 2009, operability test. The licensee has entered this issue into their corrective action program as Condition Report CR-2009-0905.

  The finding is more than minor because it is associated with the Mitigating System Cornerstone attribute of procedure quality and adversely affected the cornerstone objective of ensuring the availability, reliability, and capability of systems that respond to initiating events to prevent undesirable consequences (i.e., core damage). Using Manual Chapter 0609.04, "Phase 1 Initial Screening and Characterization of Findings," the finding was found to have very low safety significance (Green) because it was not a design deficiency; did not represent loss of a safety function, loss of a single train for greater than its allowed outage

time, or loss of a non-technical specification required train of equipment; and did not screen as potentially risk significant due to a seismic, flooding, or severe weather initiating event. The finding has a crosscutting aspect in the area of human performance associated with conservative assumptions due to the licensee failing to identify possible unintended consequences of high points in a control oil system tubing design change that could become air bound and interfere with fast starts of the turbine-driven auxiliary feedwater pump [H.1(b)] (Section 1.3.1).

- Green. A self revealing noncited violation of 10 CFR, Part 50, Appendix B, Criterion III, "Design Control," occurred when the licensee failed to ensure that the design basis of certain structures, systems and components were translated into specifications, drawings, procedures, and instructions when implementing Engineering Change 45105. Specifically, this design change reduced the turbine-driven auxiliary feedwater pump's margin between the pump discharge pressure and the pump's high discharge pressure trip set-point resulting in an April 6, 2009, high pump discharge pressure trip during a scheduled surveillance test start. The licensee entered this issue in their corrective action program as Condition Report CR-2009-1611.

  The inspectors determined the finding is more than minor because it is associated with the design control attribute of the Mitigating Systems Cornerstone, and adversely affected the cornerstone objective to ensure the availability, reliability and capability of systems that respond to initiating events to prevent undesirable consequences. Using Manual Chapter 0609.04, "Phase 1 – Initial Screening and Characterization of Findings," the issue screened as potentially risk significant since the finding represented a loss of system safety function of a single train for greater than the technical specification allowed outage time. The finding required a Phase 2 analysis. When evaluated per Manual Chapter 0609, Appendix A, "Determining the Significance of Reactor Inspection Findings for At-Power Situations," and the Fort Calhoun Phase 2 presolved table item, "Turbine-driven Auxiliary Feedwater Pump Fails to Start," the inspectors determined this finding to be potentially risk significant. The finding was forwarded to a senior reactor analyst for review. A Phase 3 analysis was performed and it was determined that the finding was of very low risk significance. The finding has a crosscutting aspect in the area of human performance because the licensee failed to use conservative assumptions in decision making when a nonconservative design margin was approved and implemented on the turbine-driven auxiliary feedwater pump [H.1(b)] (Section 1.3.2).

B. Licensee-Identified Violations

None

REPORT DETAILS

1. REACTOR SAFETY

Cornerstones: Initiating Events, Mitigating Systems, Barrier Integrity, and Emergency Preparedness

1.0 Special Inspection Scope

On February 17, 2010, the turbine-driven auxiliary feedwater pump (FW-10) tripped off following a start demand signal during a monthly operability surveillance test. The FW-10 steam turbine exhaust backpressure trip reset lever was noticed to trip shortly after the pump start. In accordance with Management Directive 8.3, “NRC Incident Investigation Program,” the NRC determined that a special inspection was warranted, in part, based on the potential safety significance and because of previous problems with this pump that were not conclusively resolved.

The inspection charter required the team to: (1) review the circumstances related to the discovery of the degraded condition, (2) assess the licensee’s determination of cause and effectiveness of actions taken to resolve and prevent recurrence of these problems, and (3) assess the effectiveness of licensee programs to maintain the physical condition of the turbine-driven auxiliary feedwater pump. The team evaluated if the licensee took appropriate actions to address these issues including extent of condition, extent of cause, and common cause questions. The inspectors reviewed the licensee’s seismic design basis to ensure the seismic robustness of the turbine-driven auxiliary feedwater pump and that the surrounding structures were maintained to ensure their function under design-basis conditions.

The team conducted their reviews in accordance with NRC Inspection Procedure 93812, "Special Inspection Procedure." The special inspection team reviewed procedures, corrective action documents, as well as design and maintenance records for the equipment of concern. The team interviewed key station personnel regarding the events, reviewed the root cause analysis, and assessed the adequacy of corrective actions. The team walked down and inspected the equipment in the field. A list of specific documents reviewed is provided in Attachment 1. The charter for the special inspection is provided as Attachment 2.

2.0 Review of the Turbine-driven Auxiliary Feedwater Pump Reset Lever Trip February 17, 2010

Background

On February 17, 2010, the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip reset lever was seen to unlatch and trip when FW-10 was started for Surveillance Test OP-ST-AFW-004, “Auxiliary Feedwater Pump FW-10 Operability Test.” The turbine-driven auxiliary feedwater pump is a steam-driven pump which utilizes a Coffin turbine as a prime mover supplied by steam from the steam generators. The turbine has an exhaust backpressure trip mechanism consisting of a trip piston actuated by a bellows connected to the turbine’s exhaust line, a trip latch and a reset lever. A high backpressure of 35 psig +/- 10 psig (normal backpressure is 4 to 6 psig) would cause the trip piston to extend pushing up on the trip latch lever, unlatching the

trip lever latch plate from the reset lever pin. When the reset lever pin is released a spring pulls the reset lever against the mechanical governor causing the turbine to shut down.

In response to the FW-10 trip the licensee performed troubleshooting to check for blockage of the steam exhaust pipe, examined the backpressure trip linkage and checked the calibration of the backpressure trip piston. It was visually verified that there was no blockage in the accessible portions of the steam exhaust piping. Examination of the trip linkage found no abnormalities and calibration of the trip piston noted the as-found setpoint was in tolerance. The calibration work records did note that there is normally a few thousandths of an inch gap between the backpressure trip piston plunger and the trip latch, but no gap was visible, and a piece of paper could not be slid between the plunger and the trip latch. Interference between the trip piston plunger and the trip lever would interfere with a full latch between the trip lever and the reset lever. Immediately prior to the trip, Surveillance Test IC-ST-IA-3009, "Operability Test of IA-YCV-1045-C and Close Stroke Test of YCV-1045," was performed. Surveillance Test IC-ST-IA-3009 results in workers being in close proximity to the reset lever, which if inadvertently bumped could have left the reset lever not fully engaged with the trip latch. A bump causing a partial unlatching between the trip latch and reset lever would increase the risk of normal vibrations causing a trip during the pump start. Based on this troubleshooting and three successful test runs FW-10 was returned to service.

Further troubleshooting on March 9 and 19, 2010, verified that the backpressure trip mechanism will trip if the trip latch or reset lever are bumped or vibrated. A reenactment of the partially unlatched condition was performed. The trip latch and reset lever were manually placed in a partially unlatched condition, and the pump was started. After the pump start, the trip latch and reset lever unlatched, tripping the pump off. This demonstrates that if the trip lever latch and reset lever pin are partially unlatched, the pump will trip when normal pump startup vibration occurs.

The licensee implemented an interim corrective action to control access to the cage that contains FW-10. A memo was issued on March 17, 2010, to operations personnel and management, ensuring that any plant personnel entering the FW-10 cage area are required to have a face to face briefing with the shift manager. The purpose of the briefing is to accomplish the following: 1) to increase personnel awareness of the exhaust backpressure trip mechanism location; 2) provide a review of operating experience associated with bumping the trip mechanism; 3) for personnel entering the FW-10 cage area, ensure that they have established basic measures to prevent bumping the backpressure trip mechanism; and 4) to establish a communication protocol to notify the control room when the personnel leave the FW-10 caged area. The process also requires that a spotter be present to ensure that all personnel and equipment remain at least six inches away from the exhaust backpressure reset lever. Finally, after personnel have left the caged area, operations personnel will verify the FW-10 backpressure trip lever is in its proper reset and fully latched condition. Longer term corrective actions are to install a design change to remove or protect the FW-10 backpressure trip mechanism and revise the FW-10 procedures to verify that the backpressure trip is fully engaged following any shutdown of FW-10.

a. Inspection Scope

The team evaluated the events leading up to and the licensee response following the failure to start of the Fort Calhoun turbine-driven auxiliary feedwater pump FW-10, on February 17, 2010. In order to review each area of the special inspection charter issued on March 11, 2010, the team reviewed calculations, design documents, licensing documents, work orders, modification packages, operational procedures, and corrective action documents. The team evaluated licensee compliance with the applicable regulatory requirements and applicable codes and standards. The team interviewed key station personnel from operations, design and system engineering and the corrective action program. The team assessed the licensee's implementation of their corrective action program, design controls, and procedure implementation.

b. Findings

.1 Introduction. A Green self-revealing noncited violation of 10 CFR 50 Appendix B, Criterion XVI, "Corrective Action," occurred for the licensee's failure to assure that a condition adverse to quality was corrected. Specifically, five instances were identified where the licensee failed to correct an adverse configuration design which allowed the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip reset lever to be bumped and unlatched which would have prevented the pump from starting when required. The failure to correct this adverse condition resulted in the turbine-driven auxiliary feedwater pump FW-10 reset lever becoming unlatched causing the pump to trip off during a surveillance test start attempt on February 17, 2010.

Description. On February 17, 2010, turbine-driven auxiliary feedwater Pump FW-10 exhaust backpressure trip reset lever was seen to unlatch and trip when started for Surveillance Test OP-ST-AFW-004, "Auxiliary Feedwater Pump FW-10 Operability Test." The licensee initiated a significant condition adverse to quality Condition Report CR-2010-0819 to investigate the trip of the turbine-driven auxiliary feedwater pump due to an apparently inadequately latched exhaust backpressure trip mechanism.

The attached timeline of activities shows that the reset lever has been bumped and tripped five times, starting in 2001 up to a period between the January 20, 2010, successful FW-10 run and the February 17, 2010, unsuccessful FW-10 surveillance start. The bumping precursor events were different from this event in that the precursor bumping immediately tripped the lever and the turbine was not running. Two of the precursor events occurred when the plant was online resulting in FW-10 being unavailable and an unplanned entry into Technical Specification 2.5(1)B which requires the inoperable pump to be restored to service within 24 hours. Two of the events occurred during the performance of surveillance Procedure IC-ST-IA-3009, "Operability Test of IA-YCV-1045-C and Close Stroke Test of YCV-1045." This test requires personnel to stand in close proximity to the turbine exhaust backpressure trip reset lever to reach an overhead valve. This surveillance test had also been performed immediately prior to the February 17, 2010, unsuccessful start attempt for the FW-10 operability test. The licensee indicated in their root-cause analysis that the reset lever may have again been bumped, this time not enough to trip, but enough to partially unlatch the mechanism. The licensee's root cause analysis determined, "The FW-10 backpressure trip reset lever (FW-64-RL) is susceptible to lateral forces that can result in the trip latch (FW-64) and reset lever (FW-64-RL) becoming partially unlatched." The licensee also identified as a contributing cause that, "the corrective action trending process prescribed

in SO-R-2, Condition Reporting and Corrective Action, and FCSG-24, Corrective Action Program Guideline, was not effective in identifying and reducing or eliminating the susceptibility of accidentally bumping the backpressure trip latch (FW-64) or reset lever (FW-64-RL)."

Sometime between the last successful FW-10 pump run on January 20, 2010, and the failure to start on February 17, 2010, the reset lever was apparently bumped enough to partially unlatch it. In this partially latched condition, FW-10 was inoperable and unavailable to support the Mitigating System Cornerstone objective of ensuring the availability and reliability of systems that respond to initiating events. The licensee has implemented interim corrective actions to verify the trip lever is fully latched after any person has entered the FW-10 cage. There is a corrective action plan to implement a design change to remove or protect the trip lever to prevent any recurrence of this failure.

Analysis. The performance deficiency associated with this finding involved the licensee's failure to correct repeated tripping of the turbine-driven auxiliary feedwater pump reset latch that demonstrated the susceptibility of the mechanism to bumping. The finding is more than minor because it is associated with the equipment performance attribute of the Mitigating Systems Cornerstone, and affected the cornerstone objective of ensuring the availability, reliability, and capability of systems that respond to initiating events. Using Manual Chapter 0609.04, "Phase 1 – Initial Screening and Characterization of Findings," the issue screened as potentially risk significant since the finding represented a loss of system safety function of a single train for greater than the technical specification allowed outage time. The finding required a Phase 2 analysis. When evaluated per Manual Chapter 0609, Appendix A, "Determining the Significance of Reactor Inspection Findings for At-Power Situations," and the Fort Calhoun Phase 2 presolved table item, "Turbine-driven Auxiliary Feedwater Pump Fails to Start," the inspectors determined this finding to be potentially risk significant. The finding was forwarded to a senior reactor analyst for review. The senior reactor analyst performed the Phase 3 analysis (Attachment 4) and it was determined that the finding was of very low risk significance. This finding has a crosscutting aspect in the area of problem identification and resolution associated with the corrective action program component because the licensee's periodic trends and assessments did not recognize the significance of precursor events related to bumping the reset lever and prompt action to prevent further problems with the turbine-driven auxiliary feedwater pump FW-10 [P.1(b)].

Enforcement. Title 10 CFR, Part 50, Appendix B, Criterion XVI, "Corrective Action," requires, in part, that conditions adverse to quality are identified and corrected. Contrary to this, repeated trips of the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip mechanism, due to bumping, occurred without the condition being corrected. Because the violation was of very low safety significance, was not repetitive or willful, and was entered into the licensee's corrective action program as Condition Report CR-2010-813, this violation is being treated as a noncited violation, consistent with the NRC Enforcement Policy Section VI.A.1: NCV 05000285/2010006-01, "Failure to Correct Repeated Tripping of the Turbine-Driven Auxiliary Feedwater Pump FW-10."

.2 Introduction. The team identified a Green noncited violation of Technical Specification 5.8.1.a regarding the licensee's failure to implement written procedures as recommended in Regulatory Guide 1.33, Revision 2, Appendix A, February 1978.

Paragraph 3.l of Appendix A requires procedures for startup, shutdown and operation of the auxiliary feedwater system. Specifically, the licensee had no procedural guidance to verify full engagement of the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip mechanism when latched. This resulted in the licensee's failure to identify the partially latched condition of the FW-10 turbine exhaust backpressure trip mechanism which subsequently vibrated loose during a surveillance test causing a start failure of FW-10, on February 17, 2010.

Description. On December 17, 2009, the turbine-driven auxiliary feedwater pump FW-10 was run per OP-ST-AFW-3011, "Auxiliary Feedwater Pump FW-10, Steam Isolation Valve, and Check Valve Tests." The backpressure trip mechanism is reset per step 7.60 but does not require verification of a fully latched condition. On December 18 and 26, 2009, and on January 20, 2010, FW-10 was run per surveillance test Procedure OP-ST-AFW-004, "Auxiliary Feedwater Startup and System Operation," and while the backpressure trip latch was not manipulated there were no procedural steps to verify the backpressure trip was fully latched after operation. On February 17, 2010, the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip reset lever was seen to unlatch and trip when started for Surveillance Test OP-ST-AFW-004. The licensee initiated a significant condition adverse to quality Condition Report CR-2010-0819 to investigate the trip of the turbine-driven auxiliary feedwater pump due to an inadequately latched exhaust backpressure trip mechanism.

The inspectors noted that industry guidance on turbine-driven auxiliary feedwater pump equipment recommends a daily walkdown to perform, among other checks, a verification of "proper system and turbine valve lineup, paying particular attention to the turbine's . . . trip latch engagement . . . ." The inspectors have found similar instances where the licensee's singular use of a Curtis turbine-driven auxiliary feedwater pump has led them to not fully utilize relevant operating experience and industry recommendations for similar equipment. In this case the failure to procedurally require verification of a fully latched condition of their trip mechanism resulted in the February 17, 2010, failure to start of the turbine-driven auxiliary feedwater pump and a resulting loss of availability and reliability of a system that is required to respond during an event to prevent undesirable consequences, an objective of the Mitigating Systems Cornerstone. The licensee has initiated interim corrective actions to control access to the FW-10 cage, including actions to verify that the exhaust backpressure trip mechanism is fully latched after any cage entry. In addition, the licensee has taken actions to revise operation procedures for FW-10 to require verification that the exhaust backpressure trip mechanism is fully latched.

Analysis. The failure to have an adequate procedure to assure that the auxiliary feedwater pump FW-10 exhaust backpressure trip mechanism is fully latched, following maintenance and/or operational activities on or near the pump, is a performance deficiency. This finding is greater than minor because it was associated with the Mitigating Systems Cornerstone attribute of procedural quality and it affected the cornerstone objective to ensure the availability, reliability, and capability of systems that respond to initiating events to prevent undesirable consequences. Using Manual Chapter 0609.04, "Phase 1 – Initial Screening and Characterization of Findings," the issue screened as very low safety significance because it was not a design or qualification deficiency that resulted in a loss of operability or functionality, did not create a loss of system safety function of a single train for greater than the technical specification allowed outage time and did not affect seismic, flooding, or severe weather

initiating events. The finding has a crosscutting aspect in the area of problem identification and resolution associated with operating experience because the licensee failed to implement and institutionalize operating experience through changes to station operating procedures when they failed to incorporate industry information to verify the turbine-driven auxiliary feedwater pump is fully latched [P.2(b)].

Enforcement. Technical Specification 5.8.1.a requires that licensees establish, implement and maintain the applicable procedures recommended in Regulatory Guide 1.33, Revision 2, Appendix A, February 1978. Section 3.l. of Appendix A requires procedures for startup, shutdown and operation of the auxiliary feedwater system. Contrary to the above, until February 17, 2010, the licensee turbine-driven auxiliary feedwater pump FW-10 operating procedures and access control procedures did not verify that the pump's turbine exhaust backpressure trip mechanism was fully latched. Because of the very low safety significance of this finding and because the licensee has entered this issue into their corrective action program as Condition Report 2010-0813, this violation is being treated as a noncited violation in accordance with Section VI.A.1 of the Enforcement Policy: NCV 05000285/2010006-02, "Failure to Verify That the Turbine-driven Auxiliary Feedwater Pump Exhaust Backpressure Trip Lever was Fully Latched."

3.0 Review of other Recent Turbine-driven Auxiliary Feedwater Pump Failures

Background

In addition to the February 17, 2010, trip of the turbine-driven auxiliary feedwater pump FW-10 on high turbine exhaust backpressure, two other FW-10 failures have occurred recently. On April 6, 2009, FW-10 tripped approximately one minute after the pump started during an increased frequency surveillance test start using Procedure OP-ST-AFW-004, "Auxilary Feedwater Pump FW-10 Operability Test." Earlier that year, on February 26, 2009, FW-10 failed to start when performing Procedure OP- ST-AFW-004 for postmaintenance testing following Construction Work Order 322162-01 maintenance.

Failure to Vent Air Following Maintenance.

Licensee Root Cause Analysis 2009-0905 investigation into the February 26, 2009, failure to start of FW-10 noted that a 2001 design change, EC 14994, "FW-10 Reliability Enhancements," created a new high point in the control oil system. As part of the design change, the external sweated copper tubing on the lube oil system and control oil system was replaced with stainless steel tubing and Swagelok fittings. During this replacement, the craft installed the tubing using prefabricated runs and field routed the tubing as necessary. As a result, the lube oil line from the mechanical oil pump to the governor speed control was installed with two high points, one high point in the line supplying the oil relay and one drip line supplying the governor hood. When this change was made in 2001 engineering did not know that the oil tubing routing was a critical factor. The concerns with high points in a system are: 1) that during idle periods, air can be introduced into the system through a leak in one of the tubing connections; or 2) if the tubing is removed for maintenance and the fluid in the system drains from any high points. As a result, an air slug can be introduced into the system during the initial operation of the affected system. The inspection team has noted at other plants that work instructions, vendor manuals and operational experience on turbine-driven auxiliary

feedwater pump governor hydraulic systems require various methods to ensure air is removed prior to returning the equipment to operational status. On February 26, 2009, work was performed to change the mechanical governor speed setpoint to raise turbine speed slightly. This required removing tubing connected to the governor hood. Following maintenance there were no instructions to ensure air was vented from the control oil system and though a maintenance run was performed prior to the operability run it was not sufficient to remove the trapped air. When the turbine was started for the operability test, the air slowed the control oil system response resulting in a slow sluggish turbine start that was then terminated by plant operations.

Inadequate Design Margin

On February 26, 2009, a design change to increase the discharge pressure of the turbine-driven auxiliary feedwater pump FW-10 from 1170 psig to 1210 psig was implemented by increasing the turbine governor speed setpoint. When initial governor speed adjustment was completed and the pump was run to check the result, discharge pressure was found slightly above the desired 1210 psig with actual pressure being 1240 psig. Due to the work being performed within a 24 hour technical specification limiting condition for operation the licensee investigation concluded that there was reluctance to perform another adjustment to lower speed due to time pressure. Instead, it was decided to accept the 1240 psig pump discharge pressure and another design change was made to document 1280 psig as the maximum discharge pressure limit. This design change also evaluated the new smaller 170 psig margin to the high pump discharge pressure trip setpoint of 1450 psig and incorrectly concluded it was adequate. The licensee staff had no information on the normal turbine startup transient response affect on discharge pressure relative to the steady state pump discharge pressure. During a subsequent pump surveillance test FW-10 tripped when the high discharge pressure trip setpoint was reached during the pump startup transient.

a. Inspection Scope

The team evaluated the events leading to and the licensee response following these two failures of the Fort Calhoun turbine-driven auxiliary feedwater pump. In order to review each area of the special inspection charter issued on March 11, 2010, the team reviewed calculations, design documents, licensing documents, work orders, modification packages, and corrective action documents. The team evaluated licensee compliance with the applicable regulatory requirements and applicable codes and standards. The team interviewed key station personnel from operations, design and system engineering and the corrective action program. The team assessed licensee implementation of their corrective action program, design controls, and procedure implementation.

b. Findings

.1 Introduction. A Green self-revealing noncited violation of Technical Specification 5.8.1.a was identified regarding the licensee's failure to implement and maintain the applicable procedures recommended in Regulatory Guide 1.33, Revision 2, Appendix A, February 1978. Paragraph 9.a of Appendix A requires that such maintenance that can affect the performance of safety-related equipment be properly preplanned and performed in accordance with documented instructions. Specifically, the licensee failed to have an adequate procedure for ensuring air was vented from the turbine-driven

auxiliary feedwater pump control oil system following maintenance. As a result, the turbine-driven auxiliary feedwater pump failed to start during an operability test.

Description. On February 26, 2009, the turbine-driven auxiliary feedwater pump FW-10 failed to start (achieve normal discharge pressure and flow) when given a start signal during an operability test. This test was performed as part of the postmaintenance testing following Construction Work Order 322162-01 maintenance to increase pump discharge pressure slightly by adjusting the governor setpoint and, therefore, operating speed of the pump.

In response to the failure of FW-10 to start, operations personnel declared the pump inoperable and entered Technical Specification 2.5(1)B, with a 24 hour limiting condition for operation. Based on troubleshooting immediately following the event, the cause for the failure of the pump was indeterminate. The pump was later declared operable at 11:55 p.m. on February 26, 2009, based on no deficient components identified during troubleshooting and subsequent multiple successful pump starts.

The licensee's Condition Report CR-2009-0905 root cause analysis determined that FW-10 failed to start because air was present in the turbine's control oil system. The air in the control oil system slowed down the response of the oil relay piston that opens the turbine's governor valve. A modification to the FW-10 oil control system was installed in 2001 that replaced the control oil system's copper tubing with stainless steel. During this modification, new stainless steel tubing was installed with high points that would not self-vent following maintenance that could have allowed air into the system. Engineering staff did not understand that this was a critical factor when implementing the design change and resulted in an oil system that could not self-vent and therefore, was sensitive to air binding.

During the February 26, 2009, maintenance to adjust turbine speed, the tubing between the control oil system and the mechanical governor was disconnected to adjust the governor which allowed air to enter the control oil system. The licensee did not have a procedure in place to vent air from the control oil system following the maintenance. This resulted in a failure to start during a surveillance of a safety-related system and additional unavailability time due to troubleshooting following the failure. This affected the Mitigating System Cornerstone objective of ensuring availability and reliability of systems that respond to initiating events. It is a standard industry practice to vent air from control oil and hydraulic systems following maintenance that introduces air into the system. On systems with high points that are difficult to vent, additional effort must be taken to assure all air is vented from the system before attempting to restore operability. The licensee had no programmatic procedures/processes to address air venting following maintenance on FW-10. The licensee corrective actions to address this issue did replace the tubing to remove the high point and make the system more likely to self-vent.

Analysis. The performance deficiency associated with this finding involved the licensee's failure to have adequate instructions in Construction Work Order332162-01 to ensure air was vented from the control oil system following maintenance. The finding is more than minor because it is associated with the Mitigating System Cornerstone attribute of procedure quality and adversely affected the cornerstone objective of ensuring the availability, reliability, and capability of systems that respond to initiating events to prevent undesirable consequences (i.e., core damage). Using Manual

Chapter 0609.04, "Phase 1 Initial Screening and Characterization of Findings," the finding was found to have very low safety significance (Green) because it was not a design deficiency; did not represent loss of a safety function, loss of a single train for greater than its allowed outage time, or loss of a non-technical specification train of equipment; and did not screen as potentially risk significant due to a seismic, flooding, or severe weather initiating event. The finding has a crosscutting aspect in the area of human performance associated with conservative assumptions due to the licensee failue to identify possible unintended consequences of high points in a control oil system tubing design change that could become air bound and interfere with fast starts of the turbine-driven auxiliary feedwater pump [H.1(b)].

Enforcement. Technical Specification 5.8.1.a requires that licensees establish, implement, and maintain the applicable procedures recommended in Regulatory Guide 1.33, Revision 2, Appendix A, February 1978. Paragraph 9.a of Appendix A requires that such maintenance that can affect the performance of safety-related equipment be properly preplanned and performed in accordance with documented instructions. Contrary to this requirement, on February 26, 2009, the licensee did not provide a process to ensure air was vented from the turbine-driven auxiliary feedwater pump control oil system during maintenance. As a result, the turbine-driven auxiliary feedwater pump failed to start during an operability test. Because this violation was of very low safety significance and it was entered into the licensee's corrective action program as Condition Report CR-2009-0905, this violation is being treated as a noncited violation in accordance with Section VI.A.1 of the Enforcement Policy:
NCV 05000285/2010006-03, "Failure to Vent Control Oil Following Maintenance Results in Failure of the Turbine-driven Auxiliary Feedwater Pump to Start."

.2 Introduction. A self revealing, Green, noncited violation of 10 CFR, Part 50, Appendix B, Criterion III, "Design Control," occurred when the licensee failed to ensure that the design basis of certain structures, systems and components were translated into specifications, drawings, procedures, and instructions when implementing Engineering Change 45105. Specifically, this design change reduced the turbine-driven auxiliary feedwater pump's margin between the pump discharge pressure and the pump's high discharge pressure trip setpoint resulting in the April 6, 2009, high pump discharge pressure trip during a scheduled surveillance test start.

Description. The turbine-driven auxiliary feedwater pump, FW-10, had a pneumatic speed control system that was removed to improve pump reliability. This changed the turbine control system from a variable speed drive to a constant speed drive. Implementation of this design change required the licensee staff to determine a mechanical governor speed setpoint to allow the pump discharge pressure to meet auxiliary feedwater system head and flow requirements. The licensee staff did not properly determine the auxiliary feedwater hydraulic friction losses and as a result, when implemented in the June 2008, design change EC 34435, it resulted in a low mechanical speed limiting governor speed setpoint of 7600 rpm. This left FW-10 operating with a discharge pressure near the low limit of the pump's surveillance test acceptance criteria. This may not have left enough design steam generator flow in the event the pump minimum recirculation flow valve failed open.

On February 26, 2009, FW-10 turbine speed was raised to 7900 rpm by design change EC 45105 to obtain a discharge pressure of 1210 psig. These actions were required to obtain a discharge pressure design margin to the surveillance test minimum pump

discharge pressure acceptance criteria and addressed required forward flow with the minimum recirculation valve open. However, once again the 7900 rpm pump speed did not provide the expected pump discharge pressure results when a steady state discharge pressure of 1240 psig was reached, 30 psig above the target discharge pressure of 1210 psig. Due to the 24 hour technical specification action statement time limit it was decided to revise the acceptance criteria in design change EC 45105 to allow a new maximum pressure limit of 1280 psig. While this prevented the need for further adjustments to the mechanical governor speed setpoint it resulted in only a 170 psig margin to the FW-10 high pump discharge pressure trip set point of 1450 psig. Licensee staff lacked knowledge on typical transient pressure response that could be expected during the startup transient of the turbine-driven auxiliary feedwater pump compared to the steady state discharge pressure and this resulted in the staff making the nonconservative judgment that the 170 psig margin was adequate.

During an emergency start of the turbine-driven auxiliary feedwater pump, the steam admission valve opens, allowing a sudden inrush of steam into the governor valve and turbine. This speeds up the turbine at the same time the attached mechanical governor is speeding up and pressurizing the control oil system. This typically results in some amount of overshoot past the steady state speed until the control system brings speed back down to the setpoint. Since the turbine is driving the pump, these speed changes are seen as pump discharge pressure changes in the auxiliary feedwater piping downstream of the pump. The pump high discharge pressure trip functions as the turbine overspeed protection device and protects downstream piping from overpressure if a loss of speed control occurs. A normal startup transient may have some momentary slightly higher pressures than steady state pump discharge pressure, further reducing the margin between pump discharge pressure and the high pump discharge pressure trip setpoint. The amount of startup transient overshoot will have some variation depending on variables related to turbine and piping standby temperature, inlet steam quality, and other conditions. The inspectors noted that the licensee's turbine-driven auxiliary feedwater pump performance monitoring does include a recommended industry practice of recording pertinent transient data. Review of the recorded transient data allows for a detailed evaluation of a surveillance test, trending evaluation of a specific test from a series of tests, and supports troubleshooting required to evaluate the malfunction or degradation of components or system problems due to abnormal transients.

Following the February 26, 2009, design change that increased pump discharge pressure, FW-10 had been on an increased frequency of weekly surveillance runs with six successful surveillance tests performed up until April 6, 2009. Then FW-10 tripped approximately 1 minute after the pump started due to high discharge pressure. The 170 psig margin coupled with an increased startup transient overshoot resulted in the pump trip. The licensee did not have the transient pressure data to conclusively determine if 170 psig was an adequate margin. This resulted in a run failure of the turbine-driven auxiliary feedwater pump and additional unavailability to correct the inadequate design margin which impacted the Mitigating Systems Cornerstone objective to ensure the availability, reliability and capability of systems that respond to initiating events. The inadequate margin was introduced on February 26, 2009, and existed until April 6, 2009. Though there were six successful weekly runs prior to the seventh, the lack of knowledge on the startup transient pressure changes indicates the trip could have occurred on any of the starts and the empirical knowledge that one out of seven starts could result in a failure during this exposure period. When a Phase 3 risk analysis

was reviewed with this failure and recovery probability during the six week exposure period it was determined that there was still a very low risk significance associated with this event.

Analysis. The performance deficiency associated with this finding involved the licensee's failure to assure that the turbine-driven auxiliary feedwater pump design margin was correctly maintained during design changes affecting pump discharge pressure. The inspectors determined the finding is more than minor because it is associated with the design control attribute of the Mitigating Systems Cornerstone, and adversely affected the cornerstone objective to ensure the availability, reliability and capability of systems that respond to initiating events to prevent undesirable consequences (i.e., core damage). Using Manual Chapter 0609.04, "Phase 1 – Initial Screening and Characterization of Findings," the issue screened as potentially risk significant since the finding represented a loss of system safety function of a single train for greater than the technical specification allowed outage time. The finding required a Phase 2 analysis. When evaluated per Manual Chapter 0609, Appendix A, "Determining the Significance of Reactor Inspection Findings for At-Power Situations," and the Fort Calhoun Phase 2 presolved table item, "Turbine-driven Auxiliary Feedwater Pump Fails to Start," the inspectors determined this finding to be potentially risk significant. The finding was forwarded to a senior reactor analyst for review. The senior reactor analyst performed the Phase 3 analysis, Attachment 4, and determined that the finding was of very low risk significance. The finding has a crosscutting aspect in the area of human performance because the licensee failed to use conservative assumptions in decision making when a nonconservative design margin was approved and implemented on the turbine-driven auxiliary feedwater pump [H.1(b)].

Enforcement. Title 10 CFR, Part 50, Appendix B, Criterion III, "Design Control," requires, in part, that established measures shall assure that the design basis is correctly translated into specifications. Contrary to that, on February 26, 2009, design change EC 45105 adjusted the speed of FW-10 to 7900 rpm resulting in an inadequate margin to prevent a high discharge pressure trip of FW-10, that occurred April 6, 2009. This condition was corrected April 6, 2009, when the FW-10 high discharge pressure switch setpoint was raised from 1450 psig to 1600 psig to restore margin. Because the violation was of very low safety significance, was not repetitive or willful, and was entered into the licensee's corrective action program as Condition Report CR-2009-0905, this violation is being treated as an noncited violation, consistent with the NRC Enforcement Policy Section VI.A.1: NCV 05000285/2010006-03, "Turbine-driven Auxiliary Feedwater Pump Trip Due to Inadequate Design Margin."

4.0 Review of Root Cause Analysis, Extent of Condition and Corrective Actions

On February 17, 2010, the licensee established a root cause analysis team to investigate the facts and identify the causes associated with the failure of the turbine-driven auxiliary feedwater pump FW-10. The team conducted their review in accordance with Procedure NOD-QP-19, "Cause Analysis Program." The licensee's procedure requires the team to:

- Identify and validate root and contributing causes
- Conduct an extent of condition review
- Determine extent of cause

- Develop corrective actions

The licensee's root cause analysis Revision 1 of Condition Report CR-2010-0813, "Steam Driven Auxiliary Feedwater Pump (FW-10) Tripped Off," was completed on April 24, 2010.

As part of the special inspection charter the inspectors also reviewed the following documents:

- CR-2009-0905, Steam Driven Auxiliary Feedwater Pump (FW-10) Failed to Achieve Normal Discharge Pressure and Flow
- CR-2009-1611, Steam Driven Auxiliary Feedwater Pump (FW-10) Tripped Off
- CR-2010-0813, Steam Driven Auxiliary Feedwater Pump (FW-10) Tripped Off
- CR 2010-0910, NRC-6 Performance Indicator, MSPI Auxiliary Feedwater System, Turned FCS Red

Root Cause Methodology

The licensee performed a root cause analysis to identify the causes of the failures of the turbine-driven auxiliary feedwater pump in 2009 and 2010. As part of their review, the licensee performed extent of condition and extent of cause reviews. The root cause utilized a structured root cause analysis method in accordance with Procedure NOD-QP-19, "Cause Analysis Program." The analysis includes the event sequence (timeline), a systematic method to indentify the root/contributing causes (events and casual factors, barrier analysis, fault tree analysis, change analysis, etc.) and the method used to gather data and what data was gathered.

Root Cause and Corrective Actions to Prevent Recurrence

Condition Report CR-2009-0905. The root cause analysis for Condition Report CR-2009-0905 determined through troubleshooting, causal factor analyses and re-enactment that the root cause of the February 26, 2009, FW-10 failure to start was, "An air slug trapped under the FW-10 oil relay piston slowed the oil relay piston's resonance time." A contributing cause to the event was, "The high point created in the FW-10 oil system during installation of DC 14994 may contribute to prolonged fast speed starts of FW-10." The high point in the oil system tubing was not identified by the licensee, but by a Coffin Turbo Pump representative hired to assist in troubleshooting FW-10. Corrective actions to prevent recurrence include a design change that eliminated the high points and tubing slope to assist with self-venting, and procedure changes to direct operators to allow up to 2 minutes for the pump to start prior to tripping the turbine. The licensee evaluated their loss of feedwater accident scenario and increased the analyzed FW-10 start times from 50.9 seconds to 2 minutes.

Air in any oil or hydraulic control system would be expected to affect that systems performance. However, the licensee investigation determined there was no extent of condition when it found no operational experience with electrohydraulic controlled pumps and valves or the emergency diesel generator governor failures related to air intrusion.

The extent of the root cause investigated a slug of air in oil affecting electrohydraulic control of pumps and valves and emergency diesel generators and while no instances of air problems were found the licensee did identify a similar cause of foreign material adversely impacting operation of a control system. This resulted in a corrective action to protect against foreign material contamination of electrohydraulic pumps/valves and emergency diesel generator governors.

Condition Report CR-2009-1611. The root cause analysis for Condition Report CR-2009-1611 used event sequence, causal factor analyses and failed barrier identification to determine the root cause of the April 6, 2009, FW-10 trip on startup was, "EC 45105 (FW-10 Speed Limiting Governor Setting) and FDCR 45607 (Revise the Acceptance Criteria I EC 45105) reduced the discharge pressure margin to trip setpoint resulting in FW-10 tripping on high discharge pressure." Due to a lack of knowledge of the operating characteristics of FW-10, licensee staff made the judgment that the reduced discharge pressure margin to trip setpoint was adequate. Corrective actions included increasing the discharge pressure margin and additional guidance for control of engineering design changes.

The licensee determined there was no extent of condition since there was no internal operating experience of similar pumps that had failed due to high discharge pressure. There is an extent of cause that other plant configuration changes or engineering analysis have had an adverse impact on equipment, plant processes, or human performance. This had been addressed by corrective actions that improved definitions of engineering changes, transferred responsibility for determining the type of change process to be used from system to design engineering, and disallowed the use of field design changes for significant changes,

Condition Report CR-2010-0813. The root cause analysis for Condition Report CR-2010-0813 used event sequence, causal factor analyses and failed barrier identification to determined the root cause of the February 17, 2010, FW-10 failure to start to be, "The FW-10 backpressure trip reset lever (FW-64-RL) is susceptible to lateral forces that can result in the trip latch (FW-64) and reset lever (FW-64-RL) becoming partially unlatched." Internal operating experience found that since the year 2000, FW-10 has been inadvertently tripped by bumping the trip latch or reset lever five times. A contributing cause was an ineffective trending process that should have identified and reduced, or eliminated, the susceptibility of accidentally bumping the backpressure trip. Corrective actions to prevent reoccurrence include an interim action that controls access to FW-10 and verifies the trip mechanism to be fully latched prior to leaving the FW-10 area, a design change to remove or protect the backpressure trip mechanism, enhancements to the station trending program, a procedure revision to include the interim access controls into the licensee equipment status control procedure and revisions to all FW-10 operating procedures to verify the backpressure trip latch is fully engaged following shutdown of FW-10.

The FW-10 trip due to the apparent backpressure trip unlatching has an extent of condition that includes any Fort Calhoun Station procedure that operates the turbine-driven auxiliary feedwater pump. While the extent of cause would include any mechanical trip device at the plant that could be bumped or forced, a review of other plant equipment did not find any mechanical devices with similar vulnerable characteristics.

Condition Report CR-2010-0910. As a result of the three turbine-driven auxiliary feedwater pump FW-10 failures since February 2009 the licensee's internal performance indicator for the auxiliary feedwater system turned red. The root cause analysis for Condition Report CR-2010-0910 determined that the root cause of these three recent FW-10 failures was due to the fact that the licensee, "lacks the technical knowledge of the FW-10 control systems and operating characteristics that is required to ensure that the Engineering Change process does not introduce errors when making configuration changes to FW-10." Corrective actions include additional training for licensee engineering staff.

a. Inspection Scope

The team reviewed the licensee's root cause analysis to determine if it was conducted to a level of detail commensurate with the significance of the problem. The team reviewed the licensee's corrective actions to ensure they addressed the extent of condition and whether they were adequate to prevent recurrence. The team interviewed key station personnel from operations, design and system engineering, maintenance, and the corrective action program.

b. Findings and Observations

The inspectors determined that the licensee's analysis accurately captured the root causes of the events. The inspectors found that the corrective actions to prevent recurrence would likely ensure improved turbine-driven auxiliary feedwater pump reliability. Effectiveness reviews were implemented by the licensee to ensure the corrective actions implemented were sufficiently robust to address the root causes. The inspectors did note that some of the root cause analysis reports were narrowly focused and failed to consider all potential causal factors and some corrective action enhancements. Specifically, the inspectors noted the following:

- The licensee's review of the three turbine-driven auxiliary feedwater pump failures in Condition Report CR 2010-0910 root cause analysis correctly determined the common thread between the causes of these pump failures was that the licensee lacks the technical knowledge of the FW-10 control systems and operating characteristics that is required to ensure that design changes do not introduce errors when making configuration changes to FW-10. The corrective actions the licensee proposes to correct this condition is additional training for the system and design engineering personnel. However, effective training on operating characteristics would be hampered by the lack of licensee performance monitoring during FW-10 starts that prevent the licensee from knowing the baseline operating characteristics of turbine transient performance. The inspection team informed the licensee of operating experience, industry standard practices and industry guides that recommend these practices. As a result, the licensee initiated Condition Report CR 2010-2424 to document this issue and track proposed changes to allow instrumentation of FW-10.

- The root cause investigation into the backpressure trip lever unlatching was narrowly focused on the 'bumping' of the latch as the most likely cause. However, licensee troubleshooting was unable to duplicate a partially latched condition by bumping the trip or reset levers. The inspectors noted that two other possible causes are the possibility of interference between the trip piston plunger

and the trip lever or an inadequate full latch when reset. The possibility of a partial latch during reset will be prevented by procedure revisions to all FW-10 operating procedures to verify full latch following operation of FW-10. The design change to remove or protect the backpressure trip mechanism will address the bumping cause. The root cause did evaluate the condition of the trip piston touching the trip lever but did not consider this a likely cause. However, the team noted that any interference between the trip piston and the trip lever would prevent the trip lever latch plate from fully engaging with the reset lever pin. The inspection team discussed this with the licensee and as a result, actions were added to specify a specific gap dimension and tolerance between the FW-10 backpressure trip piston and backpressure trip lever to ensure a gap remains and the piston plunger cannot interfere with the trip latch engagement.

- The inspectors noted that the use of communication memo as an interim action to control access to the FW-10 cage was a minor violation of Technical Specification 5.8.1.a that requires written procedures be implemented as recommended in Regulatory Guide 1.33, Revision 2, Appendix A. section 1.c. equipment control. The 'communications' memo was being used as an interim measure to control access the FW-10 cage when previous access control measures had been proven ineffective. Since the memo appeared to be used as a method to maintain FW-10 operability Technical Specification TS 5.8.1 was applicable. When informed of this issue, operations reissued the memo to control access to the FW-10 cage using the programmatic requirements which included a 50.59 screening. These controls will remain in place until the corrective action is completed that will revise SO-G-113 (Equipment Status Control) to proceduralize the memo guidance on FW-10 access control.

- The root cause investigation into the backpressure trip stated that vibrations from the running pump could contribute to the trip unlatching. The team questioned the licensee if this would affect the seismic qualification or robustness of FW-10 and if there was any possible concern with impact on the sensitive backpressure trip mechanism from external objects during a seismic event. As a result the licensee verified the seismic adequacy of FW-10 and documented this review in Revision 1 to the Condition Report CR-2010-0813 root cause analysis report.

5.0 Review of Evidence Preservation Process

a. Scope

The team reviewed the licensee's process for quarantine of affected components and equipment to preserve important characteristics needed for critical failure analysis. Evidence is needed to determine failure cause and determine appropriate corrective actions to prevent recurrence of failures.

The team reviewed the licensee's history of evidence preservation issues documented in the condition report database. In particular, the team reviewed station procedures, processes and determined if the licensee process was effective at evidence preservation. The team interviewed key station personnel from operations, design, and licensing, and the corrective action program.

b. Observations and Findings

The licensee identified deficiencies in its evidence preservation process in Condition Report CR 2009-6897 when evidence was lost during an apparent cause investigation of a failed air accumulator. Though the investigation was completed without the evidence, additional actions were taken to make improvements in the sites NOD-QP-19, "Cause Analysis Program," guidance procedure. These improvements were attempts to specify the requirements for the collection and protection of evidence as it relates to casual analysis at Fort Calhoun. However, using NOD-QP-19 to control evidence is of limited use when the station is in the discovery phase of an equipment problem that usually involves operations and maintenance personnel and procedures. The licensee Quality Assurance department noted this issue in February of 2010 and it was documented in Condition Report CR 2010-0799 that the procedure improvement corrective action for Condition Report CR 2009-6897 did not directly address the apparent cause of insufficient guidance for plant personnel involved in the planning of work where the need for preserving physical evidence is required. It recommended that processes for evidence collection and preservation be determined and incorporated into station guidance related to work planning, troubleshooting, and conduct of maintenance. However, the licensee's response considered the changes to the cause analysis program procedure as adequate and noted that Condition Report CR 2009-6897 does have an effectiveness review to check for any physical evidence lost, or compromised condition reports, in about one year.

The team also interviewed plant operations personnel on evidence preservation during the February 17, 2010, trip of the turbine-driven auxiliary feedwater pump, FW-10, and noted that operations personnel were aware of the importance of evidence preservation by minimizing operation or manipulation of failed components as much as possible consistent with keeping the plant in a safe configuration. In the case of the FW-10 trip, this resulted in operations personnel deciding not to reset the tripped exhaust backpressure reset lever but to wait on an appropriate investigation team to examine the equipment. These efforts are expected to reduce the chances for lost evidence in future Fort Calhoun cause analysis investigations.

6.0 Review of Operating Experience

a. Scope

The team reviewed internal operating experience by obtaining a list of plant corrective action documents related to the auxiliary feedwater system and selecting those documents related to failures of the turbine-driven auxiliary feedwater pump. The team inspected the licensee's review of industry operating experience for the turbine-driven auxiliary feedwater pump. The team inspection included a specific review of related operating experience during the root cause investigation for the February 17, 2010, trip of the turbine-driven auxiliary feedwater pump.

For external operating experience, the NRC Operating Experience Branch provided the results of keyword searches related to exhaust backpressure trips, such as: trip mechanisms unlatching due to wear or worn edges of the mechanism (trip tappet/head lever), inadequate engagement of the mechanism (trip tappet nut/head lever) due to improper setup, inadequate engagement due to failure to properly reset the mechanism, or excessive vibration unlatching trip mechanisms; overshoot of normal operating speed

resulting trips due to water, binding, or improper setpoints; speed control problems, slow starts or overspeed trips due to air in control oil or hydraulic control systems following maintenance. The NRC Operating Experience Branch provided a list of licensee event reports, NRC information notices, NUREG documents and other operating experience information. The team selected operating experience information that was applicable to this inspection and reviewed whether the licensee had addressed the items in their root cause analyses related to these events or had processed the information through their operating experience program.

b. Findings and Observations

Using a Coffin turbine to drive the auxiliary feedwater pump is unique in the United States commercial nuclear industry. Due to Fort Calhoun having the only Coffin turbine in the US nuclear industry the inspection of the licensee industry operational experience searches rarely turn up relevant information. However, the NRC operating experience branch did supply relevant operational experience from plants that use different turbines to drive their auxiliary feedwater pumps and relevant hydraulic controls experience. One example was a January 2003 operational experience account of an auxiliary feedwater pump which tripped on overspeed following a demand start due to a design margin that had the overspeed trip setpoint too close to operating speed. This is very similar to the Fort Calhoun April 6, 2009, high discharge pressure trip during a pump start due to inadequate design margin. Other relevant recommended standard industry practices such as transient performance monitoring is not performed at Fort Calhoun and has contributed to a lack of understanding by the station personnel of the normal transient responses of the Coffin turbine-driven auxiliary feedwater pump. There were several experiences associated with failures of feedwater and main steam hydraulically operated isolation valves due to inadequate venting of oil systems following maintenance. Information Notice 86-07 describes a loss of speed control on a standby diesel generator due to inadequate filling and venting of the governor hydraulic control system following maintenance. These are relevant to the licensee's 2009 FW-10 failure to start following inadequate venting of control oil following maintenance.

7.0 Potential Generic Issues

a. Scope

The team evaluated the failures of Fort Calhoun's turbine-driven auxiliary feedwater pump on whether any potential generic issues should be communicated to the industry (e.g., information notices, generic letters, and bulletins).

b. Findings and Observations

The team determined that this issue warrants a generic communication informing other licensees of the types of problems encountered. Specifically, the team determined that, though the design of the Coffin turbine-driven auxiliary feedwater pump trip is unique in the US nuclear power plant industry, unlatching of the a trip mechanism from bumping, wear, or improper latching is similar to industry events with other turbine-driven auxiliary feedwater pump overspeed trip mechanisms. The team will discuss this issue with the NRC Office of Nuclear Reactor Regulation for issuance on an information notice. The team did not identify any other potentially generic safety issues during the inspection.

4. OTHER ACTIVITIES

4OA6 Meetings, Including Exit

On March 26, 2010, the team presented the preliminary results of this inspection at the end of the onsite week to Mr. David Bannister, Vice President Nuclear and Chief Nuclear Officer, and other members of his staff who acknowledged the findings. The team verified that no proprietary information was retained.

On June 3, 2010, the team leader presented the final results of the inspection to Mr. Jeff Reinhart, Site Vice President, and other members of the licensee staff who acknowledged the findings. The team verified that no proprietary information was retained.

On June 30, 2010, the Project Branch 3 Chief presented the revised results of the inspection to Mr. Jeff Reinhart, Site Vice President, and other members of the licensee staff who acknowledged the findings. The team verified that no proprietary information was retained.

Attachment 1: Supplemental Information
Attachment 2: Special Inspection Charter
Attachment 3: Timeline associated with TDAFW Pump problems
Attachment 4: Final Significance Determination Evaluation

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee Personnel

R. Acker, Licensing Engineer, Licensing Department
J. Cate, Supervisor, System Engineering Department
J. Drahota, Supervisor, Reliability Engineering
H. Faulhaber, Manager, Nuclear Engineering Division
M. Ferm, Manager, Operations Support
M. Frans, Manager, System Engineering Department
J. Gasper, Manager, Design Engineering Department
J. Goodell, Manager, Nuclear Performance Improvement and Support Department
D. Guin, Supervisor, Regulatory Compliance
D. Haas, Design Engineer, Design Engineering Department
R. Haug, Manager, Training Department
J. Herman, Manager, Engineering Programs Department
E. Jun, System Engineer, System Engineering Department
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T. Matthews, Manager, Nuclear Licensing Department
T. Nellenbach, Plant Manager
T. Pilmaier, Manager, Performance Improvement Department
B. Venters, Superintendent, Maintenance Department
J. Zagata, Reliability Engineer, Reliability Engineering Division
S. Swearngin, Supervisor, Mechanical Engineering Division

NRC Personnel

J. Robles, Reactor Systems Engineer NRR/DIRS/IOEB Operating Experience Branch
R. Sigmon, Reactor Systems Engineer NRR/DIRS/IOEB Operating Experience Branch

LIST OF ITEMS OPENED, CLOSED, AND DISCUSSED

Opened and Closed

050000285/2010006-01	NCV	Failure to Correct Repeated Tripping of the Turbine-driven Auxiliary Feedwater Pump FW-10 (Section 1.2.1)
050000285/2010006-02	NCV	Failure to Verify that the Turbine-driven Auxiliary Feedwater Pump Exhaust Backpressure Trip Lever was Fully Latched (Section 1.2.2)
050000285/2010006-03	NCV	Failure to Vent Control Oil Following Maintenance Results in Failure of the Turbine-driven Auxiliary Feedwater Pump to Start (Section 1.3.1)
050000285/2010006-04	NCV	Turbine-driven Auxiliary Feedwater Pump Trip Due to Inadequate Design Margin (Section 1.3.2)

DOCUMENTS REVIEWED

DRAWINGS

NUMBER	TITLE	REVISION
11405-E-137	Schematic, Wiring Diagram & Switch Developments for Control Valve YCV-1045 to Steam Driven Aux. Feed Water Pump FW-10	27
11405-M-252	Flow Diagram Steam P & ID	103

MISCELLANEOUS DOCUMENTS

NUMBER	TITLE	REVISION / DATE
EPRI NP-7149-D	Final Report, “Summary of the Seismic Adequacy of Twenty Classes of Equipment Required for the Safe Shutdown of Nuclear Plants”	March 1991
FMEA No. 145	Failure Modes and Effects Analysis worksheet	0
FW-10	Screening Evaluation Work Sheet, Corrected 2/14/92	2
IC-CP-01-FW64	Calibration of Back Pressure Trip Device on Auxiliary Feedwater Pump FW-10	June 30, 2004
MM-PM-AFW-001	Fw-10 Control Linkage and Speed Limiting Governor Check	12
NUREG-1030	Seismic Qualification of Equipment in Operating Nuclear Power Plants	February 1987
PED-MEI-9	Instruction for Review of Seismic Equipment Qualification Reports	5
81-14	Generic Letter, “Seismic Qualification of Auxillary Feedwater Systems	February 10, 1981
753	Failure Report	April 21, 2009
754	Failure Report	May 5, 2009

CONDITION REPORT

CR 2005-04448	CR 2008-4662	CR 2009-0905	CR 2009-1611
CR 2009-5274	CR 2009-6897	CR 2010-0799	CR 2010-0813
CR 2010-0910	CR 2010-1201	CR 2010-1313	CR 2010-1429
CR 2010-1446	CR 2010-1447	CR 2010-1452	CR 2010-1853
CR 2010-2424			

WORK ORDER

00312795	00313681	00314285	00316053	00322816
00323886	00329345	00330718	00333176	00333298
00335376	00336463	00336641	00337675	00337754
00337837	00339293	00340420	00346007	00346059
00352899	00368589			

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION IV
612 EAST LAMAR BLVD, SUITE 400
ARLINGTON, TEXAS 76011-4125

March 11, 2010

MEMORANDUM TO: Mike Chambers, Team Leader
Projects Branch C
Division of Reactor Projects

Leonard Willoughby, Senior Resident Inspector
Las Vegas Field Office
Division of Nuclear Materials Safety

FROM: Dwight Chamberlain, Director
Division of Reactor Projects

SUBJECT: CHARTER FOR SPECIAL INSPECTION INVOLVING THE FAILURE OF THE TURBINE-DRIVEN AUXILIARY FEEDWATER PUMP TO START AT FORT CALHOUN STATION

On February 17, 2010, the Fort Calhoun Station's turbine-driven auxiliary feedwater pump (FW-10) failed to start properly. As a result of this failure and the potential that the pump may have been unable to perform its safety function for a period prior to the identified failure, a special inspection will be performed. You are hereby designated as the special inspection team leader.

A. Basis

On February 17, 2010, the turbine-driven auxiliary feed water pump failed a surveillance test. After starting, the pump tripped approximately 20 seconds later due to an exhaust back pressure trip. The reason for the exhaust back pressure trip has not yet been determined.

As part of troubleshooting the pump, the back pressure trip device was calibrated and during the calibration it was noted that the back pressure trip plunger was in close contact with the back pressure trip lever. The calibration procedure specifies a few thousands gap and no gap was noted. The gap was adjusted per the calibration procedure, the turbine-driven auxiliary feed water pump was subsequently tested and restored to an operable status.

A regional Senior Reactor Analyst (SRA) preliminarily estimated the Incremental Conditional Core Damage Probability for this issue to be 5×10^{-6}, which falls in the overlap region between baseline and special inspection. This risk, as well as previous problems with this pump that were not conclusively closed, warrant this special inspection.

B. Scope

1. Develop a complete sequence of events related to the discovery of the degraded condition.
2. Review operating experience involving prior opportunities to identify and evaluate actions implemented at Fort Calhoun Station as a result of operating experience.
3. Review the licensee's root cause analysis and determine if it was conducted to a level of detail commensurate with the significance of the problem.
4. Determine if the licensee's corrective actions have addressed the extent of condition and assess whether these actions appear adequate to prevent recurrence.
5. Collect facts to support an accurate estimate of exposure time.
6. Collect facts to support proper crediting of the licensee's ability to recover the turbine-driven auxiliary feed water pump as assumed in the risk assessment.
7. Review the licensee's procedures directing them to manually operate the turbine-driven auxiliary feed water pump with particular attention to whether they were sufficient to direct operators to manual operations in a timely manner and whether they are accomplishable under event-like conditions (i.e., station blackout).
8. Evaluate whether there was the potential for damaging other parts of the turbine-driven auxiliary feed water pump in the method the licensee chose to recover the valve on February 17, 2010.
9. Evaluate whether the licensee was thorough in their troubleshooting efforts on February 17, 2010, for evaluating whether other parts of the turbine-driven auxiliary feed water pump could have been damaged and caused the failure.
10. Evaluate the licensee's process for quarantine of affected components and equipment to preserve important characteristics.
11. Verify the licensee met the proper reporting requirements of 10 CFR 50.72 and 10 CFR 50.73. Also determine if the licensee has plans to issue a Licensee Event Report to document this issue.
12. Review the licensee's compliance with the Technical Specifications.

C. Guidance

Inspection Procedure 93812, “Special Inspection,” will be used during this inspection. The inspection should emphasize fact-finding in its review of the circumstance surrounding this event. It is not the responsibility of the team to examine the regulatory process. Safety concerns identified that are not directly to the event should be reported to the Region IV office for appropriate action.

The team will report to the site and begin inspection no later than March 22, 2010. While onsite, you will provide daily status briefings to Region IV management, who will coordinate with the Office of Nuclear Reactor Regulation, to ensure that all other parties are kept informed. Depending on the outcome of the inspection, inspection results will be documented in Special Inspection Report 05000285/2010006. This report will be issued within 45 days of the completion of the inspection.

This guidance may be modified should you develop significant new information that warrants review. David Loveless is the assigned senior reactor analyst for support of this special inspection. Should you have any questions concerning this guidance, contact me at (817) 860-8248.

Timeline of Activites Relating to 2009 and 2010 TDAFW Pump Failures

Date	Activity
2/27/2001	While the plant was online and FW-10 in standby the trip latch was bumped and tripped during performance of a work in the area for IC-ST-IA-3009, “Operability Test of IA-YCV-1045-C and Close Stroke Test of YCV-1045,”test, The latch was reset and condition report CR. 200100389 initiated.
4/24/2001	Design change EC 14994, a FW-10 reliability enhancement, replaced external copper oil lines going to the governor and bearings with stainless steel tubing. Two high points in the tubing that can trap air are created as the result of this design change..
4/26/2001	During the 2001 refueling outage the trip latch was tripped during a walkdown for to plan work when the trip latc was lightly touched with a pen. The lever was reset and condition report CR. 200101685 initiated.
6/1/2001	FW-10 takes 10 minutes to start. CR 200102254
1/1/2003	FW-10 failed to reach desired speed / flow. CR 200300311
7/17/2003	FW-10 Failed to accelerate to normal speed. CR 200302713
5/30/2008	During the refueling outage the exhaust backpressure piston is calibrated per IC-CP-01-FW-64, “Calibration of Back Pressure Trip Device on Auxiiliary Feedwater Pump FW-10.” is performed. A gap of a few thousands of an inch is set between the trip piston and trip latch. Then the Trip leach is reset.
6/13/08 15:13	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 2 for PMT.
6/13/08 17:41	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for OP-ST-AFW-0004.
6/13/2008	The exhaust back pressure trip linkage is checked and the gap between trip piston and trip latch verified by preventative maintenance activity MM-PM-AFW-0001.
6/14/08 2:28	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Att. 1, for performance of OP-ST-AFW-3011.
6/14/08 4:40	FW-10 started per OI-AFW-4, Att. 1, for OP-ST-AFW-3011.
6/15/2008	Design change EC 34435, FW-10 Pneumatic Speed Control Removal, removed the pneumatic speed control components and allowed the speed limiting governor to control pump speed. This initial speed setpoint resulted in lowering pump discharge pressure into the bottom of the in-service test acceptance criteria band

7/8/2008	The plant was online and FW-10 in standby when the trip latch was bumped and tripped during performance of a work in the area for IC-ST-IA-3009, “Operability Test of IA-YCV-1045-C and Close Stroke Test of YCV-1045,”test, The latch was reset and condition report CR 2008-4662 initiated.
2/26/09 10:51	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started for CWO #322162-01 per OI-AFW-4, attachment 2.
2/26/09 15:25	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), start was attempted per OP-ST-AFW-0004 for PMT, pump would not rotate when steam was admitted. YCV-1045, AUX FEEDWATER PUMP FW-10 INLET VALVE, returned to the closed position. WR 133183, CR # 2009-0905.
2/26/2009	FW-10 Failure To Start, CR 2009-0905 root cause investigation determined this was due to air in the high point of the tubing installed in 2001. This high point was removed as a corrective action in November, 2009.
2/26/2009	Design change EC 45105, FW-10 Speed Limiting Governor Setting, reset the speed limiting governor to a higher value than the as-left value for EC 34435 to add surveillance test margin. This was required due to the June 2008 design change that removed air controls and set the governor speed to low.
2/26/2009	DFDCR 45607, FW-10 Discharge Pressure Upper Limit Evaluation, revised the acceptance criteria in EC 45105 to allow FW-10 discharge pressure to be increased beyond the 1170 to 1210 psig target range prescribed in EC 45105.
2/26/09 19:34	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4 attachment 2.
2/26/09 20:24	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OP-ST-AFW-0004 and OI-AFW-4 attachment 1.
2/26/09 21:20	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4 attachment 1.
2/26/09 22:07	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4 attachment 1.
3/9/09 12:40	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OP-ST-AFW-0004 and OI-AFW--4, attachment #1 per SE testing request.
3/18/09 12:37	FW-10, AUXILLIARY FEEDWATER PUMP (TURBINE-DRIVEN) started per OI-AFW-4.
3/25/09 9:52	FW-10 started per OI-AFW-4, attachment 2, for FC-1212, WO# 133510.
3/25/09 12:26	FW-10 started per OI-AFW-4, attachment 1 for OP-ST-AFW-0004, IAW FC-1212, WO# 133510.
3/25/2009	Troubleshooting Plan WR133510, Started/Stopped pump.

3/30/09 7:46	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for weekly verification start.
4/6/09 7:50	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OP-ST-AFW-0004 for increased frequency starting. FW-10 tripped on high discharge pressure when started. Reference CR 2009-1611.
4/6/09 16:12	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4 , for data collection.
4/6/09 19:56	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, attachment 1, per FC-1212 for troubleshooting of FW-10 tripping.
4/6/09 22:12	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, attachment 1, per FC-1212 for troubleshooting of FW-10 tripping.
4/6/09 23:31	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, attachment 1, per FC-1212 for troubleshooting of FW-10 tripping.
4/6/2009	FW-10 tripped on High Discharge Pressure, CR 2009-1611 root cause investigation determined this was due to inadequate margin between the pump discharge pressure that was increased by a design change February 26, 2009 and the pump high discharge pressure trip setpoint. This was corrected by raising the high discharge pressure trip setpoint to restore margin between normal pump discharge pressure and trip setpoint.
4/7/09 1:54	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, attachment 1, per FC-1212 for troubleshooting of FW-10 tripping.
4/7/09 2:35	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, attachment 1, for OP-ST-AFW-0004 for PMT of FW-10 following Pressure switch adjustment, as a portion of the operability testing.
4/28/09 16:01	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for OP-ST-AFW-0004. This is PMT for PS-1122 replacement. WO# 338759
9/30/2009	The back pressure trip latch was tripped and reset as part of the FW-10 run per OP-ST-AFW-3011, “Auxiliary Feedwater Pump FW-10, Steam Isolation Valve, and Check Valve Tests.
11/3/2009	During the 2009 refueling outage the trip latch was found in a tripped condition during operator rounds. Condition report CR 2009-5274 was initiated.
11/12/2009	During the 2009 refueling outage the trip reset lever was bumped, tripped and then reset by an operator. Condition report CR 2010-1313 was initiated when the operator informed the February 17, 2010 trip investigative team.

11/15/2009	The oil supply tubing was reconfigured to remove high points with WO-00352899 and EC 45914. This was a corrective action from the February 26, 2009 failure to start event.
12/10/2009	The exhaust back pressure trip is calibrated by IC-CP-01-FW-64.This included a gap between the trip piston and trip latch. Then the trip latch was reset
12/16/09 17:35	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for OP-ST-AFW-0004.
12/17/09 10:58	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for OP-ST-AFW-3011. Initial remote valve position did not indicate open for YCV-1045 at either AI-66B or AI-179. Mechanically agitated open limit switch and received open indication. Secured FW-10 per OI-AFW-4 Attachment 1.
12/17/09 11:28	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, attachment 1 for OP-ST-AFW-3011.
12/17/2009	FW 10 was run per OP-ST-AFW-3011 The exhaust backpressure trip was reset. The gap between the trip piston and trip latch were verified per MM-PM-AFW-0001.
12/18/09 2:01	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, “Auxiliary Feedwater Startup and System Operation,” Attachment 1 for OP-PM-AFW-0001. The back pressure trip latch was not manipulated.
12/26/2009	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, “Auxiliary Feedwater Startup and System Operation.,” The back pressure trip latch was not manipulated.
1/20/10 8:03	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, “Auxiliary Feedwater Startup and System Operation.,” The back pressure trip latch was not manipulated.
2/17/2010	Work in the area of the reset lever for IC-ST-IA-3009, “Operability Test of IA-YCV-1045-C and Close Stroke Test of YCV-1045,”test,
2/17/10 10:51	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OP-ST-AFW-0004.and the exhaust back pressure trip occurred. Condition report CR 2010-0813 was initiated.
2/17/10 18:57	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for troubleshooting.
2/17/10 19:36	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for troubleshooting.
2/17/10 19:48	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for troubleshooting.
2/17/10 20:36	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OP-ST-AFW-0004.

3/9/10 14:52	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OP-ST-AFW-0004 for operability following completion of FC-1212 backpressure trip latch troubleshooting activities.
3/17/10 9:04	FW-10, AUXILIARY FEEDWATER PUMP (TURBINE-DRIVEN), started per OI-AFW-4, Attachment 1 for OP-ST-AFW-3011.
3/17/10 12:17	FW-10 started per OI-AFW-4, attachment 1 for OP-ST-AFW-3011.
3/19/10 12:23	FW-10 started per OI-AFW-4, attachment 1 for WO 371568 backpressure trip latch troubleshooting activities.
3/19/10 12:40	FW-10 started per OI-AFW-4, attachment 1 for WO 371568 backpressure trip latch troubleshooting activities.
3/19/10 13:00	FW-10, started per OI-AFW-4, Attachment 1 for WO371568 backpressure trip latch troubleshooting activities.
3/19/10 15:25	Started FW-10 for OP-ST-AFW-0004.
3/19/10 16:10	Started FW-10 per OP-ST-AFW-3011.
June 17, 2009	NRC Region IV approves a special inspection charter to understand the circumstances surrounding the failures of the turbine-driven auxiliary feedwater pump
June 22-26, 2009	NRC Special Inspection Team at Callaway Plant

PHASE 3 ANALYSIS
FAILURE OF AUXILIARY FEEDWATER PUMP TO START ON DEMAND

Summary of Significance Determination

The senior reactor analyst completed a Phase 3 analysis using the plant-specific Standardized Plant Analysis Risk (SPAR) Model for Fort Calhoun, Revision 3.45. The exposure period of 14.5 days represented half the time from the last successful run of the pump plus the repair time. The analyst estimated the nonrecovery probability following a backpressure trip at 5.8 percent. Seismic events and internal fire were evaluated as the only external events of concern. The final result was calculated to be 6.3×10^{-7} indicating that the finding was of very low risk significance (Green).

Details

A. Summary of Issue

On February 17, 2010, the turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip reset lever was seen to unlatch and trip when FW-10 was started for Surveillance Test OP-ST-AFW-004, "Auxiliary Feedwater Pump FW-10 Operability Test." The turbine-driven auxiliary feedwater pump is a steam-driven pump which utilizes a Coffin turbine as a prime mover supplied by steam from the steam generators. The turbine has an exhaust backpressure trip mechanism consisting of a trip piston actuated by a bellows connected to the turbine's exhaust line, a trip latch and a reset lever. A high backpressure of 35 psig +/- 10 psig (normal backpressure is 4 to 6 psig) would cause the trip piston to extend pushing up on the trip latch lever, unlatching the trip lever latch plate from the reset lever pin. When the reset lever pin is released a spring pulls the reset lever against the mechanical governor causing the turbine to shut down.

In response to the FW-10 trip, the licensee performed troubleshooting to check for blockage of the steam exhaust pipe, examined the back pressure trip linkage and checked the calibration of the backpressure trip piston. It was visually verified that there was no blockage in the accessible portions of the steam exhaust piping. Examination of the trip linkage found no abnormalities and calibration of the trip piston noted the as-found setpoint was in tolerance. The calibration work records did note that there was normally a few thousandths of an inch gap between the backpressure trip piston plunger and the trip latch, but no gap was visible, and a piece of paper could not be slid between the plunger and the trip latch. Interference between the trip piston plunger and the trip lever would interfere with a full latch between the trip lever and the reset lever. Immediately prior to the trip, Surveillance Test IC-ST-IA-3009, "Operability Test of IA-YCV-1045-C and Close Stroke Test of YCV-1045," was performed. Surveillance Test IC-ST-IA-3009 results in workers being in close proximity to the reset lever, which if inadvertently bumped could have left the reset lever not fully engaged with the trip latch. A bump causing a partial unlatching between the trip latch and reset lever would increase the risk of normal vibrations causing a trip during the pump start. Based on this troubleshooting and three successful test runs FW-10 was returned to service.

Further troubleshooting on March 9 and 19, 2010, verified that the backpressure trip mechanism will trip if the trip latch or reset lever are bumped or vibrated. A reenactment

of the partially unlatched condition was performed. The trip latch and reset lever were manually placed in a partially unlatched condition, and the pump was started. After the pump start, the trip latch and reset lever unlatched, tripping the pump off. This demonstrates that if the trip lever latch and reset lever pin are partially unlatched, the pump will trip when normal pump startup vibration occurs.

The licensee implemented an interim corrective action to control access to the cage that contains FW-10. A memo was issued on March 17, 2010, to operations personnel and management, requiring that any plant personnel entering the FW-10 cage area have a face to face briefing with the shift manager. The purpose of the briefing was to accomplish the following: 1) to increase personnel awareness of the exhaust back pressure trip mechanism location; 2) provide a review of operating experience associated with bumping the trip mechanism; 3) for personnel entering the FW-10 cage area, ensure that they have established basic measures to prevent bumping the backpressure trip mechanism; and 4) to establish a communication protocol to notify the control room when the personnel leave the FW-10 caged area. The process also requires that a spotter be present to ensure that all personnel and equipment remain at least six inches away from the exhaust back pressure reset lever. Finally, after personnel have left the caged area, operations personnel will verify the FW-10 back pressure trip lever is in its proper reset and fully latched condition. Longer term corrective actions are to install a design change to remove or protect the FW-10 backpressure trip mechanism and revise the FW-10 procedures to verify that the backpressure trip is fully engaged following any shutdown of FW-10.

B. Statement of the Performance Deficiency

The performance deficiency associated with this finding involved the licensee's failure to correct repeated tripping of the turbine-driven auxiliary feedwater pump reset latch that demonstrated the susceptibility of the mechanism to bumping.

C. Significance Determination Basis

1. Phase 1 Screening Logic, Results and Assumptions

In accordance with NRC Inspection Manual Chapter 0612, Appendix B, "Issue Screening," the analyst determined that the failure to correct repeated tripping of the turbine-driven auxiliary feedwater pump reset latch was a licensee performance deficiency. The issue is more than minor because it was associated with the mitigating systems cornerstone attribute of equipment performance and affected the cornerstone objective of ensuring the availability and reliability of systems that respond to initiating events to prevent undesirable consequences. Specifically, the turbine-driven auxiliary feedwater pump would not have been available to respond upon demand.

The analyst evaluated the issue using the Significance Determination Process (SDP) Phase 1 Screening Worksheet for the Initiating Events, Mitigating Systems, and Barrier Integrity Cornerstones provided in Manual Chapter 0609, Attachment 4, "Phase 1 – Initial Screening and Characterization of Findings." This finding affected the Mitigating Systems Cornerstone. The analyst determined that the finding represented a loss of system safety function because the failure of the turbine-driven auxiliary feedwater pump FW-10 eliminates the

capability of the plant to cope with a station blackout. Therefore, a Phase 2 estimation was conducted in accordance with Manual Chapter 0609, Appendix A, "Determining the Significance of Reactor Inspection Findings for At-Power Situations."

2. Phase 2 Risk Estimation

In accordance with Manual Chapter 0609, Appendix A, Attachment 1, "User Guidance for Phase 2 and Phase 3 Reactor Inspection Findings for At-Power Situations," the Senior Reactor Analyst evaluated the subject finding using the "Risk-Informed Inspection Notebook for Fort Calhoun Power Station," Revision 2.1a. The following assumptions were made:

a. The identified performance deficiency first occurred in 2001 when the licensee failed to correct conditions that resulted in inadvertent backpressure trips of Pump FW-10. However, the pump continued to be tested about monthly and successfully met the technical specification surveillance requirements through February 17, 2010. Therefore, the deficiency only began to affect plant risk at some point between January 20, 2010 and the time of failure on February 17, 2010.

b. The failure was identified during a test of the turbine-driven auxiliary feedwater pump conducted on February 17, 2010. The last successful test that started Pump FW-10 was completed on January 20, 2010. Pump FW-10 was repaired and returned to service approximately 10 hours later.

c. In accordance with Manual Chapter 0609, Appendix A, Attachment 2, "Site Specific Risk-Informed Inspection Notebook Usage Rules," Rule 1.1, "Exposure Time," the analyst evaluated the timeframe over which the finding impacted the risk of plant operations. The analyst determined that the performance deficiency affected plant risk for 14 days. Therefore, the exposure time used to represent the time that the performance deficiency affected plant risk in the Phase 2 estimation was greater than 3 but less than 30 days.

d. In accordance with Appendix A, Attachment 1, Step 2.1.3, "Find the Appropriate Target for the Inspection Finding in the Pre-solved Table," the analyst determined that the appropriate target for evaluating this performance deficiency was "Turbine-driven Auxiliary Feedwater Pump Fails to Start." Therefore, the analyst utilized the pre-solved table associated with the SDP notebook to perform the estimation.

e. The analyst gave no operator action credit as discussed in Manual Chapter 0609, Appendix A, Attachment 1, Table 4, "Remaining Mitigation Capability Credit." The requirements for environmental conditions and to have trained the operators in recovery under similar conditions for such credit were not clearly met.

The dominant sequences from the notebook were documented in Table 1.

TABLE 1 Failure of Turbine-Driven Auxiliary Feedwater Pump Phase 2 Sequences			
Initiating Event	Sequence	Mitigating Functions	Results
Transient with Loss of Power Conversion System	1	TPCS-AFW-HPR	6
	3	TPCS-AFW-EIHP	6
	4	TPCS-AFW-FB	5
Anticipated Transient without SCRAM	1	ATWS-AFW	6
Small-Break LOCA	4	SLOCA-AFW-FB	7
Loss of Component Cooling Water	3	LCCW-AFW-RWBU	7
	5	LCCW-AFW-FB	7

Using the pre-solved worksheet, the result from this estimation indicated that the finding was of low to moderate safety significance (White). However, the analyst determined that this estimate did not include a full coverage of the risk related to the failure identified, particularly because of the shorter exposure time, the affects of potential recovery, and the affect that certain fire and seismic initiators would have on the specific condition. Therefore, a Phase 3 evaluation was conducted to better assess the risk of the finding related to internal initiators and fully assess the risk related to external initiators.

3. Phase 3 Analysis

Assumptions

The following assumptions were made to support this Phase 3 analysis:

1. The Fort Calhoun plant-specific SPAR, Revision 3.45, was the best tool for quantifying the risk of the subject performance deficiency.

2. The turbine-driven auxiliary feedwater pump FW-10 exhaust backpressure trip reset lever was seen to unlatch and trip when FW-10 was started for Surveillance Test OP-ST-AFW-004, “Auxiliary Feedwater Pump FW-10 Operability Test,” on February 17, 2010.

3. The best-available information indicated that the failure mode of pump FW-10 was the backpressure trip reset lever having previously been bumped and left in a condition that would result in a trip upon any pump start.

4. Given Assumptions 2 and 3 and in accordance with Manual Chapter 0609, Appendix A, Attachment 1, Usage Rule 1.1, “Exposure Time,” the analyst determined that the exposure time should be estimated by using one half the time from the previous successful test to the failure

plus the time to repair the pump and return it to service because the time of inception of imminent failure is unknown.

5. Nothing was physically damaged or incorrectly adjusted on the exhaust backpressure trip reset lever that would have prevented operators from resetting the pump at the time of failure. Therefore, resetting the trip lever and manually restarting pump FW-10 was a viable recovery action.

6. The recovery discussed in Assumption 5 was possible for all evaluated core-damage sequences, provided operators diagnose the condition correctly and determine that resetting the latch and restarting the pump is a viable option.

7. The best available method to quantify the probability that operators would fail to reset the exhaust backpressure trip and manually start pump FW-10 was the SPAR-H method.

8. The majority of the risk associated with the subject performance deficiency was from station blackout or other sequences that resulted in a complete loss of all feedwater. Therefore, the time to recover the turbine-driven auxiliary feedwater pump was limited to about 75 minutes. The analyst performed a sensitivity evaluation that indicated adjustments to the recovery time for specific sequences did not significantly affect the result.

Exposure Period

As documented in the main control room log, pump FW-10 was last successfully started for a surveillance on January 20, 2010, at 8:03 a.m. The pump failed to start during testing on February 17, 2010, at 10:51 a.m. Licensee performed troubleshooting, reset the exhaust backpressure trip and the pump was returned to service at 8:36 p.m.

The team evaluated the failure mode of the pump and determined that it was unknown exactly when the exhaust backpressure trip reset lever was in a configuration of imminent failure. In accordance with the Risk Assessment of Operational Events Handbook, Section 2.3, the exposure time for a component that fails from a degradation mechanism that could have occurred at any time since the component was last functionally operated should be one-half the time from the previous successful test plus the repair time.

One-half the time from the previous test to the failure was calculated to be 14.1 days. The repair time was 0.4 days. The total exposure time was then calculated to be the sum of these two or 14.5 days.

Application of Recovery

The analyst evaluated the probability that operators fail to diagnose the condition correctly and properly reset the latch and start Pump FW-10 using the SPAR-H method described in NUREG/CR-6883, “The SPAR-H Human Reliability Analysis

Method." The following performance shaping factors were adjusted from nominal:

- Time:

  SPAR rules would indicate that a station blackout with loss of all feedwater would result in core damage in 1 hour. The licensee calculated 45 minutes to steam generator dryout for the limiting sequence. Upon steam generator dryout, licensed operators would be incapable of restarting turbine-driven auxiliary feedwater pump FW-10 because of the lack of steam.

  The analyst determined that the operators would have the nominal time required for diagnosis (25 minutes to proceed through the emergency operating procedures and dispatch an operator, and 15 minutes for the operator to follow the system operating procedure to determine that the pump needed to be reset. Therefore, diagnosis credit remained at the nominal value. Additionally, following proper diagnosis, there would be approximately 5 minutes remaining to reset and manually start the pump. This also indicated a "Nominal time" for completing the action.

- Stress:

  A station blackout scenario with a loss of all feedwater places the operators in at least a high level of stress during both diagnosis and action. Multiple competing priorities, sudden onset of stress, and the knowledge that the consequences of this task represents a threat to plant safety clearly places the operators under a high level of stress. Because the stress would not persist for long periods of time nor place the operators under a threat to their physical well being, the analyst determined that the stress would not be at the extreme level.

- Complexity:

  The analyst determined that the diagnosis of this specific failure was moderately complex. While it would be clear that the pump had not started, the cause of the failure would not be clear. The exhaust backpressure trip reset lever is unusual in design and would require accurate following of four different procedures to diagnose. Once properly diagnosed, the recovery actions are straight forward using normal operational techniques. Therefore, the analyst assumed a nominal complexity for the action portion of the recovery.

- Procedures:

  The analyst determined that the emergency operating procedures would properly focus on the turbine-driven auxiliary feedwater pump and, ultimately, the exhaust backpressure trip reset lever. Under normal conditions, these procedures, combined with operator skills and knowledge, would be sufficient to recover the pump. The complications in performing the subject recovery would not be expected to be addressed

in procedures. Therefore, the analyst determined that the procedures were of nominal level for both diagnosis and action.

- Ergonomics:

  The analyst determined that the lack of emergency lighting, hot/humid pump area, and the precise alignment needed to properly reset the exhaust backpressure trip would affect the operators ability to restart pump FW-10. Aggregate of these items were sufficient to designate a "Poor" ergonomics rating to the action for this evaluation. However, these items would not have significantly affected the ability to diagnose that the pump had tripped on exhaust backpressure.

Table 2 provides the calculations used to apply the performance shaping factors and the odds ratio. The resulting HRA non-recovery value was 5.8 percent.

TABLE 2
Reset FW-10 Backpressure Trip and Start Pump

Performance Shaping Factor	**Diagnosis**		**Action**	
	PSF Level	**Multiplier**	**PSF Level**	**Multiplier**
Time:	Nominal	1.0	Nominal	1.0
Stress:	High	2.0	High	2.0
Complexity:	Moderately Complex	2.0	Nominal	1.0
Experience:	Nominal	1.0	Nominal	1.0
Procedures:	Nominal	1.0	Nominal	1.0
Ergonomics:	Nominal	1.0	Poor	10.0
Fitness for Duty:	Nominal	1.0	Nominal	1.0
Work Processes:	Nominal	1.0	Nominal	1.0
	Nominal	1.0E-02		1.0E-03
	Adjusted	4.0E-02		2.0E-02
	Odds Ratio	3.9E-02		2.0E-02
	Composite	4		20
	Failure to Reset the Exhaust Backpressure Trip and Manually Start FW-10 Probability:			**5.8E-02**

Change in Risk from Internal Initiators

The analyst calculated the change in risk related to this performance deficiency using the following method:

1. The analyst evaluated the risk utilizing the Fort Calhoun SPAR, Revision 3.45, plus a spreadsheet evaluation of the seismic and internal fire hazards. The analyst set Basic Event AFW-TDP-FS-FW10, "AFW TDP FW-10 Fails to Start," to the house event "TRUE," indicating that Pump FW-10 failed to start on demand. The analyst quantified the model and the results are provided in Table 3 below. The analyst considered this method, hand modified for operator recovery, to be the best estimate of risk.

TABLE 3
Phase 3 Results

	SPAR Quantification
Baseline	1.29 E-5
Case	1.44E-4
Delta	1.31E-4
14.5-Day Exposure	5.22E-6
Seismic Initiator	4.39E-6
Internal Fires	1.07E-6
5.8% Non-recovery	6.25E-7**

** SDP Result with external and 5.8% nonrecovery. Analyst's best estimate.

Table 4 documents the major internal initiator sequences contributing 97 percent of the change in core damage frequency.

TABLE 4
Dominant Core Damage Sequences

Sequence	Description	ΔCDF	% of Total
LOAC1A3 15	Loss of ac Bus 1A3, Loss of all feedwater/auxiliary feedwater, and operators fail to initiate primary feed and bleed.	8.19E-5	62.4
LOOP 21	Loss of Offsite Power, Loss of auxiliary feedwater, and operators fail to initiate primary feed and bleed.	2.74E-5	20.9
SPURSGIS 15	Spurious Steam Generator Isolation Signal initiates plant transient, Loss of Auxiliary Feedwater, and operators fail to initiate primary feed and bleed.	1.51E-5	11.5
TRANS 15	Plant Transient, Loss of Auxiliary Feedwater, and operators fail to	1.67E-6	1.3

	initiate primary feed and bleed.		
RCS-LOC 3	Pipe Break in the Reactor Coolant System, Failure of the High Pressure Injection System.	1.27E-6	1.0

The analyst noted that the non-recovery probability was the only assumption sensitive enough to affect the final result of the significance determination. The analyst's sensitivity study indicated that the Green/White threshold would be at a non-recovery value of approximately 9.4 percent.

Change in Risk from External Initiators

Seismic

The analyst used the techniques delineated in the Risk Assessment of Operation Events Handbook, Volume 2, "External Events," Revision 1.01, Section 4.0, "Seismic Event Modeling and Seismic Risk Quantification," to develop a spreadsheet model of the Fort Calhoun seismic hazard. The analyst then quantified the potential of having a seismically-induced loss of offsite power over a 14.5 day exposure period as a bounding condition. The results of this analysis are shown in Table 3.

Internal Fire

From the licensee's Individual Plant Evaluation of External Events, the analyst identified twelve fire areas that the baseline risk was affected by the loss of the turbine-driven auxiliary feedwater pump, FW-10. These included fires in the main control room, cable spreading room, Room 19, the transformer yard area, and the east and west switchgear areas. The analyst quantified the change in risk by evaluating the fire ignition frequency, the nonsuppression probability, and the change in conditional core damage probability with a known failure of Pump FW-10. The results of this analysis are shown in Table 3.

Large Early Release Frequency

In accordance with the guidance in Inspection Manual Chapter 0609, Appendix H, this finding would not involve a significant increase in risk of a large, early release of radiation because Fort Calhoun has a large, dry containment and the sequences contributing to a change in the core damage frequency did not involve either a steam generator tube rupture or an inter-system loss of coolant accident.

Assessment of Licensee's Risk Evaluation

The analyst also reviewed the licensee's evaluation of the subject degraded condition. The analyst reviewed two cutset packages and determined that the licensee's model may not have completely modeled the failure modes of the Diesel-driven Auxiliary Feedwater Pump FW-54, providing a lower assessment of the risk of the subject degraded condition. Given the apparent lack of modeling affecting the Fort Calhoun PSA cutsets, the analyst determined that the SPAR

was providing the best available tool for analyzing the subject degraded condition.