UNITED STATES
NUCLEAR REGULATORY COMMISSION
REGION II
245 PEACHTREE CENTER AVENUE NE, SUITE 1200
ATLANTA, GEORGIA 30303-1257

November 29, 2017

Mr. J. W. Shea
Vice President, Nuclear Licensing
Tennessee Valley Authority
1101 Market Street, LP 3D-C
Chattanooga, TN 37402-2801

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNITS 2 AND 3 – NRC SPECIAL INSPECTION REPORT 05000260/2017008 AND 05000296/2017008

Dear Mr. Shea:

On October 19, 2017, the U.S. Nuclear Regulatory Commission (NRC) completed a reactive inspection pursuant to Inspection Procedure 93812, "Special Inspection," at your Browns Ferry Nuclear Plant, Units 2 and 3. The enclosed inspection report documents the inspection results which were discussed on October 19, 2017, and on November 20, 2017, with Mr. J. Paul and other members of your staff.

The special inspection began on October 3, 2017, in accordance with NRC Management Directive 8.3, "NRC Incident Investigation Program," and Inspection Manual Chapter 0309, "Reactive Inspection Decisions Basis for Reactors," based on the initial risk and deterministic criteria evaluation performed by the NRC. The special inspection reviewed the circumstances surrounding the high pressure coolant injection (HPCI) system injection into the Unit 3 reactor vessel during a normal in-service testing (IST) flowrate surveillance on September 24, 2017, and failure of the HPCI system discharge valve. Since the extent of condition also included a similar valve on Unit 2, this was also included as part of this inspection. The inspectors examined activities conducted under your license as they related to safety and compliance with the Agency's rules and regulations and with the conditions of your license.

The NRC inspectors did not identify any finding or violation of more than minor significance.

This letter, its enclosure, and your response (if any) will be made available for public inspection and copying at http://www.nrc.gov/reading-rm/adams.html and at the NRC Public Document Room in accordance with 10 CFR 2.390, "Public Inspections, Exemptions, Requests for Withholding."

Sincerely,

/RA/

Joel T. Munday, Director
Division of Reactor Projects

Docket Nos.: 50-260, 50-296
License Nos.: DPR-52, DPR-68

Enclosure:
IR 05000260/2017008 and
05000296/2017008 w/Attachment:
Supplemental Information

cc Distribution via ListServ

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNITS 2 AND 3 – NRC SPECIAL INSPECTION REPORT 05000260/2017008 AND 05000296/2017008
November 29, 2017

DISTRIBUTION:
S. Price, RII
M. Kowal, RII
K. Sloan, RII
OE Mail
RIDSNRRDIRS
PUBLIC
RIDSNrrPMBrownsFerry Resource

ADAMS Accession No. ML17333A173

OFFICE	RII:DRP	NRR	RII:DRP	RII:DRP	RII:DRS	RII:DRP	RII:DRP
NAME	CScott	MFarnan	DDumbacher	SNinh	AButcavage	AMasters	JMunday
DATE	11/21/2017	11/21/2017	11/24/2017	11/26/2017	11/27/2017	11/29/2017	11/29/2017

OFFICIAL RECORD COPY

U.S. NUCLEAR REGULATORY COMMISSION

REGION II

Dockets:	50-260, 50-296
Licenses:	DPR-52, DPR-68
Report Nos.:	05000260/2017008, 05000296/2017008
Licensee:	Tennessee Valley Authority (TVA)
Facility:	Browns Ferry Nuclear Plant, Units 2 and 3
Location:	Athens, AL 35611
Dates:	October 3, 2017 – October 19, 2017
Team Leader:	C. Scott, Resident Inspector, Reactor Projects Branch 1, Division of Reactor Projects, Catawba Nuclear Station, Region II
Inspectors:	M. Farnan, Mechanical Engineer, Nuclear Reactor Regulation A. Butcavage, Reactor Inspector, Engineering Branch 2, Division of Reactor Safety, Region II
Approved By:	Anthony D. Masters, Chief Reactor Projects Branch 5 Division of Reactor Projects, Region II

Enclosure

SUMMARY

IR 05000260/2017008, 05000296/2017008; 10/03/2017 – 10/19/2017; Browns Ferry Nuclear Plant, Units 2 and 3; Special Inspection Report.

The inspection activities described in this report were performed between October 3, 2017, and October 19, 2017, by one Nuclear Regulatory Commission (NRC) resident inspector from Region II, a reactor inspector from Region II and one mechanical engineer from the NRC's Office of Nuclear Reactor Regulation. The NRC's program for overseeing the safe operation of commercial nuclear power reactors is described in NUREG-1649, "Reactor Oversight Process," Revision 6.

The NRC inspectors did not identify any finding or violation of more than minor significance.

REPORT DETAILS

Event Description

On September 24, 2017, Browns Ferry Nuclear (BFN) experienced an at-power high pressure coolant injection (HPCI) system injection into the Unit 3 reactor vessel during a normal in-service testing (IST) flowrate surveillance. The surveillance flow path should have directed HPCI system flow back to the condensate storage tank (CST). On September 27, 2017, BFN determined that the unexpected HPCI system injection was the result of a failed yoke nut on the Unit 3 HPCI system discharge valve 3-FCV-73-44. The failed yoke nut on the motor operated valve (MOV) actuator allowed the valve to remain partially open, which permitted approximately 2500 gallons per minute (gpm) of HPCI system flow into the feedwater system and subsequently into the reactor vessel. Reactor power stabilized at 104.8 percent during the transient and momentarily increased to approximately 107 percent on the highest average power range monitor (APRM). This increase was due to the injection of colder water from the CST in the reactor vessel. No automatic actions occurred or were required. Reactor power returned to normal when the operators secured the HPCI turbine approximately 5 minutes into the transient.

Special Inspection Team Charter

1. Develop the maintenance/operational history of the 3-FCV-73-44 valve and the Limitorque SMB-4T actuator up to the time of failure. Assess the maintenance history for issues that could have caused or contributed to the valve failure.

2. Assess the method of control of the MOV (limit or torque switch control in the open/close directions) to determine if the assumed structural loading (weak link analysis and assumptions on the yoke nut and thrust bearings) on MOV components bounded actual set-up of the MOV. Determine if the method of control allowed excessive loads to be applied to the yoke nut and thrust bearings, potentially contributing to its failure.

3. Review and evaluate the licensee's causal evaluation related to this event, including the cause of the material failures (metallurgical lab reports for the yoke nut and thrust bearings) as well as any programmatic contributors (e.g., MOV maintenance program, vendor recommendations, parts fabrication methods, etc.).

4. Review and evaluate the licensee's immediate corrective actions related to the valve failure and the operability determination to ensure a comprehensive extent of condition evaluation was completed for the other valves with SMB-4T Limitorque actuators.

5. Review and verify that the licensee's reportability determination was in accordance with the reportability criteria in 10 CFR 50.72 and NUREG-1022.

6. Collect data necessary to support completion of the significance determination process, if applicable.

7. Review and evaluate the licensee's operator actions and procedures to detect and respond to HPCI injection into the reactor vessel.

8. Review and verify licensee actions to verify that the plant responded as designed and confirm fuel damage did not occur (thermal limits, MCPR, chemistry sample results).

9. Review and evaluate licensee actions to assess the impact on the feedwater and reactor nozzles due to the thermal transient.

10. Identify any potential generic safety issues and make recommendations for appropriate follow-up action (e.g., Information Notices, Generic Letters, and Bulletins).

4. OTHER ACTIVITIES

4OA5 Other Activities – Special Inspection (93812)

.1 Develop the maintenance/operational history of the 3-FCV-73-44 valve and the Limitorque SMB-4T actuator up to the time of failure. Assess the maintenance history for issues that could have caused or contributed to the valve failure.

a. Inspection Scope

The inspectors interviewed station personnel and reviewed control room logs, corrective action documents, maintenance work orders and work requests, test records, and previous failure analysis reports as part of the inspection activity. The following timeline is an overview of the maintenance, testing, modification history, and other pertinent milestones associated with the Unit 2 and 3 HPCI system discharge valves, 2-FCV-73-44 and, 3-FCV-73-44. It will also include the HPCI test bypass valves on Unit 2, 2-FCV-73-35 and Unit 3, 3-FCV-73-35. The intent of the timeline is to capture significant activities associated with safety related SMB-4T Limitorque actuators at Browns Ferry.

b. Findings and Observations

- Unit 2 and Unit 3, FCV-73-44 valves were installed during plant construction and were used during pre-operational testing in the mid-1970s.

- 1988: 2-FCV-73-35 was subjected to a one-time thrust of approximately 180,000 pounds. This thrust value caused no apparent after effects to the operation of the valve, and thus it was concluded to be acceptable for continued operation. Subsequent operation of the valve occurred at a lower thrust of approximately 110,000 pounds.

- 1988: The yoke nut on valve 2-FCV-73-44 failed due to intergranular stress corrosion cracking (IGSCC). The primary contributors to the IGSCC were lack of an adequate fillet radius at the flange/cylinder transition which created a high stress concentration and the presence of a contaminant.

- 1991: Laboratory report No 92-7039, documented a failed yoke nut on the 2-FCV-73-35, HPCI test bypass valve. A fracture occurred at the shoulder between the flange and cylindrical portion of the yoke nut, leading to separation of the flange. This resulted in the yoke nut cylinder to be driven out the back cover plate of the operator. The torque and limit switch settings were found to be within specification. Prior to failure of the valve, Operations noted that the valve

was not indicating its position properly and an abnormal delay was observed in illuminating the red light upon stroking the valve in the open direction. The licensee determined that the valve had an over thrust event prior to failure. Analysis believed it started with a crack and failed on tensile in the closing stroke.

TVA's review of the metallurgical analysis on the failed yoke nut concluded that the fillet radius of the yoke nut between the flange and cylindrical portion of the yoke nut was inadequate. The valve vendor was contacted and recommended TVA use a radius of at least 3/32 inches. TVA initiated an extent of condition to inspect the yoke nuts on other valves and replace or modify to improve the radius.

- 1993: An extent of condition inspection on 2-FCV-73-44 valve found the yoke nut with no or very little radius (1/32 inch). The upper thrust bearing (close direction) race was cracked. The bearing and race were replaced and the yoke nut was reinstalled because it had no signs of degradation.

- October 2001: Completed repairs for damaged motor leads on 3-FCV-73-44.

- January 2003: The Limitorque actuator for 3-FCV-73-44 was disassembled to make adjustments to the de-clutch lever and make repairs.

- March 2003: The Limitorque actuator for 2-FCV-73-44 was disassembled to make adjustments to the de-clutch lever and make repairs.

- October 2005: Repair damaged motor leads for motor from 3-FCV-73-44.

- March 2011: Implemented design change notice (DCN) 69896 to replace the stem (change lead from 1 inch to 1-1/2 inches) and wedge (weak link - stronger material) to meet motor operated valve (MOV) Joint Owner's Group (JOG) Requirements for 2-FCV-73-44.

- May 2012: DCN 69963 was implemented to meet JOG MOV requirements for 3-FCV-73-44. The modification replaced the stem, disc and wedge. The weak link wedge was replaced with a stronger material and the gear ratio was changed to meet the JOG MOV requirements.

- May 2013: Due to elevated pressures on HPCI Booster pump suction, 2-FCV-73-44 was refurbished to improve sealing capability. A ¼ inch hole was drilled in the downstream disc face on 2-FCV-73-44 to eliminate the potential for pressure locking.

- May 2014: Lubricated valve stem and stem nut interface for 3-FCV-73-44.

- January 2015: Implemented DCN 71267 to modify the control circuit to reduce the risk of spurious operation of 2-FCV-73-44 that could overload 250V Batteries. This modification was associated with transition to National Fire Protection Association (NFPA) 805.

- February 2016: Performed periodic verification diagnostic testing on 3-FCV-73-44. Adjusted the packing and lubricated the valve stem. Repaired motor lead flex on 3-FCV-73-44. DCN 71268 (NFPA-805) implemented to reduce the risk of spurious valve operation of 3-FCV-73-44 that could overload 250V Batteries.

- March 2016: Design Change 71268 implemented to reduce the risk of spurious valve operation of 3-FCV-73-44. Repacked valve 3-FCV-73-44 due to high running loads found during diagnostic testing.

- September 23, 2017: Licensee performed in-service testing of 3-FCV-73-44. The first stroke (closed to open) was in the high alert range (24.12 seconds). Subsequent re-strokes were all within acceptance criteria limits.

- September 24, 2017: Inadvertent HPCI discharge into the vessel occurred during a normal IST flowrate surveillance.

- September 27, 2017: Browns Ferry determined that a failed yoke nut on 3-FCV-73-44 caused the valve to be partially open and pass flow to the feedwater system and into the reactor.

.2 Assess the method of control of the MOV (limit or torque switch control in the open/close directions) to determine if the assumed structural loading (weak link analysis and assumptions on the yoke nut and thrust bearings) on MOV components bounded actual set-up of the MOV. Determine if the method of control allowed excessive loads to be applied to the yoke nut and thrust bearings, potentially contributing to its failure.

a. Inspection Scope

The team reviewed design documents, vendor information and interviewed MOV engineers to determine the method of control for the safety related SMB-4T Limitorque operators at Browns Ferry.

b. Findings and Observations

3-FCV-73-44 is a 14” Crane gate valve with a Limitorque SMB-4T actuator. The SMB-4T actuator internal drive sleeve assembly, which is driven by the motor and gear train, generates a rotating torque to move the stem. The torque of the SMB-4T is applied to a thrust adapter assembly which is attached to the valve upper yoke. An adapter plate mates up the SMB-4T actuator with the thrust adapter assembly.

The thrust adapter assembly is made up of the yoke nut which has threads machined to match the valve stem, upper yoke nut bearing, lower yoke nut bearing, and the cradle which holds the yoke nut and bearings. The upper and lower yoke nut bearings allow the yoke nut to be rotated by the actuator drive sleeve. During the closing stroke, the yoke nut will attempt to ride up the stem, but it is secured by the upper bearing and adapter plate. By securing the yoke nut in place, this allows the stem to move downward to close. The open direction operates the same way but in opposite direction.

The method of control for 3-FCV-73-44 is set up in the actuator circuitry. There are two methods used to set up a Limitorque actuator:

1. Limit Switch Control – Limit switches are operated by a mechanical gear train which are driven by a bevel gear which is attached to the drive sleeve. The drive sleeve is moved by the motor and motor gear set. Limit switches are used to control the valve, operate valve open and close indicators, and incorporate circuit permissive such as restricting other components from operating until the valve is in the correct position.

2. Torque Switch Control – A torque switch assembly monitors the movement of the worm. During valve movement, the motor turns the worm, which in turn moves the worm gear which is attached to the drive sleeve. When movement of the drive sleeve stops due to valve seating, the worm continues to move towards the Belleville washer spring pack assembly. The torque switch is geared to the worm movement and rotates. The Belleville washer spring pack assembly resists the movement and stores the energy. The torque switch has a set of contacts that are set with the rotation. Measurement of the spring pack movement can be correlated into the amount of torque that is being generated.

Valve 3-FCV-73-44 was set to open on limit switch control and close on torque switch control. To set the open control, the valve is manually operated until the valve contacts the back seat. Then the valve is manually operated a number of turns off the back seat and the open limit switch rotor contact gear train is set to operate at this point. The number of manual turns off of the back seat is typically set to keep the valve from contacting the back seat due to motor inertia when power is removed.

In the close direction, 3-FCV-73-44 is set on torque switch control. To set this control, the MOV engineer provides the field technician a target value of force to set the torque switch. This value is governed by the minimum required thrust to achieve closure under design basis conditions and a maximum thrust value that will not challenge any structural limits. When setting the torque switch the field technician must take into account motor inertia after the power is removed. Motor inertia after power removal can approach the upper structural limit.

When setting the torque switch control circuit, it is usually necessary to bypass the torque switch contacts during initial motor start. A motor start can jar the torque switch enough to open the contacts momentarily. If the torque switch is not bypassed, this can stop the valve travel immediately after motor start. Typical torque switch bypass setting is 5 percent of close travel. After 5 percent of close travel, the bypass is removed and allows the torque switch to control for the rest of the stroke. Unbypassing at 5 percent allows the circuit to trip if the valve closure has difficulty such as foreign material in the valve. A different strategy is to bypass the torque switch until the valve is just meeting the seat. This set up will attempt to close the valve under all conditions and credit can be taken for the actuator full capability. 3-FCV-73-44 is set with the torque switch bypassed with the valve just meeting the seat.

The original weak link calculation completed in 1988 determined that the weakest valve member for the closing stroke was the operator studs which had a calculated yield thrust of 182,896 lbs. The weakest valve member in the open stroke direction was the wedge which had a calculated yield thrust value of 231,795 lbs. Before the modification that

was completed in 2012 which addressed replacement of the wedge and upgraded the actuator for more margin (as noted in the maintenance history), the maximum closing force was approximately 85,000 lbs. or less and the opening force was approximately 45,000 lbs.

The modification of 3-FCV-73-44 completed in 2012 replaced the flexible wedge with a material that was tested by the JOG program, upgraded the actuator, replaced the stem, and replaced the valve yoke nut. The actuator gear set was upgraded to nearly double its output capability. However, doubling the output also increased the valve stroke time. To return the stroke time to its original value, which is needed to meet the design basis, the stem thread pitch and lead were changed. The new stem thread design required the valve yoke nut to be replaced with a new component that matched the valve stem thread configuration. The new stem was upgraded to a smart stem design. A smart stem has integrated into its body strain gauges which measure the torque and thrust being applied to the stem. This allows for a more accurate diagnostic test and cuts down on the test set up time. All of the new components (wedge, stem, and yoke nut) had a weak link analysis completed to determine their structural capability. The weak link was now determined to be the wedge in the closing direction with a limit of 130,650 lbs. and the open direction was the stem with a limit of 149,164 lbs.

Diagnostic testing of 3-FCV-73-44 completed after the 2012 modification showed that the final torque and thrust values for the open and closing strokes had increased. The closing stroke final thrust value increased from an as found value of 59,208 lbs. to an as left value of 116,234 lbs. which was the last periodic test performed in 2016 before the valve failure. The as left open stroke values increased about 15,000 lbs. The as left values were below what was thought to be the weakest link.

.3 Review and evaluate the licensee's causal evaluation related to this event, including the cause of the material failures (metallurgical lab reports for the yoke nut and thrust bearings) as well as any programmatic contributors (e.g., MOV maintenance program, vendor recommendations, parts fabrication methods, etc.).

a. Inspection Scope

The team interviewed maintenance and engineering personnel involved in the inspection and repairs for 3-FCV-73-44. The inspectors reviewed the condition of the removed yoke nut, thrust adapter plate and upper/lower thrust bearings. The inspectors reviewed the licensee's support refute evaluation and the metallurgy examination report for the bearings and yoke nut. The team also reviewed station corrective action reports and trends in valve performance to independently assess other factors that may have been related to this event.

b. Findings and Observations

A root cause evaluation was not completed at the time of the inspection. Condition Report (CR) 1341458 was initiated to perform the root cause evaluation and an extent of condition review. The licensee also documented preliminary findings in the prompt determination of operability evaluation for 3-FCV-73-44. The licensee noted that the final extent of condition review will be completed and documented in the root cause evaluation.

The valve failure occurred due to the yoke nut shearing. The yoke nut is constructed in a “T” fashion with the “T” section being about 1.25 inches thick. The rest of the nut is cylindrical and is connected to the actuator via sleeve and a key. The cylindrical portion sheared from the “T” section. This allowed that section to ride up the stem when going closed until it eventually bottomed out on the top cover. This provided the resistance for the stem to go closed. Due to this action the limit switches became unsynchronized. The yoke nut is enclosed in the thrust adapter assembly and extends up through the thrust adapter plate which is located on the yoke. The damaged portion of the yoke nut was also damaging the adapter plate by gouging the circumference of the inner area of the adapter plate. The gouging caused erratic performance of the yoke nut. It is believed that when the valve was closing, the severed portion of the yoke nut was binding during the closing stroke causing the torque switch contacts to open. Once the torque switch bypass limit switch opened, the motor stopped due to the torque switch being open thus the valve was still open slightly.

The licensee’s preliminary evaluation of this failure determined that the thrust adapter assembly was not fully evaluated for its weak link capability. Only the yoke nut threads were analyzed. It was also determined that the weak link analysis failed to evaluate the yoke nut upper bearing, yoke nut lower bearing, and the thrust adapter cradle that houses the yoke nut and bearings. Browns Ferry contacted the valve vendor and found that the upper and lower yoke nut bearings have a maximum strength value of 96,000 lbs. This would potentially make the bearings the limiting component. Apparent cause of the yoke nut failure was the upper yoke nut bearing cracked due to the excessive closing force applied and damaged the rolling element balls to the point where it bound up the bearing in the closed direction which in turn bound up the yoke nut which allowed the actuator force to shear the nut. This apparent cause is based on the lab analysis that concluded the shear fracture was tensile which would be in the close direction.

Unresolved Item (URI) 05000260, 296/2017008-01, Potential Inadequate Weak Link Analysis for Unit 2 and Unit 3, HPCI Discharge Valves

Introduction: A URI was identified to determine if a performance deficiency exists regarding the adequacy of the weak link analysis for the valve and actuator of the HPCI Unit 2 and Unit 3 discharge valves.

Description: During the investigation for the failure of 3-FCV-73-44, discovered on September 24, 2017, the licensee identified that the thrust adapter assembly was not fully evaluated for its weak link capability. The thrust adapter assembly consists of the yoke nut, upper yoke nut bearing, lower yoke nut bearing, and the cradle which holds the yoke nut and bearings. The weak link analysis was revised as part of the JOG modifications on 2-FCV-73-44 and 3-FCV-73-44 in 2011 and 2012, respectively. The weak link analysis was prepared by the valve vendor, and accepted by Browns Ferry. This issue was entered in the corrective action program (CAP) as CR 1344131

As a result of a potentially inadequate weak link analysis, the valve actuator settings could have been selected such that the applied actuator loads exceeded the yoke nut bearings structural capability. Once the yoke nut bearings’ structural capability was exceeded, degradation of the bearings continued to occur during normal valve operation until the upper yoke nut bearing cracked due to the excessive closing force applied and

damaged the rolling element balls to the point where it bound up the bearing in the closed direction which in turn bound up the yoke nut which allowed the actuator force to shear the nut.

This URI is being opened to review the licensee's cause evaluation and the licensee's Part 21 evaluation associated with the potentially inadequate weak link analysis. This issue is identified as URI 05000260, 296/2017008-01, "Potential Inadequate Weak Link Analysis for Unit 2 and Unit 3, HPCI Discharge Valve"

URI 05000260, 296/2017008-02, Potential Inadequate Commercial Grade Dedication of Components in Safety Related Valves

Introduction: A URI was identified to determine if a performance deficiency exists regarding the adequacy of the commercial grade dedication of the yoke nut bearings in the HPCI discharge valves on Unit 2 and Unit 3.

Description: During the investigation for the failure of Unit 3 FCV-73-44, discovered on September 24, 2017, it was identified that the yoke nut upper and lower bearings used in the HPCI discharge valves 2-FCV-73-44 and 3-FCV-73-44, were commercial grade items. The yoke nut and bearings were provided to Browns Ferry as part of the valve from a 10 CFR Part 50, Appendix B supplier. The valve vendor provided the valves as safety-related components. At the time of the inspection, Browns Ferry could not verify that the bearings were properly dedicated for use in a safety related component. Initial discussions with the valve vendor revealed that the bearings were procured as commercial grade items and incorporated into the valve design without first being specifically dedicated for use in a safety related application. This issue was entered into the CAP as CR1358257.

This URI is being opened to review the acceptance process used to provide reasonable assurance that the commercial grade items used in the HPCI discharge valves would perform their intended safety function and deemed equivalent to an item designed and manufactured under a 10 CFR Part 50, Appendix B, quality assurance program. This would also apply to the bearings that were installed on September 30, 2017, as part of the repair after this valve failed. This issue is identified as URI 05000260, 296/2017008-02, "Potential Inadequate Commercial Grade Dedication of Components in Safety Related Valves."

.4 Review and evaluate the licensee's immediate corrective actions related to the valve failure and the operability determination to ensure a comprehensive extent of condition evaluation was completed for the other SMB-4T Limitorque actuators.

a. Inspection Scope

The inspectors reviewed the immediate corrective actions related to failure of 3-FCV-74-44 and the post maintenance testing completed to verify the valve was operable following the repairs. The inspectors also reviewed the prompt determination of operability evaluations for 3-FCV-74-44 and 2-FCV-73-44.

b. Findings and Observations

At the time of discovery, the Unit 3 HPCI system was still inoperable for scheduled maintenance that began on September 17, 2017, so no immediate operability concerns existed. Subsequent licensee inspections of the valve internals identified that the valve yoke nut sheared and the yoke nut bearings were degraded. On September 30, 2017, the yoke nut and upper/lower bearings were replaced. During the repair the licensee implemented a design change to improve the design margin of the yoke nut with respect to structural integrity. The flange fillet radius of the new yoke nut was changed to 1/8 inch from the previous radius of 3/32 inches. The yoke nut flange thickness was also increased from 1.03 inches to 1.304 inches. After replacement of the yoke nut and bearings, as-left diagnostic test measured the closing thrust at 109,070 lbs.

Following the repairs, the licensee identified that the flange thickness for the yoke nut removed did not match the current vendor drawing for the valve. The vendor drawing documented a flange thickness of 1.25 inches. The work order that implemented the 2012 JOG modification, documented that the yoke nut supplied by the valve vendor, was changed to 1.03 inches to match the dimensions of the yoke nut installed prior to the 2012 modification. The licensee also found a 0.25 inches spacer that did not match the vendor drawing. Additionally, the licensee identified that the lower thrust bearing contained a single row of balls versus a double row of balls documented on the vendor drawing. At the time of the special inspection the licensee could not locate an evaluation that permitted deviation from the installation instructions in the 2012 modification package. The licensee entered this into the CAP as CR 1343734. Prior to returning the valve to service, the licensee received an evaluation from the valve vendor that determined that the single row ball bearing configuration was acceptable.

As part of the extent of condition review for 3-FCV-73-44 failure, the licensee performed a visual inspection of the 2-FCV-73-44, since it has the same actuator, similar number strokes and had the same JOG modifications in 2011. The licensee found that the installed yoke nut was intact and the bearings showed normal wear. However, the as-found valve configuration was different than the vendor drawings. Specifically, there were 20 ball bearings in the upper thrust bearing versus 24 ball bearings documented on the valve drawing. The upper bearings also had a cage installed around the bearings. Additionally, the upper/lower bearings did not match the valve drawing because the lower thrust bearing contained a single row of balls versus a double row of balls. The licensee documented this issue in CR 1347334. The licensee replaced the yoke nut and bearings in accordance with the design drawing before returning the valve to service.

Overall, the inspectors did not identify any significant issues with the licensee's corrective actions to address the cause of the 3-FCV-73-44 failure and the extent of condition for 2-FCV-73-44. However, the licensee was still developing the root cause and was working with the valve vendor to determine the root and contributing causes for the valve failure. At the end of the Special Inspection, the contributing factors to the valve failure appeared to be related to the commercial grade dedication of the upper/lower thrust bearings, potential inadequate weak link analysis for the HPCI discharge valves, and the configuration control of the valves.

URI 05000260, 296/2017008-03, Potential Inadequate Configuration Control of the Unit 2 and Unit 3 HPCI Discharge Valves

Introduction: A URI was identified to determine if a performance deficiency exists regarding the configuration control of the HPCI discharge valves on Unit 2 and Unit 3.

Description: Following the failure of 3-FCV-73-44, discovered on September 24, 2017, the licensee found that the in-plant configuration of the HPCI discharge valves on Unit 2 and Unit 3 did not match the design documentation. The yoke nut flange for 3-FCV-73-44 was found to be 1.03 inches instead of 1.25 inches documented in the design drawing. Valve 3-FCV-73-44 also contained a 0.25 inches spacer that was not included in the valve design drawing. On 2-FCV-73-44, the licensee found that the were 20 ball bearings in the upper thrust bearing versus 24 ball bearings documented on the valve drawing and the upper bearings had a cage installed around the bearings which was also not consistent with design drawings. On both valves, the licensee found that the lower thrust bearing contained a single row of balls versus the double row shown on the design drawing. This issue was entered in the CAP as CR 1347334.

Further inspection is required to determine if the undocumented as-found configurations were a performance deficiency that contributed to the failure of 3-FCV-73-44. This URI is being opened to review the licensee's cause evaluation for 3-FCV-73-44. This issue is identified as URI 0500260/, 296/2017008-03, "Potential Inadequate Configuration Control of the Unit 2 and Unit 3 HPCI Discharge Valves."

.5 Review and verify that the licensee's reportability determination was in accordance with the reportability criteria in 10 CFR 50.72 and NUREG-1022.

a. Inspection Scope

The team assessed the licensee's procedural guidance and basis for the decisions not to report the events in accordance with 10 CFR 50.72. The inspectors reviewed 10 CFR 50.72 and NUREG-1022 to determine the likely reporting criteria associated with the failure of 3-FCV-73-44 and inadvertent injection of HPCI on September 24, 2017. The inspectors interviewed station regulatory affairs personnel and station senior management to determine their logic for their decision-making process. The inspectors also interviewed licensee personnel regarding the time of discovery of failed valve.

b. Findings and Observations

No findings were identified.

.6 Collect data necessary to support completion of the significance determination process, if applicable.

a. Inspection Scope

The inspectors collected available data to support completion of the significance determination process. The inspectors reviewed the failure mechanism(s) understood at the time of the inspection and provided their findings to regional management and the

regional risk analysts. They provided additional information relative to past operability and past functionality associated with the 3-FCV-74-44. The inspectors did not identify any performance deficiencies during this inspection.

b. Findings and Observations

No findings were identified.

.7 Review and evaluate the licensee's operator actions and procedures to detect and respond to HPCI injection into the reactor vessel.

a. Inspection Scope

The inspectors reviewed the control logs, annunciator response procedures and plant data associated with the performance the HPCI IST surveillance flow test at rated reactor pressure. The team also interviewed control room operators and reviewed the operator performance assessment following the event to verify that lessons learned were captured.

b. Findings and Observations

URI 05000296/2017008-04, Potential Inadequate Operator Response to Inadvertent HPCI Injection

Introduction: A URI was identified to determine if a performance deficiency exists regarding the adequacy of control room operator's response to the inadvertent HPCI system injection into the Unit 3 reactor vessel during a HPCI in-service test (IST) flowrate surveillance. The HPCI injection lasted approximately five minutes and reactor power stabilized at 104.8 percent before operators secured the HPCI turbine.

Description: On September 24, 2017, at 2:00 p.m., with the reactor at 99.3 percent power, control room operators observed abnormalities in the power parameters during a scheduled in-service HPCI surveillance test. When the average power range monitors (APRM) displays were manually activated, operators observed that APRMs were greater than 100 percent power. Subsequently, an alarm for reactor feedwater control system input failure was received, and reactor water level was observed rising. A transient was in progress due to an inadvertent injection of the HPCI system into the reactor vessel. The inadvertent injection caused reactor power to exceed the 100 percent licensed thermal power limit of 3458 MWTH. As power continued to rise, operators noticed that the HPCI check valve 3-73-34 was indicating open, although the discharge valve 3-FCV-73-44 indicated closed. Upon identifying that 3-FCV-73-34 was open and a HPCI injection was occurring, reactor operators tripped the HPCI turbine. Plant data showed that the HPCI injection occurred for 5 minutes and reactor power stabilized at 104.8 percent during the transient. The licensee initiated CR 1343179 to investigate the cause of the event and identify appropriate corrective actions.

The inspectors reviewed the licensee's performance analysis of the event, which concluded that while the actions performed by the operating crew were adequate, their overall response time was delayed. The evaluation stated in part that "operations supervision did not clearly understand the expected plant response during the surveillance and the misunderstanding delayed the operations crew from performing a

timely identification and correction of the transient." The evaluation also identified that "what if" contingency plans were not discussed during a pre-job brief and that operator display aids were not activated prior to an evolution where reactor power should be monitored. This URI is being opened to determine if the control room operator's response to the inadvertent HPCI injection met licensee standards. This issue is identified as URI 05000296/2017008-04, "Potential Inadequate Operator Response to Inadvertent HPCI Injection."

.8 Review and verify licensee actions to verify that the plant responded as designed and confirm fuel damage did not occur (thermal limits, MCPR, chemistry sample results).

a. Inspection Scope

The team reviewed the licensee's analysis of the inadvertent HPCI injection to verify that the thermal limits were not exceeded and that fuel damage did not occur. The team reviewed data from the plant computer and interviewed reactor engineering to confirm that the assumptions used in the analysis were appropriate.

b. Findings and Observations

The licensee verified that the safety limit minimum critical power ratio (MCPR) was always protected during the event and the Core Operating Limits Report (COLR) remained bounding. No findings were identified.

.9 Review and evaluate licensee actions to assess the impact on the feedwater and reactor nozzles due to the thermal transient.

a. Inspection Scope

The team reviewed the licensee's fatigue analysis to ensure that the thermal transient that occurred on September 24, 2017, as result of the HPCI injection did not exceed the structural limits of the feedwater and reactor nozzles. The team interviewed reactor engineering and reviewed the data from the plant instruments associated with this event.

b. Observations and Findings

The licensee's evaluation determined that the thermal transient did not have a significant impact on the structural capability of the reactor and feedwater nozzles. No findings were identified.

.10 Identify any potential generic safety issues and make recommendations for appropriate follow-up action (e.g., Information Notices, Generic Letters, and Bulletins).

a. Inspection Scope

The inspectors assessed information provided by the licensee in documents and interviews for potential generic safety issues. The inspectors reviewed plant history related to previous Limitorque valve failures at Browns Ferry. The inspectors also evaluated licensee's laboratory reports in an effort to discover potential causes and likely

potential generic safety issues. Additionally, the inspectors reviewed industry information on similar events to evaluate if this occurrence was new or a repeat of other events.

b. Findings and Observations

The results described in the laboratory report are only the beginning of the licensee's causal evaluation, and did not produce enough evidence to allow the licensee to establish a definitive conclusion on the cause of the failure. The inspectors concurred that no conclusion could be drawn as yet, and determined that the potential exists that several issues could have contributed to the valve failure as discussed in the unresolved items documented in this report. The inspectors concluded that more evaluation would be required before any generic issues associated with the failure of 3-FCV-73-44 could be positively identified. This further supported the need for the inspectors to review the conclusions of the licensees' causal evaluation and the final evaluation for the potential 10 CFR Part 21 issues identified during the inspection.

4OA6 Management Meetings

.1 Exit Meeting Summary

On November 20, 2017, the team presented the inspection results to Mr. J. Paul and other members of the licensee's staff. Proprietary information that was reviewed during the inspection was returned to the licensee or destroyed in accordance with prescribed controls.

.2 Interim Exit Meetings

An interim exit was conducted on October 19, 2017. The team presented the inspection results to Mr. Hughes and other members of the licensee's staff. Proprietary information that was reviewed during the inspection was returned to the licensee or destroyed in accordance with prescribed controls.

ATTACHMENT: SUPPLEMENTAL INFORMATION

SUPPLEMENTAL INFORMATION

KEY POINTS OF CONTACT

Licensee personnel:
S. Torgersen, Chemistry Supervisor
M. Kirschenheiter, Sr. Manager of Design Engineering
P. Giancatarino, Quality Assurance Supervisor
C. Vaughn, Operations Training Manager
B. Bruce, Maintenance Director
J. Kent, Director of Plant Support
J. Garner, Site Licensing Engineer
L. Hughes, General Manager of Site Operations
S. Brown, Director of Site Projects
M. Hunter, Director of Work Management
Q. Leonard, Sr. Manager of Systems Engineering
E. Meisner, Director of Site Engineering
B. Tidwell, Site VP Technical Assistant
M. McAndrew, Director of Operations
P. Derriso, Programs Engineering Manager
M. Oliver, Sr. Program Manager of Site Licensing
J. Eggart, Sr. Manager of Radiation Protection
J. Paul, Site Licensing Manager

NRC personnel:
A. Masters, Chief, Division of Reactor Projects
D. Dumbacher, Senior Resident Inspector, Browns Ferry
K. Matthew, Resident Inspector, Browns Ferry
N. Hobbs, Acting Resident Inspector, Browns Ferry

LIST OF ITEMS OPENED, CLOSED, AND DISCUSSED

Opened

05000260, 296/2017008-01	URI	Potential Inadequate Weak Link Analysis for Unit 2 and Unit 3, HPCI Discharge Valves (4OA5.3)
05000260, 296/2017008-02	URI	Potential Inadequate Commercial Grade Dedication of Components in Safety Related Valves (4OA5.3)
05000260, 296/2017008-03	URI	Potential Inadequate Configuration Control of the Unit 2 and Unit 3 HPCI Discharge Valves (4OA5.4)
05000296/2017008-04	URI	Potential Inadequate Operator Response to Inadvertent HPCI Injection (4OA5.7)

LIST OF DOCUMENTS REVIEWED

Corrective Action Documents Written as a Result of the Inspection
1349924, NFPA-805 Functionality of 1/2/3-FCV-73-34, HPCI Outboard Discharge Valve
1344119, PDO for HPCI 2-FCV-073-0044 Valve Rev 1
1343560, PDO for HPCI 3-FCV-073-0044 Valve Rev 2
1344131, Potential Part 21 on Weak Link Analysis for FCV-73-44
1347334, Configuration of upper thrust bearing in 2-FCV-073-0044 did not match expected
1349343, PDOs for 2/3-FCV-73-44 do not address design opening thrust
1348396, Gather data in support of PDO for CR 1348396
1344633, Extent of condition for 3-FCV-073-0044 failure
1344911, Evaluate for PM

Procedures
NEDP-1, Design Basis and Design Input Control, Rev. 07
MCI-0-000-ACT004, Maintenance of SMB-0 through SMB-4T Limitorque Actuators, Rev. 49
NPG-SPP-09.3, Plant Modifications and Engineering Change Control,
NEDP-8-2, Technical Evaluation for Procurement of Safety Related and Quality Related Materials, Items, and Service
0-TI-19, Reactor Vessel and Reactor Pressure Boundary Component Fatigue Usage Factor Monitoring, Recording, Evaluating, and Reporting, Rev.11
NPG-SPP-03.5, Regulatory Reporting Requirements, Rev.13
3-EOI Appendix-11C, Alternate RPV Pressure Control Systems HPCI Test Mode, Rev. 5
3-EOI Appendix-20N, HPCI Operation during Station Blackout, Rev.0
3-EOI Appendix-7J, Alternate RPV Injection System Lineup HPCI Using Auxiliary Steam, Rev.7
3-EOI Appendix-5D, Injection System Lineup HPCI, Rev.7
3-SR-3.5.1.1(HPCI), Maintenance of Filled HPCI Discharge Piping, Revision 9
SPP-4.1, Procurement of Material, Labor and Services, Rev.25
EPI-0-000-MOV001, Electrical Preventive Maintenance for Limitorque Motor Operated Valves Revision .73
MPI-0-000-ACT001, Preventive Maintenance for Limitorque Operators, Revision .57
OPDP-1, Conduct of Operations, Rev. 0038

Drawings
Crane Dwg 0-CD03262 (2-3-FCV-073-0035)
3-PC-139988, 14” 900 W.E.O.S Press Seal Gate Valve with SMB-4T Limit Unit and Lantern Gland
PE-14133, Yoke Nut for 14” List 900 Pressure Seal- SMB-4T
3-47E610-73-1, Mechanical Control Diagram HPCI System, Unit 3
3-45E714-2, Wiring Diagram 250V DC Reactor MOV Board 3A Schematic Diagram

Calculations
Weak Link Report, WL-082, Rev. 3
NDQ099920100002 R006, BFN NFPA 805 Multiple Spurious Operation Review

Miscellaneous Documents

WO 119094689, As-left Data for 22-MVOP-73-44
NER No. 920882, IN 92-059: Horizontally-Installed Motor-Operated Gate Valves
DCN 69963, Perform JOG Updates for valve 3-FCV-73-44
BFN-VTD-C8665-0050, CRANE LIST 900 AND LIST 150 GATE VALVES
BFN-VTD-C8665-0030, 10X810" L953 W.E. Pressure Seal Globe Valve
0048-0056-LTR-001, MPR Review of TVA Browns Ferry HPCI MOV Yoke Nut Bearing Capacity
CLA Report No. AU27708, Bearing Dimensional and Material Analysis
CLA Report No. AU27274, BFN Bearings
CLA Report No. AU27033 BFN Bearings
BFN-3-17-111, PRA Evaluation Response for CR 1341468
Evaluation No. 91103590000, Thrust Bearing
3-FCV-073-0044 Total Thrust 09-30-17 following repairs
FP-BFN-403, Cycle-Based Fatigue Report for the Transient and Fatigue Monitoring System for the Browns Ferry Nuclear Power Plant, Rev 0
BFN U3 (2016) Cycle Summary Report
BFN U3 (2016) Fatigue Summary Report
Report No. 927039, Filed Yoke Nut from HPCI Pump Test Return Valve No. 2FCV-73-35
Failure Analysis of the Valve Operator Yoke Nut, HPCI Pump Test Return 2-FCV-73-35
193440-2 Purchase Order: Stem, Valve, QA1, Gate, 14in, 900lb
DCN 69896, JOG modifications 2-MVOP-73-44
EWR17PROG073244, Justification for why the 3-FCV-73-44 would have opened with the broken yoke nut.
UFSAR Section 6.4 ECCS
Document No: 51 – 9147696, Browns Ferry Disposition of Inadvertent HPCI Pump Start Event
Just-in-Time Training for HPCI 3-SR-3.5.1.7
CAI Report No. OTC-258 Rev. 0
D281844-2, Metallurgical Test Report for Valve 73-44 Stem Nut, Rev. 1
D281844-1, Tensile Test Report, Rev.1
DCN 71268, 3-73-44 Circuit 805 modification
DCN 69963 JOG modifications 3-MVOP-73-44
MDQ2073910100, MOV 2-FCV-073-0035 Operator Requirements and Capabilities
MDQ3073920417, MOV 3-FCV-073-0044 Operator Requirements and Capabilities
MDQ2073910103, MOV 2-FCV-073-0044 Operator Requirements and Capabilities
MDQ3073920414, MOV 3-FCV-073-0035 Operator Requirements and Capabilities
3-47B370-2, Mechanical Motor Operated Valves- Testing Requirements, Unit 3
Limitorque Maintenance Update 92-1
BFN-50-7073, High Pressure Coolant Injection System

Corrective Action Documents

1341595, 3-ARF-9-3F Panel not immediately followed
1349004, Past NFPA 805 functionality evaluation for 3-FCV-73-44
1347334, Past Operability Evaluation for 20FCV-073-0044
1343179, Performance Analysis Worksheet HPCI Flowrate Test
1346828, Work order for inspection / repair of 3-FCV-073-0035
1345453, NRC special inspection team (3-FCV-73-44)
1344416, 3-FCV-73-44 machining on yoke nut in 2012
1344378, Implementation of DEC 72668
1343735, Implement Monitoring Actions for 3-FCV-073-00441344119, Extent of condition for 3-FCV-73-44 failure
1343734, Restore 3-FCV-073-0044 to Fully Qualified

1343560, Analysis on the 3-FCV-73-44
1343179, Narrative Log Entries deficient after U3 HPCI inadvertent injection
1341468, BFN-3-HS-073-0044A appears to be not fully closed
1341458, U3 HPCI injection to vessel during flow rate
1341315, BFN-3-MVOP-073-0044 out of stroke time
1347395, As-left MOV diagnostic testing on 10/12/2017

Work Orders
WO 111044065, Replace Parts to Meet MOV JOG Requirements
WO 92-48327-01, Perform Inspection of Yoke Nut of FCV-73-44
WO 91-40085-00, 2-MVOP-70-35 Corrective Maintenance
WO 99-001461, Perform MOVATS Testing on FCV-73-44
WO 99-001388, Perform Preventive Maintenance Inspection on BFN-MVOP-73-44
WO 08-717455, Perform Preventive Maintenance Inspection on BFN-MVOP-73-44
WO 02-008295, Limitorque is Very Hard to stay on Handwheel
WO 18065762, 3-SR-3.5.1.7, HPCI Main Booster PMP Flowrate Test
WO 09-727703, BFN-2-MVOP-073-44