TP16-1-112
Revision 4
August 2017

Recommendations to Resolve Flowserve 10CFR Part 21 Notification Affecting Anchor Darling Double Disc Gate Valve Wedge Pin Failures (Revision 4)

BWROG Valve Technical Resolution Group

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NRR

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Duke Energy– Brunswick	FirstEnergy – Perry
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Exelon - Dresden / Quad Cities / LaSalle	Xcel Energy– Monticello
Exelon – Nine Mile Point	

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Revision Summary

Original Release "BWROG-TP-13-006".

Revision 1 – Update to incorporate Operating Experience based on industry inspections - Addendum 1. (Distributed as TP16-1-112 r1 due to BWROG document naming convention change).

Revision 2 – Revision to incorporate lessons learned and recommendations resulting from a stem/disc separation event that occurred at Exelon's LaSalle Station in February 2017. The document has been rewritten to better integrate the latest operating experience and recommendations. Addendum 1 has been eliminated with applicable information incorporated into the body of the report. (Distributed as TP17-1-112 but should have been TP16-1-112 r2).

Revision 3 – Update to incorporate comments from Flowserve and others to facilitate formal Flowserve Corporation endorsement of the updated Topical Report. (TP16-1-112 r3).

Revision 4 – Revision to incorporate results of detailed failure analysis of the LaSalle HPCS MOV stem/disc separation event which led Flowserve to issue a revised Part 21 Notification over newly discovered limitations with the pressed-on stem collar to support the actuator thrust loads and maintain stem-wedge preload. The revision provides a discussion on the potential scope impacts of this discovery as well as recommended actions to permanently resolve the issue. The revision also provides additional guidance on the proper conduct of MOV stem rotation checks (SRCs) as well as a new recommendation to periodically perform SRCs for applicable Anchor Darling Double Disc Gate Valves.

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I. EXECUTIVE SUMMARY

Revision 4 Update

In July 2017, Flowserve issued a letter to the NRC which provided an update to the original February 2013 10CFR21 notification based on the additional insights and information gained from the engineering failure analysis of the LaSalle HPCS MOV (Feb 2017). This analysis showed that limitations of the pressed-on stem collar design played a contributing causal factor leading up to the LaSalle MOV stem-disc separation. The update provides additional scoping criteria and recommendations to address this discovery. The update provides additional guidance regarding stem rotation check methods to ensure they are sufficient accurate, representative and trendable. Flowserve provided a review and endorsement of this update. Finally, the update also aligns recommended actions in Attachment 10 to the July 31 2017 NRC letter to NEI.

New actions from revision 4.

1. Evaluate impact of pressed-on stem collar on possible susceptible MOV scope additions.
2. Schedule applicable safety related MOVs for periodic stem rotation checks in conjunction with periodic verification (diagnostic) testing.
3. Evaluate existing Stem Rotation Check techniques against recommended guidance provided in Attachment 7 (new).
4. Review recommended actions and schedule in Attachment 10 (new) and take appropriate actions.
5. Review changes to configuration control recommendations to prevent reoccurrence.

Revision 3 Update

In May 2017, following the issuance of Revision 2 of this document, several minor changes were made to the content of the report to obtain vendor (Flowserve) endorsement of the report as well as address several minor comments from VTRG committee members. Minor changes made include clarifications on the recommended approach for performing stem rotation checks, update the recommended action table for lower priority valves to include a wedge pin analysis option, and a clarification on when the use of thread friction is considered acceptable. The overall intent of this report is not impacted by Revision 3.

New actions from revision 3.

1. Evaluate additional guidance for the conduct of stem rotation checks.
2. Evaluate Flowserve endorsed guidance and limitations on the performance of wedge pin shear capability analysis.

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Revision 2 Update

On February 11, 2017, Exelon's LaSalle Unit 2 experienced a stem-disc separation of their High-Pressure Core Spray (HPCS) Pump Discharge Valve (Ref: ICES 407589). It was concluded that the 12-inch motor operated valve (MOV) had failed during the refueling outage sometime between the local leak rate testing and the HPCS system fill and vent procedure. The subject MOV was identified to be one of 22 LaSalle MOVs potentially susceptible to wedge pin failures under the Flowserve Title 10 of the Code of Federal Regulations (10 CFR) Part 21 Notification discussed below. LaSalle had been monitoring this valve using guidance provided under the original version of this BWROG Guidance (TP-13-006). The MOV was last diagnostically tested in 2015 during L2R15. Post failure analysis of the 2015 diagnostic test traces identified anomalies in the valve open pullout region that were not present during the previous 2011 and 2005 traces. A lesson learned from the event is that the MOV diagnostic test data anomalies were not attributed to a potentially degraded stem-disc connection. Given that the failure occurred within just one operating cycle from possible detection in 2015, it is unlikely that this failure could have been prevented unless more aggressive corrective actions were instituted. This failure led Exelon to issue fleet wide actions that provide more aggressive and comprehensive remediation of this valve reliability issue. The important lessons learned and recommended actions from the LaSalle event are captured in the Revision 2 update.

<u>New actions from revision 2.</u>

1. Evaluate and Implement risk based schedule of actions to permanently repair all susceptible MOVs.
2. Perform interim Stem Rotation Checks and Diagnostic Testing in accordance with recommended schedule until susceptible MOVs are repaired.
3. Review diagnostic trace learnings from the LaSalle HPCS MOV failure.

Revision 1 Update

In December 2016, Topical Report TP-13-006 was revised (as TP16-1-112) that included an Addendum that reviewed applicable US Nuclear Operating Experience (including 26 stem/disc connection disassembly and inspections) over the last three years since TP-13-006 was issued and make any appropriate changes to the original set of recommendations. Surprisingly, 24 of 26 MOVs with various manufacture dates were found with loose stem to wedge connections (i.e. no factory pre-torque). In all cases, the upper wedge could be unthreaded from the stem by hand after the pin was removed. In most cases, there was a measurable gap between the upper wedge and stem shoulder when the stem, wedge, and pin were completely assembled. Based on the inspection results, it should not be assumed that the upper wedge and stem were originally torqued by Flowserve when assembled. Therefore, the pin should be considered in the load-path (from a torque perspective). The pin is the only structural member preventing the upper wedge from unthreading from the stem (while traveling open). Given these findings, the BWROG updated its guidance to recommend only two long-term solutions to satisfactorily resolve the issue. These include:

a. Analyze the stem/wedge connection from a torque perspective and show that all anticipated operating loads are acceptable. It should not be assumed that the

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connection was pre-torqued during assembly unless documented evidence is available.

OR IF a. is UNSUCCESSFUL

b. Disassemble the valve and torque the stem/wedge connection to a value that exceeds all anticipated operational loads plus a margin allowance. This approach may require purchasing a replacement stem, pin, upper/lower wedges, and disc retainer hardware (as applicable).

The December 2016 BWROG Guidance recommended the industry implement the repair approach (as required) no later than three Refuel Outages (maximum six years). This recommendation was largely based on the fact that no A/D DDG stem-disc had actually failed in service by way of stem-disc separation in service and less than four industry events where the pin was bent or sheared as a result of operating the MOV.

New actions from revision 1.

1. Revise plant actions to repair all susceptible MOVs within three refuel outages (6 year maximum).

Original Executive Summary (Background)

On February 25, 2013 Flowserve issued a 10CFR Part 21 Notification (Reference 1) concerning Wedge Pin Failure of an Anchor Darling Double Disc Gate Valve (A/D DDGV) at Browns Ferry Nuclear Plant Unit 1 (BFN1). Previously on January 4, 2013 Tennessee Valley Authority (TVA) issued a 10CFR21 Notification Letter (Reference 2) to the NRC on the same subject. The 10CFR Part 21 notifications referenced the most recent failure on October 20, 2012 of a BFN1 Unit 1 HPCI Inboard Steam Isolation Valve which significantly exceeded its leakage rate administrative limit. Disassembly and inspection revealed that the valve stem to wedge anti-rotation pin (referred to by Flowserve as the "wedge pin") had broken in several locations and the disc retainer had fallen from the wedge assembly and was found between the valve discs. Browns Ferry has had previous wedge pin failures on identical A/D DDGVs dating back to 2001 when they began installing and replacing their HPCI system steam isolation valves with the Anchor Darling Double Disc Valve design in order to improve valve LLRT performance and reliability. Flowserve in their 10CFR Part 21 Notification concluded that the root cause of the wedge pin failure was excessive load on the wedge pin. The stem operating torque exceeded the torque used to tighten the stem into the upper wedge before installation of the wedge pin, ultimately causing the wedge pin to shear. Flowserve states that this situation can potentially occur on any A/D DDGV with a threaded stem to upper wedge connection (typically size 2.5 inch and larger) operated by an actuator that applies torque on the stem to produce the required valve operating force. This would typically include most A/D DDGVs in motor operated valve applications which utilize Limitorque or Rotork actuators. Flowserve recommends that all critical A/D DDGVs with threaded stem to upper wedge connections and actuators that produce torque on the stem be evaluated for potential wedge pin failure. Flowserve further states that there is no non-intrusive test or inspection

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method to determine if the stems were adequately torqued into the upper wedge prior to pin installation. However, abnormal rotation of the stem immediately after valve seating or unseating, short valve stroke or poor, unusual operation may be symptoms of a degraded or failure stem disc connection and should be investigated.

On a positive note, the A/D DDGV design is widely used in many critical MOV applications across the US Nuclear industry with installed US Nuclear safety related MOV applications in the thousands most of which have been installed during original construction (average time in service 25 to 30 years). The valve design has had an otherwise excellent performance record particularly for reducing valve leakage.

In April 2013, Topical Report TP-13-006 was developed by the BWROG Valve Technical Resolution Group (VTRG) to provide a recommended industry response to the Flowserve 10CFR Part 21 Notification given the enormous potential industry impact if intrusive inspections and repairs are performed on every susceptible A/D DDGV. The US nuclear industry could not realistically intrusively inspect and repair every affected valve application in the short term without negative impacts on safety system availability, outage duration, O&M costs and total radiation exposure. The report provided a prioritized inspection and evaluation plan developed based on a thorough review of all applicable Nuclear Operating Experience with A/D DDGV wedge pin failures. From this review, the BWROG VTRG believed that there are specific attributes that put selected A/D DDGV applications at higher risk of wedge pin failures than others and that these attributes provide the basis for prioritizing the susceptible valve populations at each affected plant. Each of these risk attributes will be described and validated using industry operating experience. This report then provided suggested evaluation methods which can be used to disposition the susceptibility to wedge pin failure. These evaluation methods range include: analytical calculations, visual observations of stem movement, diagnostic test evaluations, Borescope inspections and intrusive inspections and stem/wedge connection restoration. Minimum recommended methods of evaluation and a suggested schedule was to be assigned to each assigned priority category. Finally, the report provided guidance for maintenance and valve program procedures to ensure that future wedge pin failures are eliminated.

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II. BACKGROUND

Detailed Valve / Failure Description (Browns Ferry MOV Failures)

The 2012 Failure Event - Reference 3 – TVA BFN Root Cause Report (PER 639155) Dated 12/21/2012.

On October 20, 2012, the as-found local leak rate test (LLRT) for 1-FCV-073-0002, Unit 1 HPCI Inboard Steam Isolation Valve, significantly exceeded administrative limits. The measured leak rate was 599.8 standard cubic feet per hour (scfh) with an administrative limit of 30 scfh. 1-FCV-073-0002 was subsequently disassembled on 11/06/2012 to investigate the cause for the failure. This investigation revealed that the wedge pin had broken in several locations and the disc retainer had fallen from the wedge assembly and was found located between the valve discs. This valve was originally installed in July 2005 with the plant returning to power operation in June 2007 (74 total cycles).

Direct Cause: *The direct cause for the wedge pin shearing in 1-FCV-073-0002 is rotation of the valve stem at its threaded connection to the upper wedge connection.*

Root Cause: *BFN failed to validate that vendor had torqued 1-FCV-73-2 stem to upper wedge connection per vendor's procedures which were modified in response to earlier failures of the same valve design.*

Previous Browns Ferry Nuclear Failures:

(2001) - The first failure occurred on 2-FCV-073-0003 right after the valve was installed in April 2001. The valve was over-thrust during initial setup (only 3 strokes) resulting in the wedge pin failure. The vendor provided a letter stating that the failure of the wedge pin should not have occurred during the MOVATS testing. At the time, it was Flowserve's opinion the failure was attributed to the stem not being threaded/shouldered against the stem collar. They also stated that they assured TVA that the remaining equipment on order was inspected prior to shipment. With reasonable assurance, it can be assumed the Unit 3 HPCI valves (3-FCV-073-0002 and 3-FCV-073-0003) stem to upper wedge were torqued to the correct value. The valve serial number for the wedge pin failure was E125T-2-1.

(2008) - The second failure occurred on 1-FCV-073-0003 during U1R7 (first) refueling outage in November 2008. The valve had been installed in June 2006 during Unit 1 Restart. As-found MOVATS and an as-found LLRT testing identified the wedge pin failure. The pin broke in the middle of the wedge signifying loads were put on the retainer clip. Several other issues were identified with this valve/actuator: wrong motor pinion gear installed and minimal contact surface between the worm and worm gear. All the loose valve parts were identified in the valve body above the seating area.

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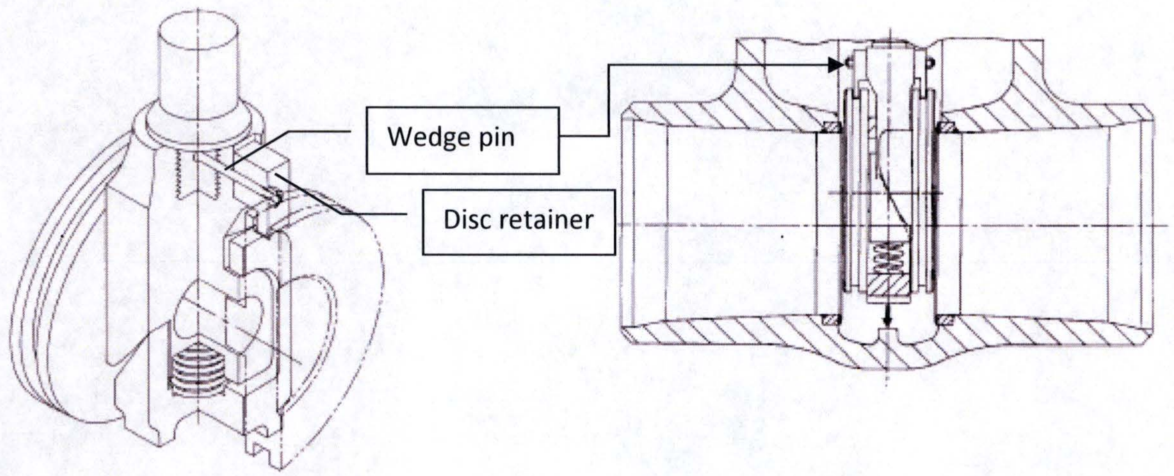
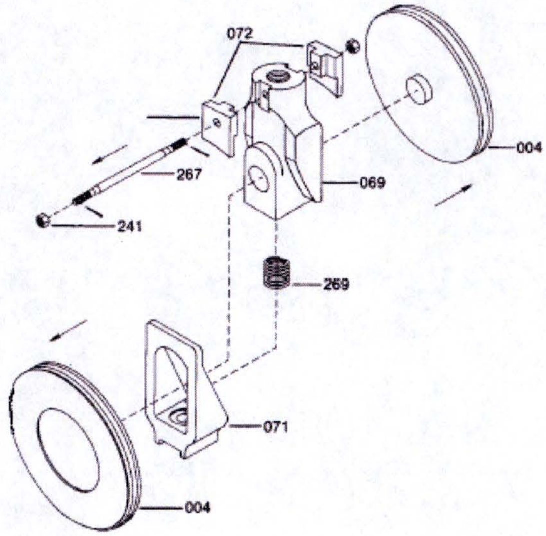
Anchor Darling Double Disc Gate Valve Design Information for BFN

Cutaway pictures of a typical anchor darling double disc valve with threaded upper wedge stem connection with wedge pin and disc retaining clips



Exploding picture of the disc assembly



1/2/3-FCV-073-0002, 1/2/3-FCV-073-0003 and 2/3-FCV-073-0016 are 10-inch, Anchor/Darling (A/D), Class 900, pressure seal, double disc gate valves. The original BFN valves were installed with Crane pressure seal wedge gate valves. Units 2 and 3 HPCI inboard and outboard valves (73-2 and 73-3) had frequently failed local leak rate testing (LLRT) and were constant maintenance problems. Due to these constant problems, Units 2 and 3 replaced these valves beginning 2001 with the double disc gate valve design. Unit 1 recovery incorporated this same change prior to the restart. 1/2/3-

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FCV-073-0002 are located in a vertical line of pipe (stem horizontal), 1/2/3-FCV-073-0003 are in a horizontal line of pipe with the stem horizontal and 2/3-FCV-073-0016 are in a horizontal line with the stem vertical.

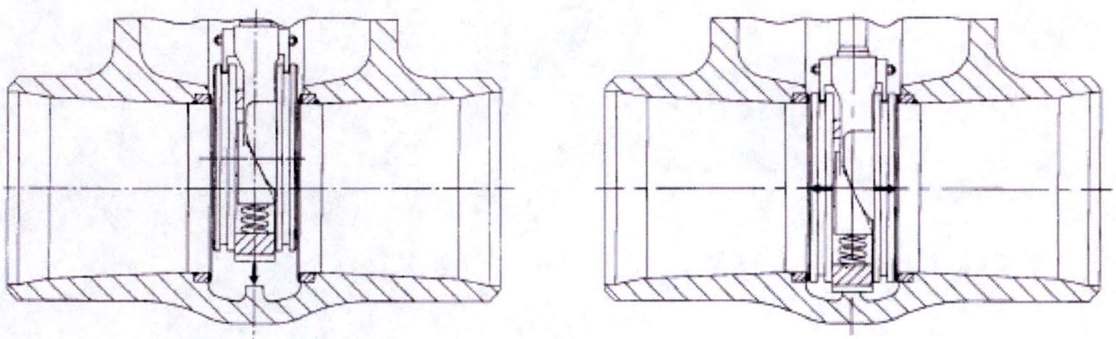
Anchor Darling Double disc gate valves are designed to improve the sealing capabilities of the valve utilizing the following features:

1. Four-piece double disc wedge assembly to impart sufficient thrust to each disc to enhance seating of both the upstream and downstream discs.

2. Discs that rotate during each closing stroke to equalize wear on the seats and discs.

The disc assembly consists of dual floating discs with a two-piece wedging mechanism between them. Trunnions on the back of each disc fit into holes in the upper wedge. The stem is threaded and torqued into the upper wedge. A hole is drilled through the stem for the wedge pin to hold the disc retainers in place. The stem disc trunnions and retainers allow it to serve as a carrier for the discs. A lower wedge is loosely hung on a land on the upper wedge between the discs. Note: Not all valves are supplied with disc retainers.

The closing stroke is the main concern for isolation. During the closing stroke of the double disc gate valve, the actuator moves the valve stem lowering the disc assembly into the flow path. As the disc assembly begins to provide flow resistance, differential pressure forces the downstream disc against the downstream seat, where disc-to seat friction resists valve closure. As shown in the first picture below, the lower wedge contacts a "bridge" in the bottom of the valve body between the seats. Further travel of the upper wedge causes it to contact the lower wedge on the beveled interface and spread both the wedges and the discs out against the seats as shown in the second picture. The valve seal is primarily created by DP loading on the downstream disc. The wedging mechanism provides additional seating stress where the DP provides insufficient seating stress to affect a seal. When the stem is raised, the upper wedge immediately pulls away from the lower wedge, eliminating the wedging force of the discs on the seat.



Double disc gate valves stems use either a T-slot configuration or a threaded connection for the stem to wedge interface. 1-FCV-073-0002 is designed with a threaded stem to wedge interface. The stem diameter is 1-3/4" with a 1/2" pitch and 1" lead (stem nut). The stem to upper wedge connection is comprised of a 1-1/2" – UNF thread on the bottom of the stem with a shoulder. The shoulder mates to the top of the upper wedge to prevent additional stem rotation in the threaded connection. Provided this threaded connection

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is properly pre-loaded, no additional rotation of the valve stem should occur. The torque should be transmitted directly from the shoulder on the valve stem to the upper wedge. The wedge pin is not intended to be a load bearing component. Because the wedge pin is not load bearing the weak link and seismic reports did not include this connection in their report. Thus, torsional stem loading is carried by the threaded stem and shoulder and their connection to the upper wedge.

The stem to stem nut threads are left handed Stub ACME threads and the threads in between the stem and upper wedge are right handed threads. Therefore, the right-handed thread into the upper wedge tightens as the valve goes closed and can loosen going open.

Actuator and motor Information

1-FCV-073-0002 actuator is an SMB-2 with a 72.01 overall gear ratio (OAR). The motor is an 80 ft-lb, 3600 rpm and frame size EA210TY motor. Based on the stem lead, OAR and motor size, this valve is considered to be a high-speed valve with considerable inertia loading after control switch trip (CST). This is shown in the MOVATs MOV diagnostic trace where CST is approximately 4,500 lbs. and the inertia carries the valve to the total thrust of approx. 55,000 lbs.

Valve Controls

The HPCI valves are controlled by a limit switch in the opening and closing directions. The closing limit switch is designed to close between 0 and 1% from full closure. This ensures the actuator will do everything possible to close the valve within 99% of travel. The open limit is set between 80 – 90% from full open to address inertia from the high-speed valve.

Disassembly Inspection Results of the 1-FCV-073-0002 Valve (11/2012 Failure)

Upon valve disassembly, it was identified that the shoulder of the stem was hard against the upper wedge (no gap) as shown left. The plant initially decided to try and unthread the stem from the upper wedge. The stem and wedge were secured in a chuck and the valve maintenance team attempted to unthread the stem from the wedge with a 48" pipe wrench. The stem did not move with the efforts of two able bodied men pulling on the end of the wrench. When the stem could not be unthreaded from the upper wedge, it was cut / machined to determine which way the stem had rotated as shown in the picture below. The picture below shows the stem had tightened in the upper wedge approximately 80˚. This signifies the stem had tightened in the upper wedge going in the closed direction. After discussion with the valve vendor, it was concluded the stem to wedge connection was not torqued adequately when Flowserve assembled it at the factory. Flowserve identified they did not have any as-built documentation showing the stem was torqued into the upper wedge when the valve was assembled at the factory.

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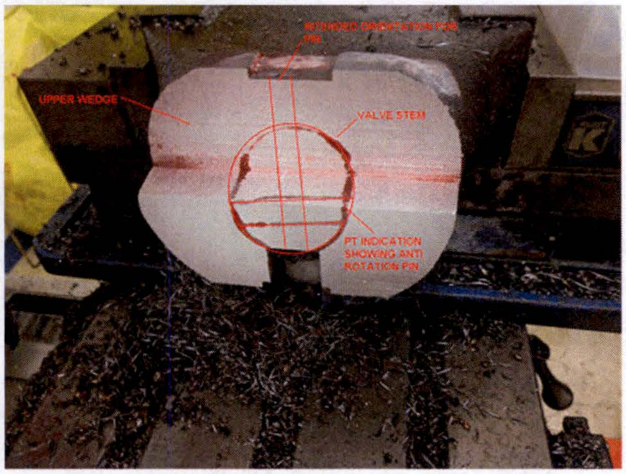

TVA BFN Issues 10CFR Part 21 Notification (January 4 2013)

On January 4, 2013, TVA in accordance with 10 CFR Part 21, "Reporting of Defects and Noncompliance provided the NRC written notification of a defect in a basic component, i.e., a defect discovered in the High-Pressure Coolant Injection system inboard containment isolation valve due to a failure in the anti-rotation pin in an Anchor Darling (Flowserve) double disc gate valve. The actual TVA Notification is provided as Attachment 1 to this topical report.

The Flowserve 10CFR Part 21 (February 25, 2013)

On February 25, 2013, Flowserve issued a 10CFR Part 21 Report to the NRC regarding the "Wedge Pin Failure of an Anchor Darling Double-Disc Gate Valve at BFN1". The Flowserve Letter was a formal follow-up to the TVA Notification associated with a failure of the HPCI 10" 900# rating Anchor Darling Double Disc Gate Valve in 2012. Flowserve's evaluation concluded that the failure was due to the shearing of the wedge pin which serves a joint locking function at the threaded interface between the valve stem and upper wedge. The pin is designed to ensure that the joint does not loosen due to vibration and other secondary loading. Flowserve's evaluation of the failure concluded that the stem/wedge pin failed due to excessive torque loading. The applied stem operating torque exceeded the pre-torque used to tighten the stem into the upper wedge during valve assembly. This operating torque then produced stress loading on the wedge pin which exceeded the pin shear strength causing the failure. Before 1996, Anchor Darling did not have quantitative quality control on the stem/wedge pre-torque values. Consequently, Flowserve is recommending that all Critical Anchor Darling Double Disc Gate valves with threaded stem disc to upper wedge connections be evaluated for potential wedge pin failure. Flowserve further states that there is no non-intrusive test or inspection method to determine if the stems were completely torqued into the upper wedge prior to pin installation. Valves with stems 1.5" and smaller would require replacement since these stems cannot be re-drilled without compromising stem structural integrity. The complete Flowserve Letter is provided as Attachment 2 to this topical report.

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Additional Input from Flowserve (not included in Part 21 Notification)

The BWROG VTRG received additional input from Flowserve in response to a formal request for information during a March 14, 2013 teleconference. This information is provided as Attachment 3 to this report.

III. APPLICABLE OPERATING EXPERIENCE

Operating Experience (OPEX) Review – Other Industry Failures of Anchor Darling Double Disc Gate Valve (A/D DDGV) Stem/Wedge Connections

LaSalle Unit 1 (BWR-5) 1993-02-10 12:00 PM #133963

(10 inch DDGV Class 900 – Stem = 1¾ inch) Forced normal Rx shutdown due to failure of Reactor Core Iso. Cooling Sys. (BWR) gate valve 1E51-F063.

Recently installed new Anchor Darling Double Disc Gate Valve failed to open during a system surveillance test and resulted in a forced reactor shutdown to repair. It was discovered that the wedge pin had failed and the stem and wedge had separated. The cause as reported in the INPO OPEX report was overtorquing of the valve disc into the seat during closure caused by set point drift from loose torque switch adjusting screws. Hydraulic locking was also suspected in the OPEX report. A follow-up plant led root-cause investigation revised the primary cause to be pressure locking which created an opening torque requirement which exceeded the torque carrying capability of the stem/disc wedge pin connection.
PRIMARY CAUSE: Pressure Locking

Surry Unit 2 2011-02-02 5:33 AM #247366

(32 x 30 x 32 inch DDGV venturi body Class 1500) Automatic reactor scram and AP-913 failure event due to failure of disc and wedge pin in the 2-RC-MOV-2595-VALVE.

On 2/2/2011, failure of a Loop Stop Valve on Surry Unit 2 at full power caused a Low Flow Reactor Trip. Investigation determined that the cold leg loop isolation valve was blocking flow in the "C" loop. The direct cause of the reactor trip was determined to be a stem to disc separation of the "C" loop Cold Leg Stop Valve. The disc assembly fell into the Reactor Coolant flow stream, reducing RCS flow below the Reactor trip set point of 92%. The "C" loop Cold Leg Stop Valve experienced a stem to disk separation caused by vibration induced failure of the threaded connection and failure of the wedge pin. This failure allowed the valve disc assembly to fall into the "C" loop flow stream, partially blocking flow and causing a low RCS flow Reactor trip.
PRIMARY CAUSE: Flow Vibration induced failure

Surry Unit 2 1999-07-05 11:22 AM #180885

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(32 x 30 x 32 inch DDGV venturi body Class 1500) Automatic reactor scram due to failure of Reactor Coolant System (PWR) gate valve 2-RC-MOV-2591-VALVE.

On July 5, 1999, Surry Unit 2 experienced an automatic scram from 100% power on indication of low reactor coolant flow in coolant loop A. The loss of coolant flow in coolant loop A was caused by the disc separating from the stem in the cold leg loop stop valve. The wedge pin that fastens the disc to the stem had broken, allowing the disc to unthread from the stem and fall to the closed position. There were two root causes for this event. The first was inadequate preventive maintenance. Inadequate lubrication of the stem nut contributed to excessive torque being applied to the shaft, allowing the shaft/wedge pin to shear, which in turn allowed the shaft to unthread from the wedge/disc assembly during normal MOV operation. The second root cause was operating practices contrary to vendor recommendations, such as applying excessive closing torque and routinely back-seating the valves during operation, which contributed to excessive torque being applied to the stem, causing the wedge pin to shear.
PRIMARY CAUSE: Overtorquing and routine power backseating

River Bend Unit 1 (BWR-6) 2007-05-23 5:16 PM #226858

(20 x 16 x 20 inch DDGV venturi Class 1500 ~2½ inch stem) Forced normal Rx shutdown and AP-913 high critical component failure due to failure of wedge pins in *Reactor Recirc. Pump Disch. Valve B33-MOVF067A VALVE.

On 5/21/2007, an unexplained drop in Reactor Recirculation System Loop A flow occurred. As a result, reactor power lowered to approximately 96.5% with no operator actions and no change in loop A flow control valve position. After determining the most probable cause for the condition to be internal damage of the Loop A Discharge Isolation Valve B33-MOVF067A leading to partial blockage of flow, the plant was shut down on 5/22/07. The failure mechanism was determined to be as follows:

- Disc assembly vibrated due to turbulent flow through valve and partial extension of disc assembly into flow stream (flow-induced vibrations).
- Flow-induced vibrations cause relative motion between the parts and fretting wear of stem and wedge threads and wedge pin.
- As threads wear, load is shared with wedge pin and pin begins to wear.
- Threads become worn to point of not being able to carry weight of disc assembly and wedge pin fails due to wear and overload and/or fatigue.
- The stem to upper wedge assembly joint was not properly torqued when the RDGVs were rebuilt in 1992 due to lack of vendor torque requirements and lack of questioning of this consideration by RBS Engineering

PRIMARY CAUSE: Flow Induced Vibration combined with inadequate torque when the valves were rebuilt in 1992.

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Grand Gulf Unit 1 (BWR-6) 2001-11-27 12:00 AM #195369

(20 x 16 x 20 inch DDGV venturi Class 1500 ~2½" stem)

OE15185 - Failure of Wedge Pin on Reactor Recirculation Pump Discharge Isolation Valve Creates Loose Part That Is Captured by Jet Pump Nozzle. Follow-up to OE13051 In October 2002 (RF12) inspection of the jet pump determined that one of the five jet pump nozzles associated with JP #13 was almost completely blocked with the nuts and threaded portion of the upper retainer pin from a reactor recirculation pump discharge valve. The pin failed at the base of the threads on the downstream side of the anti-rotation plate. Boroscopic inspections of the recirculation pump discharge isolation valves identified galling on the "B" disk and anti-rotation plate and absence of the portion of the wedge pin, double nuts and cotter pin on the downstream side. The boroscope inspections on the "A" valve revealed significantly less damage than that experienced by the "B" valve. With the assistance of magnification from a microscope, engineering inspected the failed wedge pin. The failure occurred where the threads start and indicated high cycle bending induced stress as the cause of failure. No indications of stress corrosion cracking were observed. Forces causing the pin failure were not due to flow induced rotational forces imposed against the disk and wedge pin. Pin failure was most probably due to tensile forces induced by fluttering of the valve disk as a result of high flow and clearances between the disk and the guides. The 'A-564-630' material was replaced with Inconel 625-B446 as it has superior resistance to stress corrosion cracking, its yield stress is almost one third higher and it is pre-stressed to reduce high cycle fatigue affects. High cycle bending induced fatigue of the wedge pin caused by valve disk flutter. Valve disk flutter is attributed to flow and valve guide tolerances
PRIMARY CAUSE: Flow Induced Vibration

Grand Gulf Unit 1 (BWR-6) 2004-06-14 12:00 AM #210785

(20 x 16 x 20 inch DDGV venturi Class 1500 ~2½" stem)
OE19912 - Axial Play in The Recirculation Pump A Discharge Valve Stem to Upper Wedge Connection

Thread wear on the recirculation pump A discharge valve stem created a gap between the wedge pack and the stem shoulder. Therefore, the wedge pack/disc weight was being held by the wedge pin and not the threaded connection between the stem and wedge pack. Evidence also indicates that some twisting action normally takes place. The apparent cause for the axial play is that there was insufficient torque on the connection during the assembly. The original design for the stem/wedge joint didn't require a specific torque, but was torqued as an assembly using either off-center leather mallet strikes to the upper wedge or several snaps of a strap wrench on the stem. The wedge pin is used as a locking device for the threaded connection. The present design requires 750 ft-lbs torque. The apparent cause for the axial play in the recirculation pump “A” discharge valve stem to upper wedge connection is insufficient torque on the connection during the assembly. Without the proper torque, the service loads/vibration loads overcame the frictional resistance in the connection allowing the threads to fret. The wedge pins

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minimize the fretting but the tolerances in the hole dimension were too great to prevent the erosion of the connection.
PRIMARY CAUSE: Flow Induced Vibration application combined with Inadequate Torque

Vermont Yankee Unit 1 (BWR-4) 2011-10-09 9:54 AM #251277

(4 inch DDGV, Class 900) Outage impacted and AP-913 failure event due to failure of wedge and pin(s) in Reactor Recirculation System (BWR) gate valve V2-54A.

During Recirc valve operability test RV-54A tripped on thermals at 31.46 seconds while being tested closed. IST range on this valve in the closed direction is 18.70 to 25.30 seconds. Thermals reset and tripped a second time. Based on IST results and industry OE, a valve internal (disc trunnion, upper wedge pin) is presumed to have failed. Using the weak link analysis, the upper or lower wedge failure is unlikely; the wedge pin or disc trunnions are probable. A failed wedge pin could result in the stem unthreading and prevent the limit switch trip resulting in the thermal overload trip observed. Note: The valve internals have not been disassembled for inspection nor have they had radiographic analysis, so the specific part that has failed cannot be determined.
PRIMARY CAUSE: Indeterminate

Salem Unit 1 2007-4-02 EQACE # 70068379

(4-" DDGV Class 1500 lb.) The valve stem is 1-5/8" diameter, A-564 type 630 (17-4PH) material. Safety injection valve high running loads due to stem to upper wedge connection loose

During as found diagnostic testing of the (BIT) Safety injection MOV running loads were found to have increased 6,000 lbs. over the past test which was performed 18 months earlier. The valve was disassembled and it was identified that there was internal body damage in the guide area due to a loose stem to upper wedge connection. The history of this valve is as follows;

- In 1995 this valve was disassembled then re-assembled including the stem to upper wedge threaded / pinned connection. At that time our maintenance procedure did not have a torque requirement for the stem to upper wedge.
- In 2002 during valve setup and testing this valve experienced an overthrust event which was evaluated and did not exceed the yield strength of any analyzed component at normal room temperature. The valve was also found to be backseating during this test.
- In 2004 the actuator was refurbished with tested running loads between 3,000 to 3500#.
- In 2005 valve bonnet was removed due to a gasket leak, testing was performed and running loads had increased to 5,500 lbs. (This was probably the 1st sign of an issue with the valve)
- In April 2007, a limit seat modification was going to be installed. As found testing found closed running loads up to 11,000 lbs. in the closed direction.

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This valve is stroked quarterly for IST and no issues were identified during the cycle. The apparent cause of the failure was attributed to the backseating event in 2002, combined with not having torque requirements for the stem to upper wedge connection in our maintenance procedure.
PRIMARY CAUSE: Power backseating and No pre-torque during prior disassembly by Maintenance.

GE RICSIL 032, GE SIL 528 and GE SIL 620

These GE service information letters discuss Recirculation Discharge Gate Valve Vibration Induced Damage – including stem/disc separation as a result of flow induced vibration in BWR-5 and 6 plants valve issues.

BWROG OPERATING EXPERIENCE (2013 to 2016)

There were no reported industry events where the stem became separated from the upper wedge due to unthreading, fracture, or other means.

There were less than four industry events where the pin was bent or sheared as a result of operating the MOV.

Disassembly and inspections results of susceptible A-D DDGVs (26 MOVs):

Twenty-four MOVs were found with loose stem to wedge connections (i.e. no factory pre-torque). In all cases, the upper wedge could be unthreaded from the stem by hand after the pin was removed. In most cases, there was a measurable gap between the upper wedge and stem shoulder when the stem, wedge, and pin were completely assembled, see photo (a). In all cases the upper wedge, stem threads, and pin were in good condition. See photos (a), (b), (c), (d), (e).

Two MOVs were found with torqued stem to wedge connections. The amount of pre-torque was not determined.

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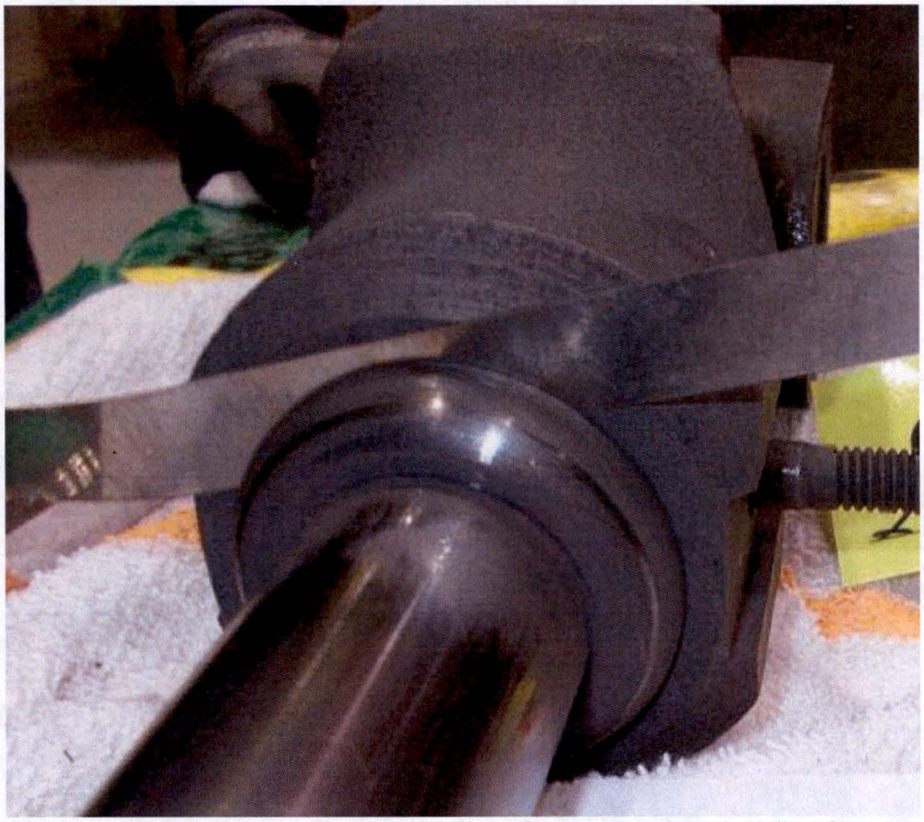

Photo (a); Stem, upper wedge, and pin assembled. Gage showing gap (i.e. loose connection)

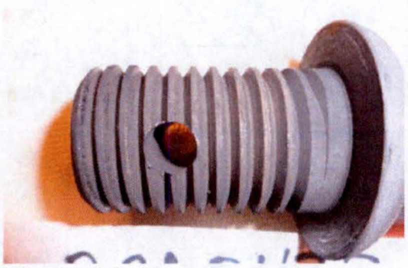

Photo (b); Stem threads

Photo (c); wedge pin hole

Photo (d); wedge threads

Photo (e); Pin

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BWROG Evaluation of 2013-2016 OPEX:

1) There have been no reported industry events where the stem became separated from the upper wedge due to unthreading, fracture, or other means. This helps alleviate the need for aggressive and immediate action.

2) Based on the inspection results, it should not be assumed that the upper wedge and stem were originally torqued by Flowserve when assembled. Therefore, the pin should be considered in the load-path (from a torque perspective). The pin is the only structural member preventing the upper wedge from unthreading from the stem (while traveling open).

3) Based on this OPEX, the BWROG in Revision 1 (TP-16-1-112) recommended only two long term remediation paths for the Flowserve Part 21 issue. These are:

   a. Analyze the stem/wedge connection from a torque perspective and show that all anticipated operating loads are acceptable. It should not be assumed that the connection was pre-torque during assembly unless documented evidence is available.

   OR IF a. is UNSUCCESSFUL

   b. Disassemble the valve and torque the stem/wedge connection to a value that exceeds all anticipated operational loads plus a margin allowance. This approach may require purchasing a replacement stem, pin, upper/lower wedges, and disc retainer hardware (as applicable)

2017 LASALLE HPCS MOV A-D DDGV STEM-DISC SEPARATION EVENT

On February 11, 2017, while attempting to fill and vent the High Pressure Core Spray (HPCS) system during the LaSalle Unit 2 Refueling outage, it was determined that the Unit 2 HPCS Pump Discharge Valve (2E22-F004) had experienced a stem-disc separation failure where the valve indicated open but was functionally closed not allowing the system to be filled and vented.

This subject 12" 900# valve manufactured in 1972 and installed since plant start-up in 1984 has been operating without incident until the 2017 stem-disc separation failure. In 2013, the MOV was identified to be one of 22 LaSalle MOVs potentially susceptible to wedge pin failures under the 2013 Flowserve 10CFRPart21 Notification.
Beginning in 2013, LaSalle had been monitoring this and other susceptible valves using BWROG TP-13-006 Rev.0 guidance by way of stem rotation checks and diagnostic thrust signature analysis. Wedge pin structural analysis performed in 2013 was not able to provide evidence that the wedge pin alone could handle the required operational torque load. The MOV was last diagnostically tested in 2015 during L2R15 but post-test engineering trend analysis did not identify any anomalies from this testing.

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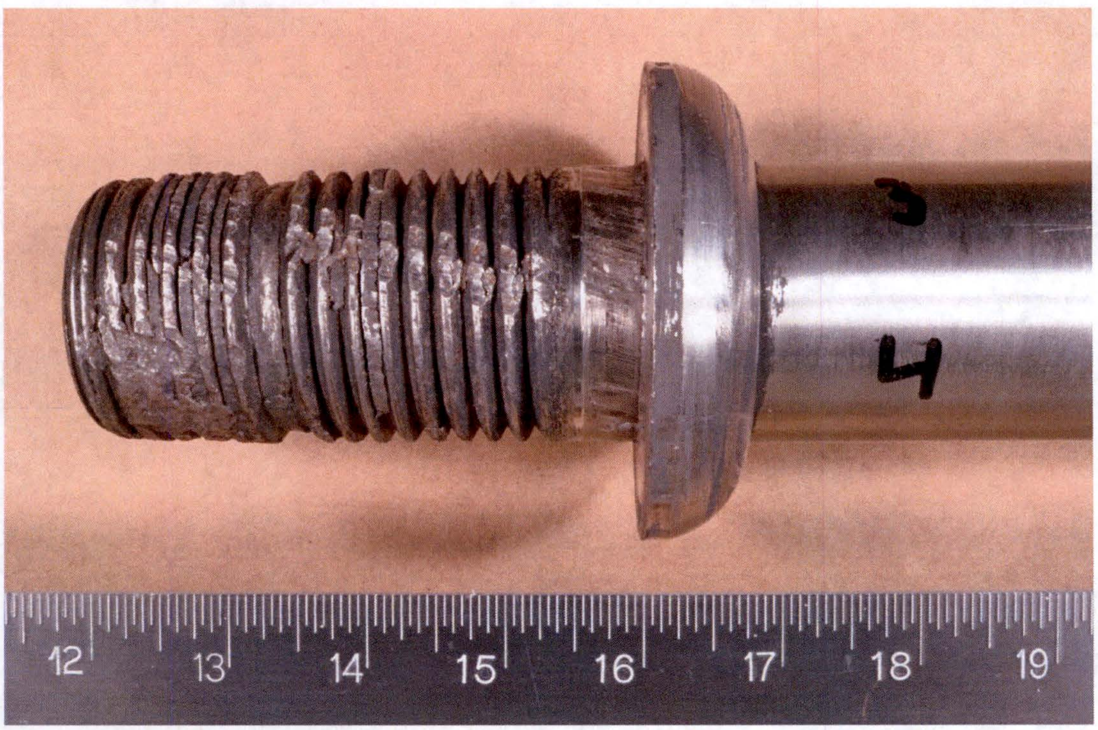
LaSalle 2E22-F004 - Stem with external threads with severe wear degradation



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LaSalle 2E22-F004 – Upper wedge with internal threads with severe wear degradation, wedge pin was found sheared.

Post failure analysis of the 2015 2E22-F004 Diagnostic traces identified anomalies in the valve open pullout region that were not present during the previous 2011 and 2005 traces. Additional review of maintenance work order inspection data indicated that the stem rotation checks were at the maximum allowable value. A lesson learned from the event is that the MOV diagnostic test data anomalies were not attributed to a potentially degraded stem-disc connection (see diagnostic trace overlays in Section V.). Given that the failure occurred within just one operating cycle from possible detection in 2015, it is unlikely that this failure could have been prevented unless more aggressive corrective actions are instituted.

LaSalle Unit 2 HPCS MOV Failure Analysis

The failure of the valve 2E22-F004 stem-to-wedge connection was due to multiple closing high load cycles (with both axial thrust and torque components) which caused loosening and eventual shear failure of the wedge pin, followed by wear and shear failure of the threads. The loosening and shear failure were caused by an insufficient capacity of the shrink fit stem collar for the 2E22-F004 application, which was routinely subjected to loads exceeding 200 kips. The failure evaluation provides the following specific conclusions:

1. The stem-to-wedge connection failure occurred due to axial shear failure of degraded wedge threads while being subjected to high loads in the closing direction.

2. The wedge thread degradation occurred over multiple high load cycles after the thread connection loosened over a period of many years.

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3. The loose connection was caused by an inadequate preload and insufficient capacity for the stem collar and pin assembly. In particular, the collar axial load capacity was only about 50% to 60% of the normally applied loads, such that collar slip occurred.

4. The thread degradation mode is most likely due to wear and local plastic deformation with each load cycle after the connection loosened.

5. With the wedge pin sheared, interferences between the broken pin fragments/debris and adjacent threads can cause damage and interferences between the mating threads, while also limiting rotation. The interferences may be sufficient to bind the joint during subsequent strokes, preventing detection of a loosened or degraded connection.

Additional 2017 Operating Experience

Columbia HPCS Injection MOV

On May 31, 2017, Columbia Generating Station while in a refueling outage performed a stem rotation check and diagnostic test of their high pressure core spray (HPCS) injection valve V-4 (Similar to the LaSalle 2E22-F004). The observed stem rotation of approximately 60 degrees significantly exceeded the acceptance criteria indicating a failed test. The Columbia noted that this valve had passed prior testing in December 2016 (stem rotation checks) and August 2011 (force trace). As part of planned maintenance to replace the valve internals (as required by the VTRG document), on June 1, 2017, Columbia disassembled the valve and identified a broken wedge pin and found the stem could be unthreaded by hand. The stem-to-wedge threads were otherwise not significantly degraded. Columbia corrected the condition by replacing the valve internals, torqued the stem to the upper wedge connection in accordance with manufacturer's recommendations (maximum for the joint connection), and replaced the wedge pin with a higher strength Inconel pin. Following the replacement of the internals, the Columbia verified that the MOV actuator motor torque was set below the combined stem to upper wedge torque and wedge pin torque capacity. It should be noted that HPCS-V-4 stem-to-wedge connection had been rebuilt twice, once in 1987 due to excessive thrust loads, and again in 2001 in install a pressure locking modification.

During the same outage, Columbia disassembled their other susceptible valves and found a gap between the stem and upper wedge, the pin in-tack and the connection loose.

LaSalle Unit 1 HPCS Injection MOV

On June 22 2017, LaSalle County Station Unit 1 entered into a Maintenance Outage to inspect, test and repair their 1E22-F004 HPCS Injection MOV which is an identical sister valve to the 2E22-F004 MOV that experienced the stem-disc separation earlier the same

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year. The as-found stem rotation check was evaluated SAT with less than 5 degrees of observed rotation and the as-found diagnostics revealed no anomalies suggestive of active stem-wedge degradation. The in-body visual inspection revealed a tight connection with no gap observed between the wedge and stem collar. Subsequent stem/wedge degradation identified that the wedge pin had sheared and the stem/wedge threads had experienced limited localized damage in the vicinity of the broken wedge pin. The valve was considered to not be in eminent risk of stem/wedge thread shear failure and stem-disc separation.

Lessons Learned for the Industry:

- Depending on the application and applied loads, stem disc separation for Anchor Darling Valves subject to the 2013 10CFR21 Notification can occur within several valve operating cycles from detection during diagnostic testing.

- More aggressive long term solutions are required to eliminate the vulnerability by either replacing or repairing the susceptible valve stem and disc assembly. This is in line with the revised BWROG recommendations issued in December 2016 (TP16-1-112 r1).

- Non-Intrusive Valve Diagnostic Testing and Stem Rotation Checks are at best an interim compensatory action that must be instituted each outage until the required permanent repair/replacements are installed.

- Spare replacement parts should be aggressively pursued and made available for immediate installation should the non-intrusive diagnostic testing indications warrant.

- Stem rotation checks should be performed by personnel using quantifiable measurement techniques vs. informal visual observation of stem movement. Stem rotation data should be of sufficient accuracy to be trended over time. (e.g. recording SAT or "< 5 degrees" is no longer considered acceptable). More specific recommendations regarding the stem rotation checks is provided in Attachment 7.

- Any anomalies or adverse trends (diagnostics and stem rotation checks) observed on valves subject to this Part 21 should be formally evaluated for pre-cursors to stem-disc separation. Station should have a bias towards repair vs. acceptance.

- Corrective Actions (repair or replacement) for degraded or non-conforming SSC's should be evaluated in the corrective action program vs. OPEX or programmatic reviews.

- Applicable valves with pressed-on stem collars are susceptible to loss of stem to wedge preload torque as a result of excessive thrust loading which was not

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historically addressed by the valve weak link analysis. This could cause a small percentage of valves that were previously excluded as being potentially susceptible to loss of stem preload and wedge pin failure. Recommendations to address this issue have been included in the next section.

IV. EVALUATION OF OPERATING EXPERIENCE

VTRG Evaluation of the BFN and Other Related A/D DDGV Wedge Pin Failures

Evaluation of LaSalle Unit 2 Event

In light of the 2017 LaSalle Unit 2 event, MOV Stem Disc Separation Failure can occur within a few valve operating cycles of susceptible valves. This supports the long-term solutions recommended in the TP-16-1-112 Revision; that being either 1) satisfactory wedge pin analysis or 2) intrusive stem-disc inspection and repair.

Additionally, the rapid progression from initial detection of stem-disc degradation to physical separation observed at LaSalle warrants more aggressive action including interim diagnostic testing and stem rotation checks at least every operating cycle until the valves can be repaired. Consequently; the Prioritized Recommended Actions and Implementation have been updated accordingly.

Acceptance criteria for interim diagnostic testing and stem rotation checks should be more rigorous and incorporate the observations and lessons learned from LaSalle. Diagnostic Test Trace overlays of previous test should be applied and focus on anomalies observed during the unseating region. **Stem rotation checks should be limited to 5 degrees or less of rotation during the initial stem moment going from close to open.** Absolutely no "barber polling" of the stem marking should be visually observed.

The wedge stem threads failed due to previously undetected wedge pin shearing and a loose threaded joint. The wedge pin did not have sufficient strength to support the loads on the joint without an adequate preload. The threads degraded through repeated valve cycles of a loose joint without a functioning wedge pin until the threads could not support the stem thrust. The joint preload cannot be maintained if the stem thrust exceeds the capability of the stem-wedge connection which can be limited for a stem with a pressed on collar. Many previous weak-link / maximum stem thrust evaluations did not account for joint preload and the limitations of the pressed on stem collar.

The added insights gained from the LaSalle HPCS MOV failure indicate that the potential ADDDGV susceptibility to stem/wedge degradation must be expanded to include a review of the stem collar thrust capability of any MOV supplied with a pressed-on collar even if the valve met the Flowserve recommended torque preload values. Alternatively, wedge pin analysis may be performed to eliminate the valve susceptibility. This insight has resulted in additional recommended actions to follow in Section V.

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Previous Evaluations

All three (3) of the TVA Browns Ferry A-D DDGV wedge pin failures starting in 2001 have been associated with valves which were manufactured since 1996 after which Flowserve changed their assembly practice to apply a specific pre-torque to the stem/wedge connection before installing the wedge pin. The first failure in 2001 (2-FCV-073-0003) occurred with zero in service time during post maintenance testing after initial installation of the valve. The next failure (1-FCV-073-0003) occurred in 2008 with in service time of less than two years (1 cycle). The most recent 2012 failure (1-FCV-073-0002) occurred within seven years of installation in 2005. These failures all have the characteristic signature of an infant mortality based failure attributed to a vendor specific manufacturing/assembly issue. In all these BFN cases, the failures are all uniquely grouped to a specific valve size and model manufactured after the vendor Flowserve changed its valve assembly process. These valves were supplied to TVA during the same period when Flowserve was relocating the manufacturing plant from Williamsport, PA to Raleigh, NC. Two of the three BFN failures occurred without an associated failure precursor event that could be associated with overloading or degrading the stem/wedge connection. Comparatively, there have been no other similar designed A-D DDGVs industry failures during routine operation without an associated failure precursor event and/or casual factors. Most of these valves have been in service in the US nuclear industry for over twenty-five or more years. This conclusion is supported by a thorough industry operating experience review documented in this report.

Consequently, it is the recommendation of the BWROG VTRG that the highest priority valves (Priority 1) requiring near-term action (typically within two years) should focus on those MOVs considered most at risk. These MOVs would have one or more of the following attributes.

Susceptible MOVs that:

- Have symptoms of stem disc separation based on visual or diagnostic test data review.

- Have been subjected to precursor events (e.g. flow induced vibration, motor stall over torques) that are known causal factors for previous wedge pin failures.

- Were manufactured by Flowserve on or after 1996 whose operating torques exceed vendor Attachment 1 of the Reference 1 Letter recommendations. (BFN infant mortality issue).

- Have an open design basis (accident) torque requirement that will exceed all current/previous valve set-ups. The concern here is for MOVs that have never sufficiently challenged the stem/wedge pin during operation and would only do so during a design basis safety function scenario in the open direction which would cause the stem/disc to unthread.

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V. RECOMMENDED METHODOLOGY

NOTE: Under Revision 4, a simplified consolidation of the recommended actions and implementation schedule is provided in Attachment 10 to this document. It assumes that the plant/utility has implemented the prioritization and screening of the affected valve population under previous revisions to this document.

Prioritization and Screening Criteria

Part 21 Applicable Valves – Anchor Darling Double Disc Gate Valves with threaded and pinned stem / upper wedge connections and subjected to valve actuator torque (e.g. Limitorque motor actuator). In its most recent update, Flowserve indicates that valve sizes as small as 2 inches may be impacted. Based on new insights from the LaSalle MOV failure, valves previously excluded based on established pre-torque values are now considered susceptible if furnished with a pressed-on stem collar.

Note: Based on content and wording from the original Part21 Notification, some plants may have assumed that only valves sizes 2.5 and larger were affected.

Active Safety Related Valves – Valves that must actively reposition to perform their design basis safety function. Typically, MOVs included in the Generic Letter 96-05 MOV Program scope.

Priority 1a – Applicable active Safety related valves which meet at least one of the following criteria:

- In the last 10 years, have been subjected to significant overtorque due to motor stall, pressure locking or power back-seating which is estimated to exceed Attachment 1 torque loading and wedge pin shear capability (if necessary).
- Have been subject to flow induced vibration or which are short stroked such that the valve disc pack is located in the turbulent flow stream.
- Have evidence of disc separation based on review of diagnostic test data or based on excessive stem rotation.
- Have an open safety related design basis torque requirement which exceeds current or previous valve set-ups and Attachment 1 torque values. The concern is for MOVs that have never sufficiently challenged the stem/wedge pin during operation and would do so during a design basis safety function scenario in the open direction which would cause the stem/disc to unthread.

Priority 1b – Applicable Reactor Recirc. Discharge Valves in GE BWR-5 and BWR-6 Plants where the plant has not fully complied with GE SIL 528 and GE SIL 620 recommendations.

Priority 1c – Applicable Active Safety Related valves which have been manufactured since 1996 and where the total applied torque exceeds or has exceeded the values listed in Attachment 1 of the Reference 1 Letter. Active Safety Related susceptible valves where the stem/disc connection was assembled by plant maintenance procedures with **no** record of adequate stem pre-torque.

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Priority 1d – Applicable Valves deemed Critical by the Plant (not GL 96-05) which meet any of the attributes from Priority 1a.

Priority 2 – Applicable Active Safety Related valves which have been installed and operated with known in-body issues (e.g. seat leakage) which will require valve disassembly and repair.

Note: MOV Risk Ranking is in accordance with GL96-05 MOV Program criteria

Priority 3a – Applicable High and Medium Risk Active Safety Related valves which have been installed and operated with no known issues and no evidence of disc separation based on review of diagnostic test data.

Priority 3b – Applicable Low Risk Active Safety Related valves which have been installed and operated with no known issues and no evidence of disc separation based on review of diagnostic test data.

Priority 4 –Applicable Valves deemed Critical by the Plant with no known issues and no evidence of disc separation based on review of diagnostic test data.

Priority 5 – Applicable Valves with one of the following attributes are considered "Not Susceptible":

a. Valves which have been manufactured since 1996 and where the applied total torque has never exceeded the Flowserve recommended stem/wedge pre-torque values listed in Attachment 1 of the Reference 1 Letter. If equipped with a pressed-on stem collar, also verify that the stem collar is able to bear the maximum applied actuator thrust seating load (Contact Flowserve as required).
b. Any valve having been successfully evaluated for stem/disc wedge pin shear capability (Method a.) using the guidance provided in Attachment 4.
c. Any valve that has been repaired (Method e.) using the guidance provided in Attachment 6.

Evaluation / Inspection / Repair Methods

Method Description

a. **Wedge Pin Analysis** - Analytical evaluation of shear capability of wedge pin – if the wedge pin shear capability exceeds the maximum torque applied, intrusive inspections are not required unless visual or diagnostic symptoms of stem disc separation are present. See Attachment 4 for more information on the development of wedge pin shear capability evaluations.

b. **Stem Rotation Checks** - Verification of minimal stem rotation during operation between open and close strokes– Stem rotation shall be less than or equal to 5 degrees of rotation during the initial stem moment going from full closed to open.

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Stem rotation of 5 degrees or less provides reasonably high confidence of stem/disc connection integrity given the industry operating experience data and variation in the valve seat/disc/guide internal clearances. Stem rotation of greater than 5 degrees is considered to be at high risk of stem/disc connection degradation. Stem Rotation data should be of sufficient accuracy to be trended over time. No increasing trend in measured stem rotation above the established maximum 5 degree criteria is acceptable unless evaluated by engineering. Only small variations less than 2 degrees from the established baseline reference value should be accepted. Stem rotation checks are to be performed using a least one full open-close-open or close-open-close sequence. If practical, three (3) full stroke cycles is recommended. This would better determine whether the associated valve stem is "ratcheting" in one particular stroke direction. See Attachment 7 for more guidance on Stem Rotation Check Methods.

c. **Non-Intrusive Valve diagnostic testing** (w/ Stem Rotation Monitoring - Method B) – Evaluation of diagnostic test data has been shown to provide evidence of a broken wedge pin and the start of stem / disc separation (see next section for examples). The VTRG also recommends monitoring for change in stem rotational displacement overtime which may be indicative of unthreading the stem/wedge connection by match marking the stem relative to a fixed object such as the valve yoke and looking for change over time for a fixed valve position. For susceptible valves (i.e. Not Priority 5), the recommended stem monitoring interval is every year for accessible valves and every cycle for inaccessible valves. **If potential stem/disc degradation as evidenced by unacceptable or increasing stem rotation or unanalyzed trace anomalies are detected, then the valve should be repaired before returning to service. All exceptions to this recommendation must be technically evaluated and documented using the Corrective Action Program**. Important: The valve stem position monitoring recommendations supplement and do not replace the diagnostic test recommendations which are on different intervals.

d. **Internal Valve Inspection** - Valve disassembly or the use of borescope for non-intrusive inspection of stem/wedge connection. A physical inspection of the stem – disc connection with proper contact between the stem shoulder and the upper wedge with all related hardware intact (nuts, disc retainers, etc.). If potential stem/disc degradation is observed, then the valve should be repaired before returning to service. All exceptions to this recommendation must be technically evaluated and documented using the Corrective Action Program. This method is not widely used if at all.

e. **Valve Repair / Replacement** - Valve disassembly with intrusive inspection and retorque of stem/wedge connection. Repair and replace assembly parts based on the guidance provided in Attachment 6. Stem/wedge connection is pre-torqued prior to wedge pin installation to a value that exceeds whichever value is highest: the maximum expected valve torque loading or the pre-torque value provided in Attachment 1 of the Reference 1 Letter. The maximum stem/wedge assembly pre-

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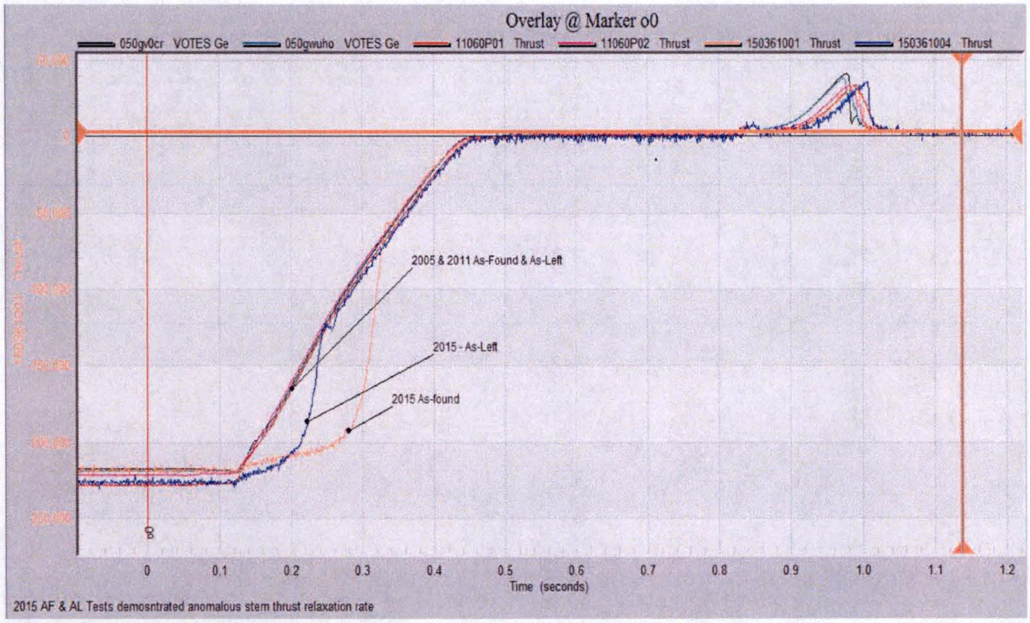
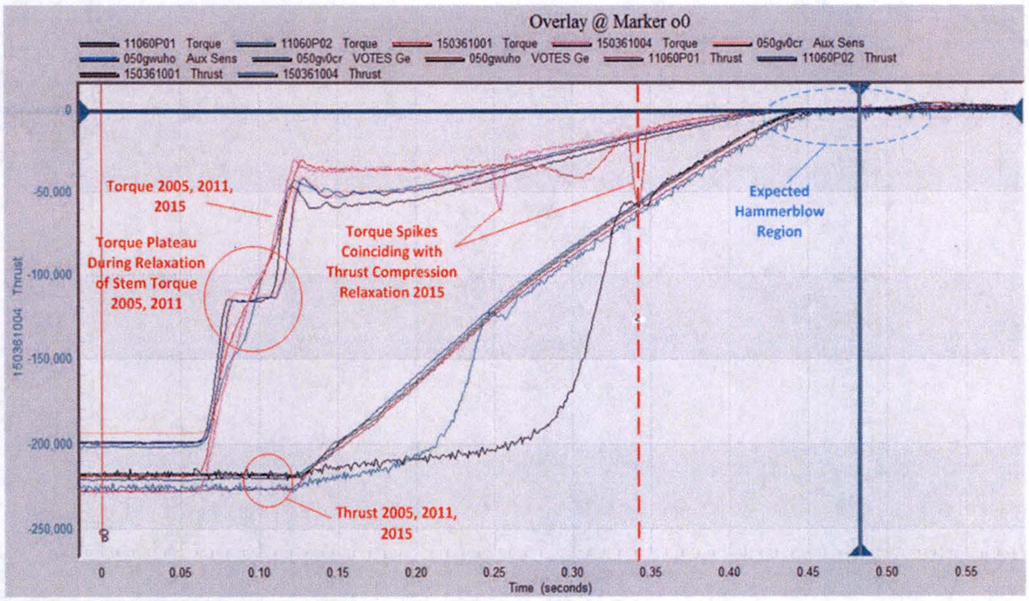
torque must also be less than the structural limit for the affected components as determined by Flowserve.

Diagnostic Test Data Evaluations

LaSalle MOV Thrust and Torque Signature Overlay Open Stroke @ Motor Start (Tests from 2005, 2011 and 2015)



2E22-F004 Thrust Overlay showing anomalous thrust decompression on both 2015 AL & AL Diagnostic Tests



2E22-F004 Thrust and Torque Overlay showing unusual torque spikes coincident with 2015 Thrust decompression anomaly. Also, unusual torque plateau during torque relaxation in 2005 and 2011.

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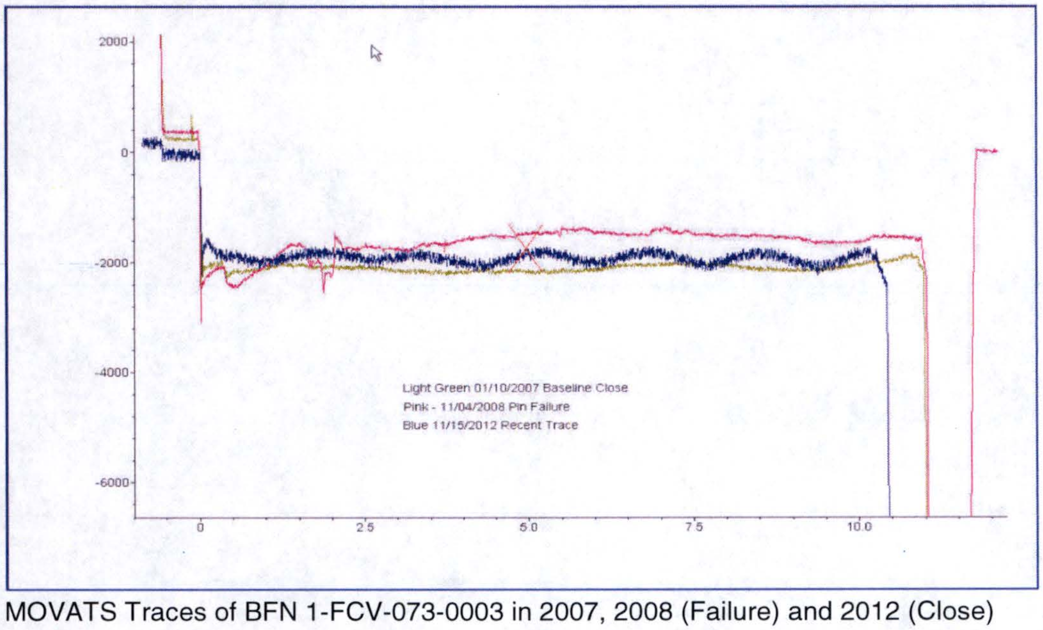
Anomalous characteristics were observed on both the as-found and as-left 2015 Quiklook Thrust and Torque Signatures in the open stem decompression region that were not observed in previous 2011 and 2005 tests. Also, note that in 2005 and 2011, anomalous torque plateaus were observed during the torque relaxation region just after motor start. Additionally, stem rotation checks performed in 2015, demonstrated 10 degrees of stem rotation which had previously (under TP-13-006 Rev.0) been at the extreme range of acceptability. No other Exelon MOV has demonstrated stem rotation checks beyond 5 degrees. Given the February 2017 LaSalle MOV failure, these observations are now considered indicative of active stem-disc connection degradation.

Previous Browns Ferry & Salem MOV Diagnostic Test Signatures

Both the 2008-BFN and 2007-Salem events were initially identified by diagnostic test trace anomalies. The diagnostic test traces shown below is from the 2008 BFN wedge pin failure. Both these traces showed anomalies in the running thrust/torque near the seating and unseating areas. Increasing time between trace markers C8 (Open light out) and C11 (Hard seat contact) and or C14 (Control switch trip) would be another potential indicator of wedge pin failure.



MOVATS Traces of BFN 1-FCV-073-0003 in 2007, 2008 (Failure) and 2012 (Close)

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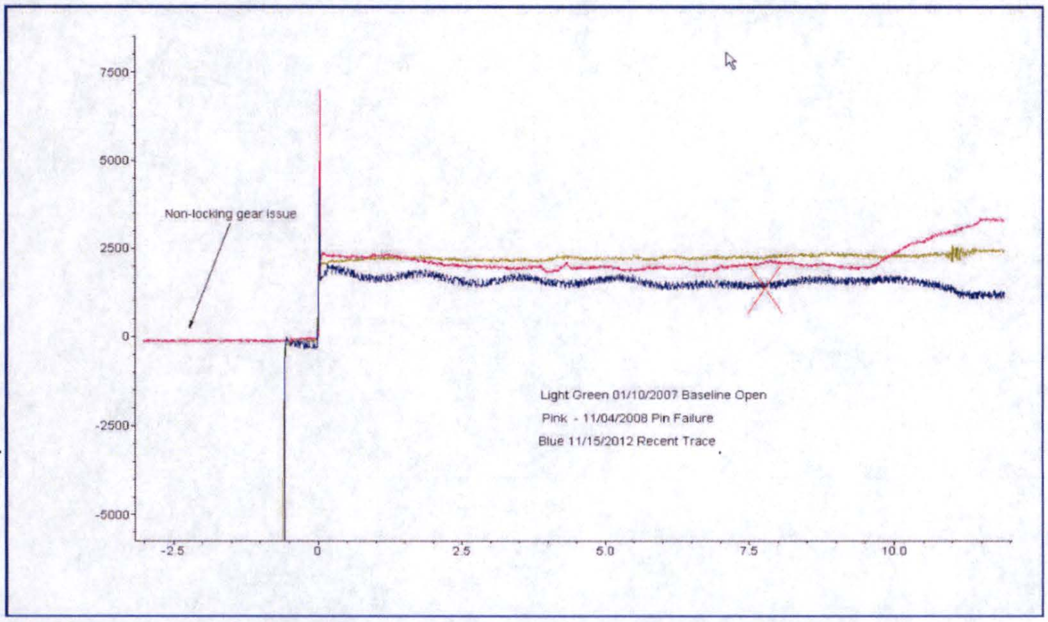

MOVATS Trace of BFN 1-FCV-073-0003 in 2007, 2008 (Failure) and 2012 Open)

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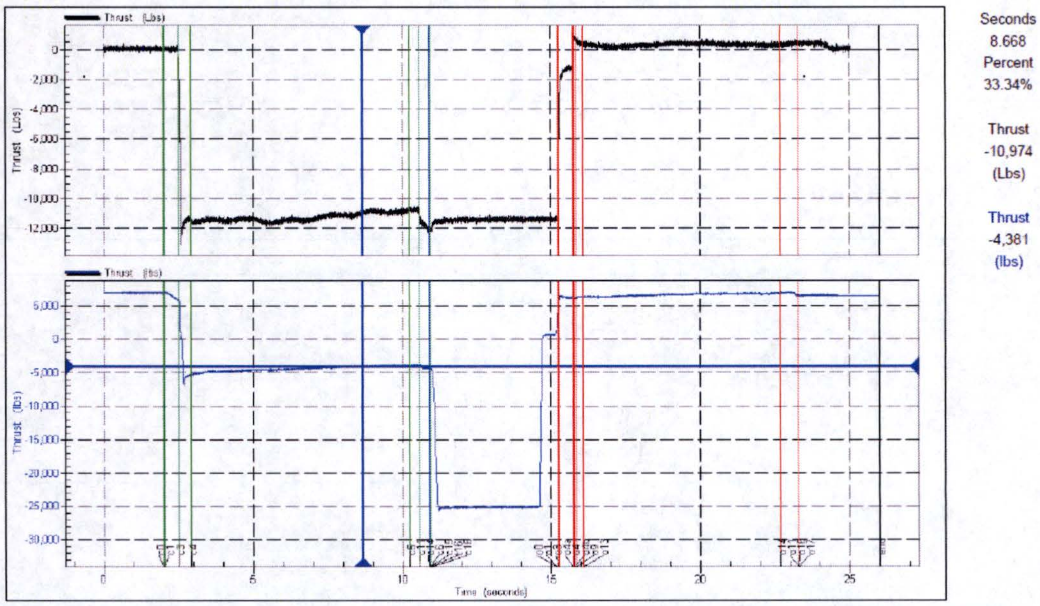
Salem Wedge Pin Failure on 1SJ5 discovered in 2007

Two diagnostic thrust traces are shown below. The top trace is from 2007 which shows the as-found thrust signature of the 1SJ5, 4-inch, 1500 # DD Anchor Darling valve – This is the trace where Salem discovered the failure – Very high running loads in the closing direction (Marker placed in running load region shows about 11,000 lbs. of running load). The bottom trace is the as left thrust signature from 2005.

1SJ5 30104572 As-Left

10/24/2005 14:18:31 File 1SJ5 failure



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Prioritized Recommendations and Implementation Schedule (Note: Action Intervals are established from Revision 3, June 2017).

Note: Go to Attachment 10 for Simplified Recommended Actions and Schedule if initial screening and prioritization of applicable valves were previously performed.

Initial Screening of Applicable Valves (to be completed within 3 months)

1. If accessible and able to be stroked, perform visual verification of minimal stem rotation during valve stroke. (Method b).

2. Perform trend analysis of the last two available valve diagnostic tests looking for symptoms of stem disc separation (Method c). This analysis should be revisited by member utilities based on the LaSalle Diagnostic Test Lessons Learned. **NOTE: This is considered a back-fit to the initial screening performed under Revision 0.**

3. Perform stem/disc wedge pin shear capability analysis (Method a.) to show that all operating loads are acceptable (document this evaluation). It should not be assumed that the connection was pre-torqued during assembly.

If only the first two (2) evaluations are satisfactory, the applicable valves may be treated as Priority 3a or 3b depending on Valve Risk Ranking. If all three (3) evaluations are satisfactory, the applicable valves can be treated as Priority 5 (Not-Susceptible).

Priority	Recommended Actions and Interval	Comments
1a	Perform Method e. at the first available opportunity (i.e. first outage where intrusive inspection/repair can be performed within next 2 years).	Satisfactory Operability Evaluation required until inspection can be performed.
1b	Perform Method c. every refuel cycle.	RDGV Issue per SIL 620
1c	Perform Method a. or Method e. within 2 years; OR Perform Method c. or Method d. every 2 years until the issue is permanently repaired using Method e. within 2RFOs or up to 4 year.	Per Flowserve, Method a. may be used as a permanent solution if the allowable applied torque to the wedge pin in double shear exceeds the valve actuator capability.
1d	Perform Method a. or Method e. at Owners Discretion (highly recommend within 2 years).	Critical Non-GL96-05 Valves with symptoms of stem/wedge connection degradation.
2	Perform Method e. in conjunction with planned in-body valve repair	Recommend repair in conjunction with other required in-body work.
3a	Perform Method a. or Method e. within 2 years; OR Perform Method c. diagnostic test or Method d. every 2 years until the issue is permanently	High & Medium Risk GL96-05 Valves with no symptoms of stem/wedge connection degradation.

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	repaired using Method e. within 2 RFO (4 years). Valves with multiple design basis post-accident strokes (e.g. open and close) should be repaired using Method e. within 1 RFO (2 years)	
3b	Perform Method a. or Method e. within 2 years; OR Perform Method c. diagnostic test or Method d. every 2 years until the issue is permanently repaired using Method e. within 3 RFO (6 years)	Low Risk GL96-05 Valves with no symptoms of stem/wedge connection degradation
4	Perform Method a. or Method e. within 8 years (at Owners Discretion); AND Perform Method c. every 2 years until the issue is permanently repaired using Method e. (at Owners Discretion).	Critical Non-GL96-05 Valves with no symptoms of stem/wedge connection degradation.
5	Perform Method b. (Stem Rotation Checks) in conjunction with established GL96-05 periodic diagnostic testing requirements.	**NOTE: Valves are not considered susceptible.** Non-Intrusive Stem Rotation Checks provide an additional level of assurance that the threaded stem/wedge connection is structurally intact.

Important Notes: (PLEASE READ)

A. Method c. also includes stem rotation check monitoring either every year or cycle depending on valve on-line accessibility.

B. If potential stem/disc degradation as evidenced by unacceptable or increasing stem rotation or unanalyzed anomalies is detected using Method c. or d., then the valve should be repaired before returning to service. All exceptions to this recommendation must be technically evaluated and documented using the Operability Evaluation Process.

VI. LESSONS LEARNED - MOVING FORWARD

As evidenced by the periodic updates to this document, the BWROG VTRG has committed to monitor industry feedback (i.e. results of inspections and tests) and any additional Flowserve recommendations regarding the wedge pin failure issue. This will be a mandatory topic during scheduled regular VTRG meetings.

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VII. RECOMMENDED BASES FOR INTERIM VALVE OPERABILITY

The recommended bases for Interim Operability until the 10CFR Part 21 can be fully evaluated by each affected plant are as follows:

- Valve Stroke Time (IST) surveillance tests are satisfactory and consistent with expected variance.
- Observation of stem rotation is minimal with 5 degrees or less stem rotation between open and close strokes.
- Review of past diagnostic test results shows no new unexplained anomalies in the seating/ unseating region. Time between trace markers C8 (Open light out) and C11 (Hard seat contact) and or C14 (Control switch trip) is consistent within expected repeatability.
- Valve seat leakage (LLRT) results are satisfactory with no unexplained adverse trends.
- Valve is normally open and only has a safety function to close one time and no requirement to reopen (example: Reactor Recirc. Pump discharge isolation valves).

Note that these conditions are not a basis to conclude that an A/D DDGV wedge pin is not over torqued but only that wedge pin failure has not introduced conditions that would put the valve at risk of imminent failure and loss of safety function capability.

Supporting Material for Plant Valve Specific Evaluations

1) <u>Valve Information</u>

- Valve size / Pressure class
- Design of disk (Wedge or parallel slide)
- Drawing number
- Weak Link Calc. number
- Accident temperature (used in weak link)
- Normal operating temperature
- Maximum DP during accident
- Maximum DP during normal stroke
- Safety function Open / Close / Both, identify any post-accident reposition requirements
- How often is valve stroked

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2) Review Past Test Traces

- Any changes to trace over history?
- What are maximum closing torque / opening torque values?
- Any significant change in running loads?
- Any anomalies at seating or unseating region?
- Overlay past traces to look for changes.

3) Review Past History

- Any stall / overthrust events in the past (Into the seat, or into the backseat)
- When was the valve last disassembled?
- Was the stem to upper wedge connection ever disassembled?
- When was valve installed?
- Has the torque switch been recently increased?
- Is the assembly torque of the stem/upper wedge known?
- When was the valve manufactured?
- The maximum actuator applied stem torque must be less than the installed stem/wedge assembly torque

4) Look at Design Calculation

- What is expected maximum torque to close or open valve under DP conditions (Normal operation and accident conditions)?
- What is the expected or target output torque of the actuator?
- Compare static test torque to recommended torque from Flowserve Part 21 charts. (Stem to upper wedge).
- If Maximum torque under DP or static conditions does not exceed Stem connection torque from Flowserve, then there is a reasonable assurance that there should not be an issue.
- Evaluate the stem-wedge thread connection shear margin using industry standard methods (e.g. ASME B1.1)

5) Interim Actions that can be taken

- Stroke valve and observe stem rotation.
- Perform diagnostic test looking for abnormalities (Increased running loads, additional stem movement after hard seat). Observed anomalies in the unseating and seating regions as determined using diagnostic test trace overlays.
- Lower torque switch setting (If margin available).

6) Actions After Data Review

- If any significant issues are identified above, consider entering in your Op-Eval Process. Any valve with unsatisfactory wedge pin analysis should be evaluated by the corrective action program for potential operability concerns.

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Configuration Control to Prevent Reoccurrence

1) Susceptible MOV limit and torque switches must be configured so that required operating torques both open and close are within the torque capability of the stem/wedge pin assembly and the pressed-on stem collar (if applicable).

2) MOV weak links should be revised to include the stem/wedge torque capability including the wedge pin shear analysis (if used to eliminate the valve from susceptibility) and any application thrust limitation associated with the pressed-on stem collar.

3) Stem/wedge connection is pre-torqued prior to wedge pin installation to a value that exceeds whichever value is highest: the maximum expected valve torque loading or the pre-torque value provided in Attachment 1 of the Reference 1 Letter. The maximum stem/wedge assembly pre-torque must also be less than the structural limit for the affected components as determined by Flowserve.

4) Consider using a stronger wedge pin (e.g. Inconel 718, 17-4PH Stainless) to increase the shear strength of the stem/wedge assembly. This is recommended as part of the Method e. repair (see Attachment 6).

5) Revise station maintenance procedures to ensure pre-torque load applied to the stem/wedge during assembly bounds the higher of two values: the MOV expected torque loads or the value provided in Attachment 1 of the Reference 1 Letter. Coordinate with vendor to obtain maximum torque value that can be applied to the connection based on stem configuration.

6) Fabricate and/or obtain tooling from Flowserve to allow stations to torque stem into wedge in conjunction valve in-body maintenance. Contact Flowserve for details.

Flowserve Contact Information:
Flowserve Flow Control Division / Raleigh Operations
Phone: 1-919-832-0525 / Toll Free: 1-800-225-6989

VIII. BENEFIT TO THE INDUSTRY

This topical report developed by the BWROG Valve Technical Resolution Group (VTRG) provides a recommended industry response to the Flowserve 10CFR Part 21 Notification given the enormous potential industry impact if intrusive inspections and repairs are performed on every susceptible A/D DDGV. The US nuclear industry cannot realistically intrusively inspect and repair every affected valve application in the short term without negative impacts on safety system availability, Outage Duration, O&M Costs and Total Radiation Exposure. The report provides a prioritized inspection and evaluation plan developed based on a thorough review of all applicable Nuclear Operating Experience with A/D DDGV wedge pin failures.

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IX. REFERENCES

1. Flowserve 10CFR Part 21 Letter to the NRC dated February 25, 2013 (Att. 2)
2. TVA 10CFR Part 21 Notification to NRC Dated January, 2013 (Att. 1)
3. TVA Root Cause Report (BFN PER 639155) for the 1-FCV-073-0002 Stem to Wedge Anti-Rotation Pin Failure Dated 12/21/13.
4. Flowserve 10CFR Part 21 Letter to the NRC dated July 11, 2017 (Att. 8).
5. Flowserve Memo from Mark Cowell Dated June 27, 2017, "Stem-Wedge Separation Evaluation – Anchor/Darling Double Disc Gate Valve" (Att.9)

Flowserve Recommended Stem Pre-Torque Values (Ft-lbs.) [Reprinted from Reference 1]

RECOMMENDED STEM PRE-TORQUE (FT-LBS) FOR STEM/UPPER WEDGE JOINT
ANCHOR-/ DARLING DOUBLE-DISC GATE VALVES

VALVE	PRESSURE CLASS					
SIZE	150	300	600	900	1500	2500
2.5	11	13	21	38	60	114
3	17	16	26	48	89	171
4	25	28	57	82	154	292
6	42	57	139	228	414	844
8	46	104	275	444	805	1848
10	74	172	483	776	1497	3436
12	110	262	720	1240	2467	5436
14	156	380	1022	1726	3434	7409
16	215	528	1398	2346	4844	9699
18	289	770	1955	3250	6888	12394
20	377	1006	2496	2960	9003	15750
22	448	1355	N/A	N/A	N/A	N/A
24	604	1697	3724	6999	14154	25132

X. ATTACHMENTS

1. TVA 10CFR Part 21 Notification to NRC Dated January 4, 2013.
2. Flowserve 10CFR Part 21 Letter to the NRC dated February 25, 2013.
3. BWROG VTRG Questions to Flowserve with responses.
4. Wedge Pin Shear Capability Analysis.
5. Staking of Anchor Darling Double Disc Wedge Pins.
6. Flowserve Guidance on Stem-Disc Assembly Repair / Replacement.
7. MOV Stem Rotation Check Methodology Guidance
8. Flowserve Updated 10CFR Part 21 Letter to the NRC dated July 11, 2017.
9. Flowserve Memo from Mark Cowell Dated June 27, 2017, "Stem-Wedge Separation Evaluation – Anchor/Darling Double Disc Gate Valve"
10. Simplified Recommendations and Schedule for Part 21 Applicable MOVs
11. NRC Letter to NEI Dated July 31 2017

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TVA 10CFR Part 21 Notification to NRC Dated January 4, 2013

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TVA

Tennessee Valley Authority, Post Office Box 2000, Decatur, Alabama 35609-2000

January 4, 2013

10 CFR 21

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Browns Ferry Nuclear Plant, Unit 1
Facility Operating License No. DPR-33
NRC Docket No. 50-259

Subject: **Anti-Rotation Pin Failure in Anchor Darling (Flowserve) Double Disc Gate Valve**

In accordance with Title 10 of the Code of Federal Regulations (10 CFR) 21, "Reporting of Defects and Noncompliance," the Tennessee Valley Authority is providing the required written notification of a defect in a basic component, i.e., a defect discovered in the High Pressure Coolant Injection system inboard containment isolation valve due to a failure in the anti-rotation pin in an Anchor Darling (Flowserve) double disc gate valve. The enclosure to this letter provides the information required by 10 CFR 21.21(d)(4).

There are no new regulatory commitments contained in this letter. Should you have any questions concerning this submittal, please contact J. E. Emens, Jr., Nuclear Site Licensing Manager, at (256) 729-2636.

Respectfully,

K. J. Polson
Vice President

Enclosure: Notification of 10 CFR 21 Defect, Anti-Rotation Pin Failure in Anchor Darling (Flowserve) Double Disc Gate Valve

cc (w/Enclosure):

NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant

IE19
NRR

ML13008A321

Attachment 1

ENCLOSURE

Browns Ferry Nuclear Plant, Unit 1

Notification of 10 CFR 21 Defect,
Anti-Rotation Pin Failure in Anchor Darling (Flowserve) Double Disc Gate Valve

---

(i) Name and address of individual informing the Commission

Mr. K. J. Polson
Tennessee Valley Authority
Vice President, Browns Ferry Nuclear Plant
Post Office Box 2000
Decatur, AL 35609-2000

(ii) Identification of the facility, the activity, or the basic component supplied for such facility or such activity within the United States which fails to comply or contains a defect.

Browns Ferry Nuclear Plant, Unit 1
Facility Operating License No. DPR-33
NRC Docket No. 50-259

Basic component contains a defect:

The subject valve is an Anchor Darling 10 inch, double disc gate valve. The equipment identification number for the valve is 1-FCV-073-0002. The valve is the High Pressure Coolant Injection (HPCI) system inboard containment isolation valve. The HPCI system is provided to assure that the reactor is adequately cooled to limit fuel cladding temperature in the event of a small break in the nuclear system and loss of coolant which does not result in rapid depressurization of the reactor vessel. The HPCI system permits the nuclear plant to be shut down, while maintaining sufficient reactor vessel water inventory until the reactor vessel is depressurized. The HPCI system continues to operate until the reactor vessel pressure is below the pressure at which Low Pressure Coolant Injection (LPCI) operation or Core Spray system operation maintains core cooling.

The design functions of valve 1-FCV-073-0002 are as follows.

1. To provide a means of supplying steam to the HPCI system steam line.
2. To maintain structural integrity while installed in the HPCI system (i.e., the valve is designed to meet Seismic Class I requirements).
3. To maintain reactor pressure boundary integrity while installed in the HPCI system.
4. To provide primary containment pressure boundary integrity while installed in the HPCI system.
5. To provide a steam path isolation function in the event that HPCI system isolation is required.

(iii) Identification of the firm constructing the facility or supplying the basic component which fails to comply or contains a defect.

Flowserve Corporation
Raleigh, NC

Contact: Mr. Mark Cowell, Senior Principal Product Engineer, 919-831-3377

For this particular valve, 1-FCV-073-0002, the manufacturing location was changed in the middle of its assembly. The Flowserve manufacturing plant for double disc gate valves was formerly located in Williamsport, Pennsylvania. In 2004, Flowserve moved their manufacturing plant to Raleigh, North Carolina. All of the valves for Browns Ferry Nuclear Plant (BFN), Units 2 and 3, provided by Flowserve were manufactured in Williamsport, Pennsylvania, between 1997 and 2001. Of the valves provided for the BFN by Flowserve, valve 1-FCV-073-0002 was the only valve for which the manufacturing/assembly was started in the Williamsport, Pennsylvania, plant and finished in Raleigh, North Carolina. The manufacturing/assembly of valve 1-FCV-073-0002 was completed by March 2004.

(iv) Nature of the defect or failure to comply and the safety hazard which is created or could be created by such defect of failure to comply.

Nature of the defect:

In the Tennessee Valley Authority (TVA) Corrective Action Program, Problem Evaluation Report 639155 identified that the disc retainer bolt was found sheared when maintenance was performed on valve 1-FCV-073-0002. Further investigation revealed that the anti-rotation pin had failed. A review of work order history identified that the valve was installed during BFN, Unit 1, recovery (Spring 2007) and had not been disassembled since installation. The valve was ordered under BFN, Unit 1, Design Change Notice 51198. The valve was repaired/restored during BFN, Unit 1, Fall 2012 refueling outage.

Valve Design

Valve 1-FCV-073-0002 is a 10 inch, Anchor Darling, double disc gate valve. This valve was installed during BFN, Unit 1, recovery. Valve 1-FCV-073-0002 is installed in a vertical line of pipe with the valve stem mounted in a horizontal orientation. Double disc gate valves are designed to improve the sealing capabilities of the valve utilizing the following features.

1. Four piece double disc wedge assembly to impart sufficient thrust to each disc to enhance seating of both the upstream and downstream discs.
2. Discs that rotate during each closing stroke to equalize wear on the seats and discs.

Safety hazard which could be created by such defect:

The cause of the anti-rotation pin failure for valve 1-FCV-073-0002 was determined to be that the stem was not adequately torqued to the upper wedge at the manufacturing plant. This cause was confirmed by internal inspections of the valve that were performed at BFN. Flowserve Corporation is also conducting an investigation of this event.

In this non-conforming condition, valve 1-FCV-073-0002 was able to perform its design function for the operation of the HPCI system and maintain seat leakage to a minimum. The HPCI system was able to provide flow to support shutdown down to a reactor pressure of 150 psig for the BFN, Unit 1, Fall 2012 refueling outage. The as-found 10 CFR 50 Appendix J Local Leak Rate Test (LLRT) performed on 1-FCV-073-0002 showed the upstream (reactor side) disc had a gross failure. However, when the LLRT was performed between valves 1-FCV-073-0002, -0003, and -0081, the downstream (sealing side) disc of 1-FCV-073-0002 was able to perform its isolation function. Due to the installed configuration of valve 1-FCV-073-0002 (i.e., installed in a vertical run of pipe), any loose parts are expected to fall through the pipe and into valve 1-FCV-073-0003. Valve 1-FCV-073-0003 is located in a horizontal pipe line. Therefore, valve 1-FCV-073-0002 remained capable of performing its containment isolation function. There is a potential that the loose parts from the sheared disc retainer bolt and the failed anti-rotation pin of valve 1-FCV-073-0002 could fall through the piping and stick in the seat area of downstream valve 1-FCV-073-0003 preventing this valve from closing. However, with the steam flow that exists through 1-FCV-073-0003 when the HPCI system is operated, there is reasonable assurance that the loose parts would be transported to the drain pot upstream of valve 1-FCV-073-0016. In addition, during the BFN, Unit 1, Fall 2012 refueling outage, the as-found LLRT was successfully performed on valve 1-FCV-073-0003 and no loose parts were found in this valve. Therefore, valve 1-FCV-073-0003 remained capable of performing its containment isolation function.

HPCI System Injection Function

The HPCI system design basis is to provide adequate core cooling for all break sizes which do not result in rapid depressurization of the reactor vessel and to function independent of off-site power sources and diesel generators. The HPCI system provides adequate reactor core cooling to depressurize the reactor primary system such that the LPCI and Core Spray systems can be initiated. During normal plant operation, the HPCI system is not required to operate. However, the HPCI system is required to be in standby condition whenever there is fuel in the reactor and the reactor pressure is greater than 150 psig.

The HPCI system is safety related and consists of a steam driven turbine used to operate two pumps in series in the event of a break that creates a LOCA with the reactor still pressurized above 150 psig. A series of valves and piping provide a path for steam to travel from the "B" main steam line to the HPCI turbine. This series of valves includes valves 1-FCV-073-0002, 1-FCV-073-0003, and 1-FCV-073-0016. Another series of valves and piping transfer water from the suction source through the HPCI pumps to the reactor via injection into the "A" feedwater line. The design functions of valves 1-FCV-073-0002 and 1-FCV-073-0003 are to provide a means of supplying steam to the HPCI turbine while maintaining primary containment pressure boundary integrity, including the function of isolating the steam supply line when necessary. Valves 1-FCV-073-0002 and 1-FCV-073-0003 are maintained in the normally open position during routine plant operations but close on HPCI system isolation signals.

Valves 1-FCV-073-0002 and 1-FCV-073-0003 remained opened prior to discovery of the failure. As a result, HPCI system operability was maintained and this failure did not result is a loss of the HPCI system injection function.

HPCI System Primary Containment Isolation Function

As previously stated, valves 1-FCV-073-0002 and 1-FCV-073-0003 are maintained in the normally open position during routine plant operations but close on HPCI system isolation signals. The HPCI system isolation signals are in response to conditions indicative of a HPCI system pipe break.

Valves 1-FCV-073-0002 and 1-FCV-073-0003 are HPCI steam supply line primary containment isolation valves (PCIVs). Valves 1-FCV-073-0002 and 1-FCV-073-0003 are the PCIVs for penetration X-11 as identified in Updated Final Safety Analysis Report Table 5.2-2, "Principle Primary Containment Penetrations and Associated Isolation Valves." The function of the PCIVs associated with the HPCI system is to limit fission product release and to prevent or minimize core damage during and following a postulated HPCI steam line break.

In the event of a postulated failure of valve 1-FCV-073-0003 to perform its containment isolation function (due to the loose parts generated as a result of this defect) and a postulated single failure of the redundant PCIV in the penetration, i.e., valve 1-FCV-073-0002, the primary containment isolation function for the HPCI system steam line would have been lost. Therefore, this condition can result in a loss of safety function necessary to mitigate the consequences of an accident and is considered to be a substantial safety hazard.

(v) The date on which the information of such defect or failure to comply was obtained.

December 29, 2012

(vi) In the case of a basic component which contains a defect or fails to comply, the number and location of these components in use at, being supplied for, or may be supplied for, manufactured, or being manufactured for one or more facilities or activities subject to the regulations in this part.

The TVA is not the basic component supplier. Therefore, TVA does not have a listing of where these valves are in use.

The following BFN valves potentially share the same vulnerability as valve 1-FCV-073-0002.

- 2/3-FCV-073-0002, HPCI Steam Line Inboard Isolation Valves
- 1/2/3-FCV-073-0003, HPCI Steam Line Outboard Isolation Valves
- 2/3-FCV-073-0016, HPCI Steam Admission Valves
- 1-FCV-075-0009, Core Spray Loop I Minimum Flow Isolation Valve
- 1-FCV-075-0037, Core Spray Loop II Minimum Flow Isolation Valve
- 1/2/3-FCV-069-0001, RWCU Inboard Containment Isolation Valve
- 1/2/3-FCV-069-0002, RWCU Outboard Containment Isolation Valve

(vii) The corrective action which has been, is being, or will be taken; the name of the individual or organization responsible for the action; and the length of time that has been taken or will be taken to complete the action.

Valve 1-FCV-073-0002 was repaired/restored during the BFN, Unit 1, Fall 2012 refueling outage.

All valves listed in the response to item (vi) above were evaluated. As a result of this evaluation, valve 2-FCV-073-0002 is considered to be non-conforming and will be inspected by TVA personnel during the BFN, Unit 2, Spring 2013 refueling outage.

For the other valves listed in the response to item (vi) above,

1. Documentation exists demonstrating that the stem to upper wedge was torqued to manufacturer requirements, or
2. It can be reasonably concluded that the anti-rotation pin has not been sheared based on MOVATS test data, or
3. The valve was disassembled and inspected and the anti-rotation pin was determined to not be sheared.

(viii) Any advice related to the defect or failure to comply about the facility, activity, or basic component that has been, is being, or will be given to purchasers or licensee.

Future procurement requests will require documentation of verification of stem to upper wedge torque during valve manufacture/assembly.

Attachment 2

Flowserve 10CFR Part 21 Letter to the NRC dated February 25, 2013

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FLOWSERVE®

Flow Control Division
Anchor/Darling Valves
BW/IP Valves
Edward Valves
Valtek Control Products
Worcester Valves

February 25, 2013

US Nuclear Regulatory Commission
Document Control Desk
11545 Rockville Pike
Rockville MD 20852-2746

Subject: Wedge Pin Failure of an Anchor/Darling Double- Disc Gate Valve at Browns Ferry Nuclear Plant Unit 1

Reference: Tennessee Valley Authority's 10CFR Part 21 Notification Letter Dated January 4, 2013 and Flowserve Letter to the NRC dated January 25, 2013.

Attachment 1: Recommended Stem Pre-Torque for Stem Upper Wedge
Attachment 2: List of Potentially Affected Customers and Plants

Gentlemen:

This is to notify the US Nuclear Regulatory Commission that, in accordance with the provisions of 10CFR Part 21, we have identified a potential issue and are submitting our evaluation of the event.

Flowserve has been working with the Tennessee Valley Authority's (TVA) Browns Ferry Nuclear Plant to investigate the failure of a Size 10, Class 900 Anchor/Darling motor-operated double-disc gate valve. The failure was due to the shearing of the wedge pin which serves a joint locking function at the threaded interface between the valve stem and upper wedge. The pin is designed to ensure that the joint does not loosen due to vibration and other secondary loads. On some valve designs, the pin also is used to attach the disc retainers to the upper wedge. The pin shearing allowed rotation of the stem during the closing stroke when the valve was seating and ultimately resulted in loss of the stem to upper wedge joint integrity.

Flowserve has completed an evaluation of the failure and concluded the root cause of the wedge pin failure was excessive load on the pin. The stem operating torque exceeded the torque to tighten the stem into the upper wedge before installation of the wedge pin. The additional stem torque produced a load on the wedge pin creating a stress which exceeded the pin shear strength causing the failure. The recommended assembly stem torque did not envelope the operating torque for the TVA application providing the potential for an over load situation and ultimate failure. The operating torque for the TVA valve was unusually high due to the fast closing time of the actuator and very conservative closing thrust margin.

Flowserve U S Inc
Flow Control Division

Raleigh Operations
PO Box 1961
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Raleigh, NC 27603

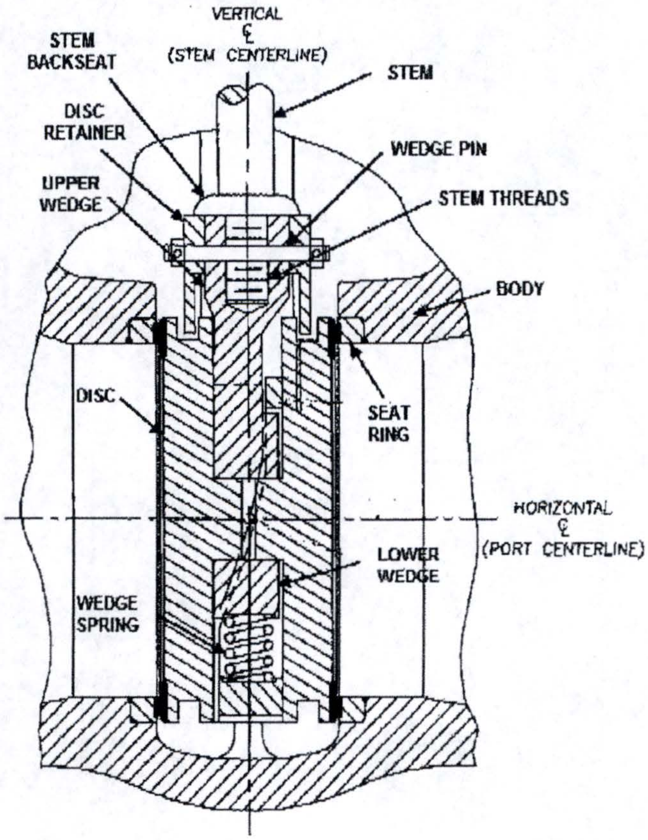
Toll Free: 1-800-225-6989
Phone: 1-919-832-0525
Facsimile: 1-919-831-3369
www.flowserve.com

ML13064A012

This situation can potentially occur on any Anchor/Darling type double-disc gate valve with a threaded stem to upper wedge connection, typically size 2.5" and larger, operated by an actuator that applies torque on the stem to produce the required valve operating thrust. An operating stem torque greater than the assembly stem torque can provide the opportunity for excessive pin load and potentially failure.

The stems on most double-disc (DD) gate valves larger than size 2" are attached to the upper wedge using UN threads. A pin is installed through the hub of the upper wedge and stem threaded section to prevent the stem from loosening and eventually unscrewing from the wedge. In addition, the disc retainers on some DD gate valves are attached using the wedge pin. See Figure 1. The output torque of the actuator is transmitted to the stem/wedge joint through the stem and is resisted by the disc wedge pack, therefore the stem to wedge connection is loaded by the stem torque and thrust. The wedge pin is not designed to withstand the full actuator output torque. The actuator torque direction tends to tighten the stem into the wedge during closing and tends to loosen the stem during opening.

Figure 1
Typical Double-Disc Gate Valve Trim



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Anchor Darling double-disc gate valves have been supplied to the commercial nuclear industry for critical service since the early 1970's. In April 1996, a specific stem preload torque value was established based on valve size and pressure class. This recommended standard stem preload torque is based on a calculated, required stem thrust to close the valve which is considered great enough to envelope most applications. Attachment 1 details the recommended torque by valve size and pressure class.

Failure of the wedge pin can cause loosening of the stem in the upper wedge and eventually separation of the stem leaving the valve inoperable. For certain designs pin failure could allow the retainers and miscellaneous attachment parts to fall out of position and become loose parts in the valve and piping system.

We have reviewed our records, and the only similar wedge pin failure that we can identify, in addition to the Browns Ferry problems, is a sheared wedge pin at LaSalle Nuclear Station in 1993. Our investigation of the LaSalle failure concluded that the wedge pin failed due to excessive torque in the opening direction due to bonnet over pressurization.

Flowserve recommends that all critical Anchor/Darling Double-Disc Gate valves with threaded stem to upper wedge connections and actuators that produce a torque on the stem be evaluated for potential wedge pin failure. Valves with electric motor actuators which produce high output torques are the most susceptible to failure. Valves which were assembled with stem torques that exceed the operating torque are not candidates for failure.

There is no test or inspection method to determine if the stems were completely torqued into the upper wedge prior to pin installation. Abnormal rotation of the stem immediately after valve seating or unseating, short valve stroke, or poor, unusual operation are signs of possible issues and should be investigated. Valve stems which have any gap between the stem backseat and top of the upper wedge need to be re-torqued. Valves with operating torques greater than the stem installation torque should be corrected by increasing the stem installation torque to at least the maximum expected operating stem torque. As provided in the Anchor/Darling 12/05 instruction manual, the existing stem can be reused by torqueing and drilling for a new pin if it is greater than 1.50" diameter and not reused previously. Stems of 1.50" and less diameter or stems which cannot be re-drilled for a new pin should be replaced.

Attachment 2 is a list, based on our records, of customers, utilities and nuclear plants which were supplied with Anchor/Darling Double-Disc Gate valves with motor actuators on contracts with ASME Section III and/or 10CFR21 imposed.

Flowserve plans to provide each of the customers identified in Attachment 2 with a copy of this notification letter.

Please do not hesitate to contact me if you have questions or require additional information.

Respectfully submitted,

James P. Tucker
Manager, Engineering
Flowserve Corporation
Flow Control Division
1900 S. Saunders St.
Raleigh, NC 27603

ATTACHMENT 1

RECOMMENDED STEM PRE-TORQUE (FT-LBS) FOR STEM/UPPER WEDGE JOINT ANCHOR-/ DARLING DOUBLE-DISC GATE VALVES

VALVE	PRESSURE CLASS					
SIZE	150	300	600	900	1500	2500
2.5	11	13	21	38	60	114
3	17	16	26	48	89	171
4	25	28	57	82	154	292
6	42	57	139	228	414	844
8	46	104	275	444	805	1848
10	74	172	483	776	1497	3436
12	110	262	720	1240	2467	5436
14	156	380	1022	1726	3434	7409
16	215	528	1398	2346	4844	9699
18	289	770	1955	3250	6888	12394
20	377	1006	2496	2960	9003	15750
22	448	1355	N/A	N/A	N/A	N/A
24	604	1697	3724	6999	14154	25132

Flowserve U S Inc
Flow Control Division

Raleigh Operations
PO Box 1961
1900 South Saunders Street
Raleigh, NC 27603

Toll Free: 1-800-225-6989
Phone: 1-919-832-0525
Facsimile: 1-919-831-3369
www.flowserve.com

ATTACHMENT 2

ANCHOR/DARLING DOUBLE-DISC GATE VALVES WITH WEDGE PINS AND MOTOR ACTUATORS	
AE / UTILITY	NUCLEAR PLANT
B&W	THREE MILE ISLAND 2
BECHTEL	ANO 1, CALLAWAY, WOLF CREEK, MILSTONE
CFE	LAGUNA VERDE
COM ED	DRESDEN, LASALLE, QUAD CITIES
CPL	BRUNSWICK, ROBINSON
DOMINION	SURRY
DUKE	CATAWBA, OCONEE
EBASCO	MILLSTONE
ENTERGY	GRAND GULF, NINE MILE, WATERFORD
EXELON	PEACH BOTTOM,
FPL	CRYSTAL RIVER, ST. LUCIE
GE	BROWNS FERRY, BRUNSWICK, CHINSHAN, CLINTON, COLUMBIA, CONFENTES
GE	COOPER, DUANE ARNOLD, FITZPATRICK, FORT CALHOUN, FUKISHIMA
GE	GRAND GULF, HATCH, KUOSHENG, LAGUNA VERDE, LASALLE, LIMERICK
GE	NINE MILE, PEACH BOTTOM, PERRY, PILGRIM, RIVER BEND, SHIMANE
GPC	HATCH
GPU	OYSTER CREEK
GULF STATES	RIVER BEND
ILL POWER	CLINTON
INDIANA MICH POWER	COOK
MAINE YANKEE	MAINE YANKEE
NEU	MILLSTONE
NIAGARA MOHAWK	NINE MILE
NORTHEAST NUC	MILLSTONE
NPPD	COOPER
NSP	MONTICELLO, PRARIE ISLAND
NYPA	FITZPATRICK
ONT HYDRO	BRUCE
PG&E	DIABLO CANYON
PHILA ELECTRIC	PEACH BOTTOM
PPL	SSES
PROGRESS ENERGY	ROBINSON
SCE	SAN ONOFRE
SCE&G	VC SUMMER
SNC LAVALIN	BRUCE

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TPC	CHINSHAN, KUOSHENG, LUNGMEN
TVA	BROWNS FERRY
VEPCO	NORTH ANNA, SURRY
VERMONT YANKEE	VERMONT YANKEE
WESTINGHOUSE	COOK, DIABLO CANYON, INDIAN POINT, KANSAI ELECTRIC, KEWAUNEE
WESTINGHOUSE	KORI 1, NORTH ANNA, POINT BEACH, PRAIRIE ISLAND, RINGALS, ROBINSON

BWR Owners' Group
c/o GE Hitachi Nuclear Energy
P. O. Box 780 – M/C A70
Wilmington, NC 28402 USA

BWROG Valve Technical Resolution Group (VTRG)

Date: March 8, 2013

From: Ted Neckowicz – BWROG VTRG Chairman, Exelon Generation

To: Floyd Bensinger – Flowserve Valve Engineering Manager

Subject: Flowserve Information Requests Related to the February 25 2013 10CFR Part 21 Notification

Purpose:

Request information from Flowserve Corporation in order to develop an industry wide response / evaluation plan to address the subject 10CFR Part21 Notification concerning Anchor Darling Double Disc Gate Valve Wedge Pin Failure

Information requests have been grouped into the following Priorities suggested by the VTRG:
1st - MOV Operability / Repair Issues for plants with current or near-term refuel outages
2nd - Industry VTRG Priority 1 questions
3rd - Industry VTRG Priority 2 questions
4th – Other plant specific valve data requests

VTRG Priority 1 Questions/Requests

a) Could valve diagnostic testing be used to assess the condition of the stem/wedge connection? What would we be specifically looking for? Torque, stroke time, load profile, stroke length, increased running load?
Response: Diagnostic testing could not guarantee that the wedge pin was overtorqued or had failed but should be able to detect whether the stem/wedge were unthreading. Diagnostic testing at several plants had shown trace anomalies before discovery of wedge pin failure.

b) Could a visual or other non-intrusive inspection of the stem/disc connection be performed in lieu of disassembling and retorquing? What about the shoulder on the stem making good contact with the upper wedge?
Response: Visual inspection of the upper wedge not shouldered would be an indication of loss of adequate pre-torque.

c) Is valve leak tightness as determined by LLRTs a possible indicator of wedge pin failure?
Response: Valve seat leakage is considered a secondary indicator caused by disc retainer clip failure and disc misalignment

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Attachment 4

Stem-Disc Wedge Pin Shear Capability Analysis

Summary

On Page 14 of the report, Method a. describes Wedge Pin Shear Capability Analysis as an approach to either prioritize or permanently disposition the Anchor Darling Double Disc Gate Valve threaded stem/wedge connection for adequate structural integrity to preclude stem/disc separation. This attachment provides considerations for inclusion and acceptable disposition by this analysis.

The following inputs are required from Flowserve or other valve related sources:

- Wedge Pin material specifications
- Wedge pin diameter (OD_{PIN})
- Wedge pin length
- Stem pitch diameter @ upper wedge (ODP_{STEM})
- Stem/Wedge thread engagement length
- Integral Stem Shoulder (Yes/No)

Other sources could include: Weak link analysis, valve drawing, bill of materials, spare parts

Additional inputs required (provided by plant)

- Valve operating temperature
- Actuator maximum output thrust and torque
- Conservative Stem Factor to convert thrust to torque
- A correction for test uncertainty and expected output variability (e.g. Stem lube degradation)

Basic Equation for Pin Shear Torque

$$\tau_{PIN} = \frac{Applied\ Torque\ (in - lbs)}{ODP_{STEM} * (\pi * \frac{(OD_{PIN})^2}{4})}$$

Allowable Wedge Pin Shear Stress Values

(NOTE: This may vary based on plant valve design standards and valve weak link analysis)

$\tau = 0.577*S_Y$ (pure shear limit per distortion energy theory)
$\tau = 0.50*S_Y$ (pure shear limit per maximum shear stress theory)
Recommend use of $\tau = 0.50*S_Y$ unless justified in the plant specific analysis and/or applicable code.

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Attachment 4

Assumptions / Analysis Methods

1. The bearing and friction between the stem shoulder and upper wedge top surface is not relied upon in the load transfer between the stem and disc. 100% of the actuator torque is assumed to transfer through the threads and pin. Effectively, no credit for stem/wedge preload should be assumed. (Conservative)

2. Yield strength values of the wedge pin should be determined based on material specification and grade provided as documented in valve drawings and bills of material, as quite often these pins did not have CMTRs. Minimum required mechanical values should be used and appropriate engineering judgement applied to determine allowable yield strength when only the material specification is known. Yield strength values should be corrected for maximum operating temperature.

3. The thrust load is transferred through shear strength of the threads (i.e., thread stripping resistance) and is not applied to the wedge pin. (Reasonable Engineering judgment)

4. If necessary, credit for thread resistance may be taken to reduce the torque induced shear load on the wedge pin provided that the valve being analyzed shows no indication of thread damage (e.g., no anomalous behavior from diagnostic trending that could potentially be attributed to thread / upper wedge threaded joint damage) and assumed thread friction is conservative. For MOVs with pin torque capacity smaller than the maximum applied torque, the excess applied torque is considered to be resisted by stem/wedge thread friction. This excess torque may then be used to calculate the minimum required coefficient of friction across the stem/wedge threads. The coefficient of friction can be computed by dividing the excess torque by the stem thrust to obtain thread torque-thrust factor (similar to the stem factor for the actuator stem nut). The torque-thrust factor is a function of the thread geometry and coefficient of friction. Provided that the required friction coefficient values are reasonably low based on engineering judgment, then credit for thread friction is acceptable. (Reasonable Engineering judgment)

5. Fatigue failure of the wedge pin is not a concern. This is supported by the BFN root cause analysis and the Flowserve Part 21 where it was shown that the pin failure was due to overload and no indications of fatigue failure were observed. (Reasonable Engineering judgment)

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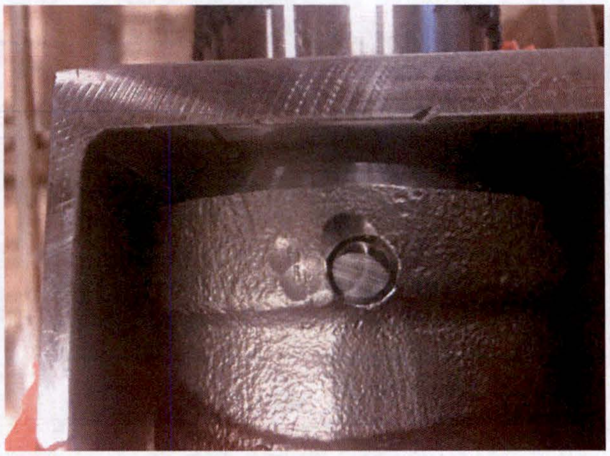
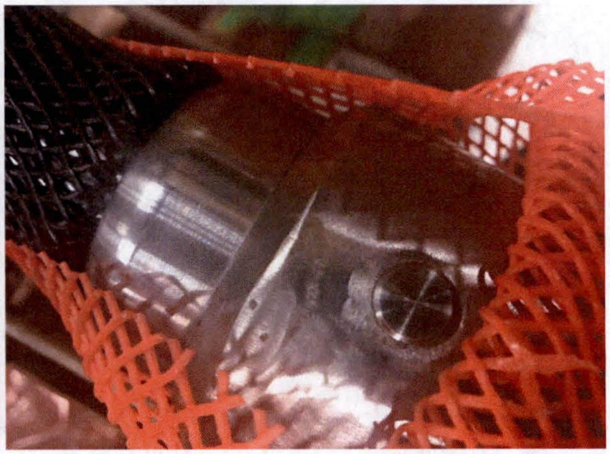
Staking of Anchor Darling Double Disc Wedge Pins

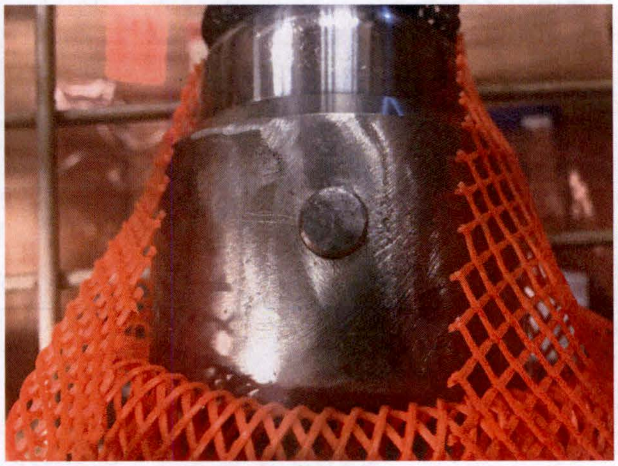
The wedge pin is not necessarily pressed into the pin hole. The hole is drilled using a bit the same nominal size as the pin therefore there may be a loose fit, expect .001 interference to .003 diametrical clearance. Heavy peening the pin or hole on both sides is required if threaded pins with nuts for disc retainers are not used.

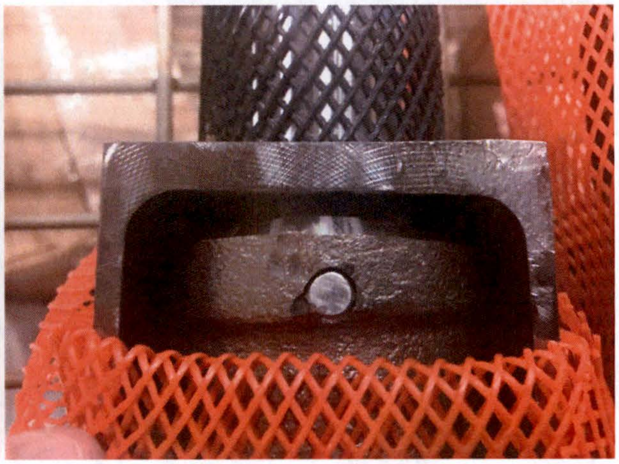
Both ends of the pin should be deformed by peening the pin end edge manually with a hammer to enlarge a section of the pin end. An alternate method to deform the pin end is to stake the pin edge using a blunt chisel. One or two stakes per pin end will be sufficient. The opposite side of the pin must be supported during striking to keep the pin approximately centered in the upper wedge hub.
Note: Pin staking guidance only applies to pins that do not act as disc retainers/keepers which have nuts

Photos of the properly staked stem / wedge assemblies with wedge pins staked or pinned are shown below.









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Flowserve Guidance on Stem-Disc Assembly Repair / Replacement

Disc/Wedge Assembly

The disc wedge assembly should only be reused if the internal threads are not worn or degraded.

Wedge Pins

Normally plan on replacing the wedge pin since it may be damaged during disassembly. The wedge pin may have been exposed to reversing stresses, particularly if the stem was not originally torqued, resulting in a possible future fatigue failure.

Stems

In all cases, stems should only be reused if no stem damage is indicated.

For stems 1-1/2" or less, plan on replacing the stem since the original stem hole will likely not align. Original stems may only be reused if the disc/stem assembly can be properly torqued and have the wedge/stem holes in alignment.

For stems, larger than 1-1/2" with overlapping holes, remove enough material from the top of the wedge to allow the wedge to turn approximately 90 degrees. Retorque and re-drill the wedge pin hole.

Consider stem replacement if original uses pressed-on stem backseat collar (i.e. 2-piece stem). A 1-piece stem with an integral stem back seat collar will allow a significantly higher maximum applied torque to the stem/upper wedge connection.

Applied Torque to Stem/Disc Wedge Connections

The Flowserve applied torque values are for general valve applications. For nuclear work, Flowserve recommends that the applied value bound the specific valve application by ensuring it exceeds the maximum possible applied stem torque. Under no circumstances is it permissible to reduce the torque in order to align the wedge pin holes in power actuated valves.

Flowserve can provide the maximum applied installation torque as a function as whether the stem backseat is integral or a separate collar. Flowserve can also supply a maximum stem torque for different wedge pin materials assuming no applied installation torque. See examples below recently provided to a member utility.

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Attachment 6

VALVE SIZE-CLASS	DRAWING	MAXIMUM INSTALLATION TORQUE (FT-LBS)		WEDGE PIN		
				DIAMETER (INCH)	MAX STEM TORQUE (FT-LBS) 100 ^{0}F	
		Collar	Integral		SA306-60	B637-7718
12-900 DD	94-13401	1391	5187	0.500	594	2971
4-900 DD	94-13306	322	852	0.375	183	917
18-150 DD	94-13473	979	3081	0.500	498	2492
14-150 DD	94-13274	682	1935	0.375	241	1203

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MOV Stem Rotation Check (SRC) Methodology Guidance

Background:
The LaSalle HPCS MOV Stem/Disc Failure event identified improvement opportunities for the conduct of Stem Rotation Checks that provide an indication of stem-to-disc integrity. The Stem Rotation Check is referred to as Method b. in the Recommended Methodology Section V and in Attachment 10. Two techniques that have been shown to provide accurate and trendable Stem Rotation Check Data in order to meet Method b. requirements are provided in this guidance.

Criteria:
Stem rotation should be less than or equal to 5 degrees. Stem rotation of 5 degrees or less provides reasonably high confidence of stem/disc connection integrity given the industry operating experience data and variation in the valve seat/disc/guide internal clearances. Stem rotation of greater than 5 degrees is considered to be at higher risk of stem/disc connection degradation. Stem Rotation data should be of sufficient accuracy to be trended over time. No increasing trend in measured stem rotation above the established maximum 5 degree criteria acceptable unless evaluated by engineering. Only small variations less than 2 degrees from the baseline reference value (once established) should be accepted without engineering evaluation.

When and where to measure:
Stem Rotation Checks should be performed during the initial stem movement from the Full Closed position. A baseline reference SRC should be established for trending purposes during subsequent SRCs. Note that stem rotation checks performed from the Full Open position have been observed to have more rotation than from the Full Close position due to the larger clearances associated with the disc being out of the seat.

Repeatability
If practical, three (3) full stroke cycles is recommended. This would better determine whether the associated valve stem is "ratcheting" in small rotational increments.

Established Methods:
- Visual Stem Rotation Check - Visual Observation Recording using etched metal stem templates
- Diagnostics using stem mounted gage - Stem Rotation Check using SPMD and stem clamp adapted device

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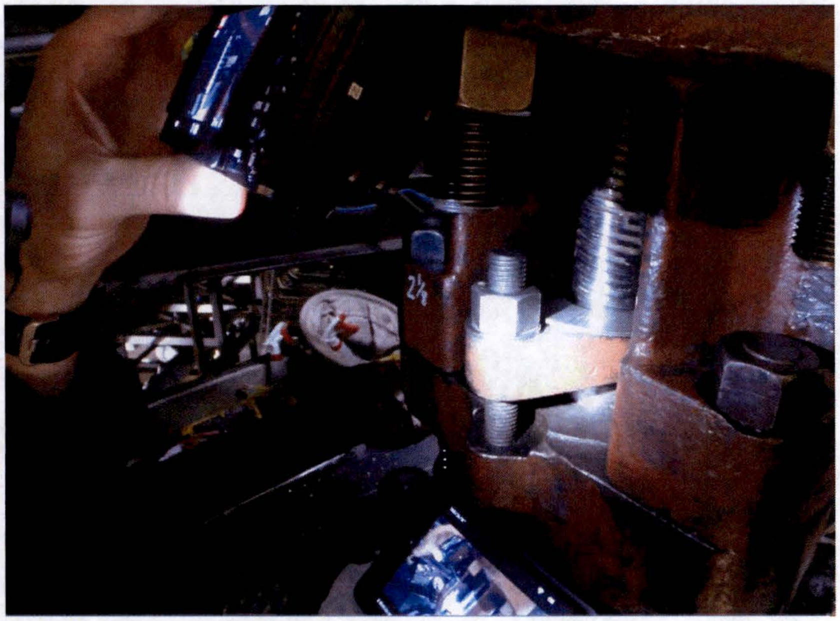
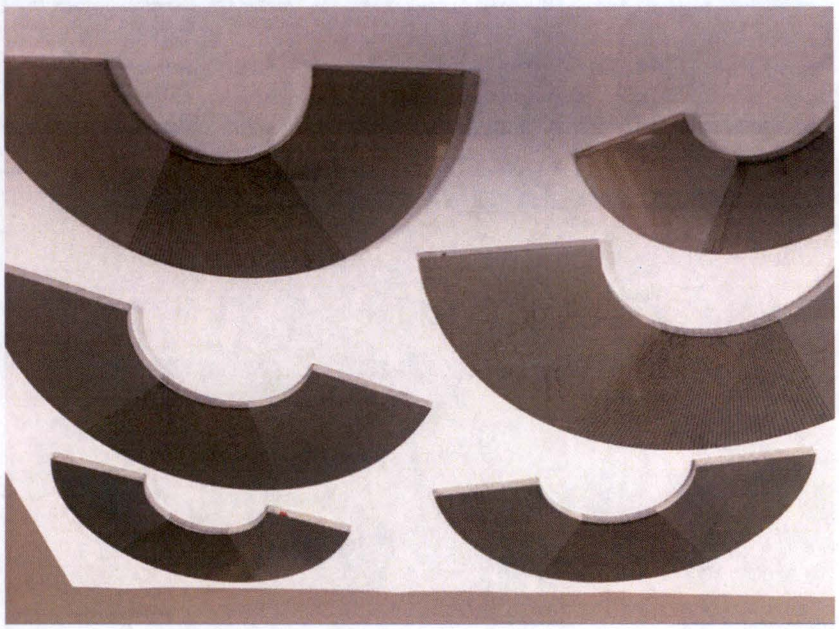
Attachment 7

Visual Stem Rotation Check – Use of Video Recorder with etched stem templates gaged to specific stem diameter. A video recorder is highly recommended since the initial stem movement where rotation can be observed happens within a second.



Handheld video recorder being used to record Stem Rotation Check Data.



Stem Rotation Check etched templates are made for each applicable valve stem diameter. Etched fine lines are provided in 1 degree increments.

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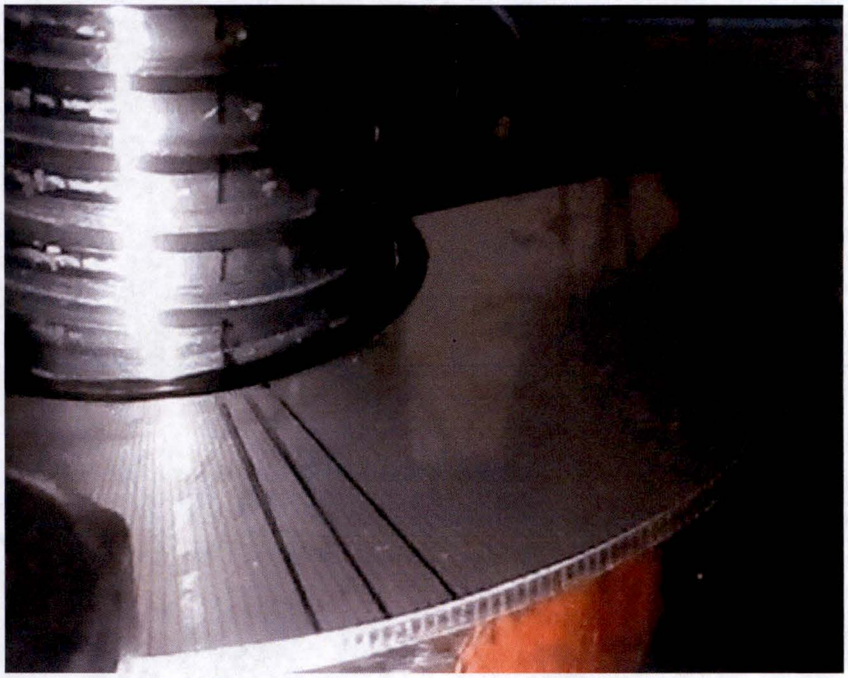
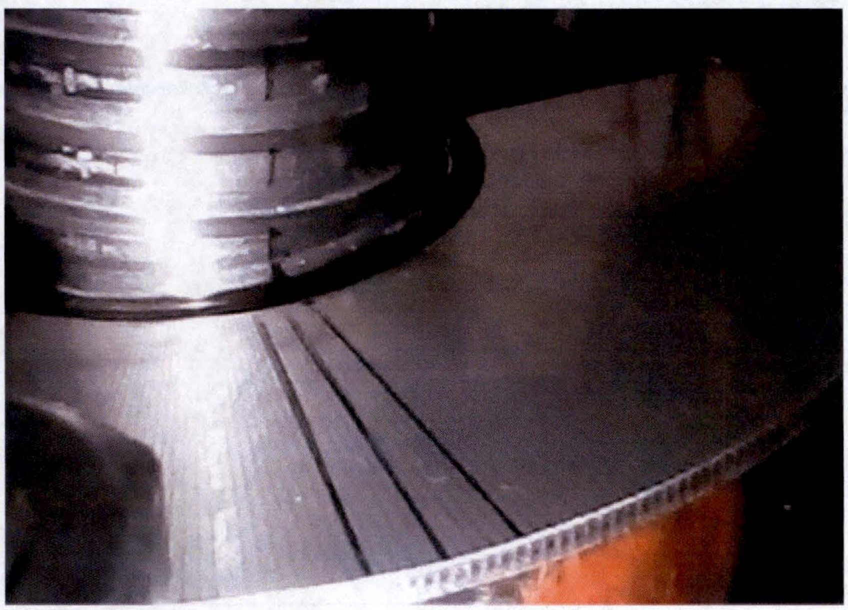
Attachment 7



FULL CLOSED POSITION –
set on zero
Minor Lines 1 degree
Major Lines 5 degrees

MOV Stem Rotation Check (From Full Close)



AFTER START OF STEM
MOVEMENT –
Record 3 degrees of CCW
rotation

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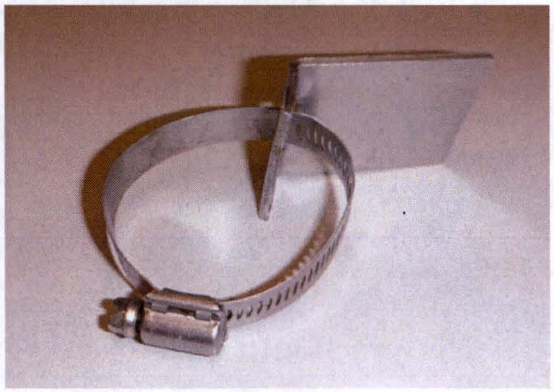
Attachment 7

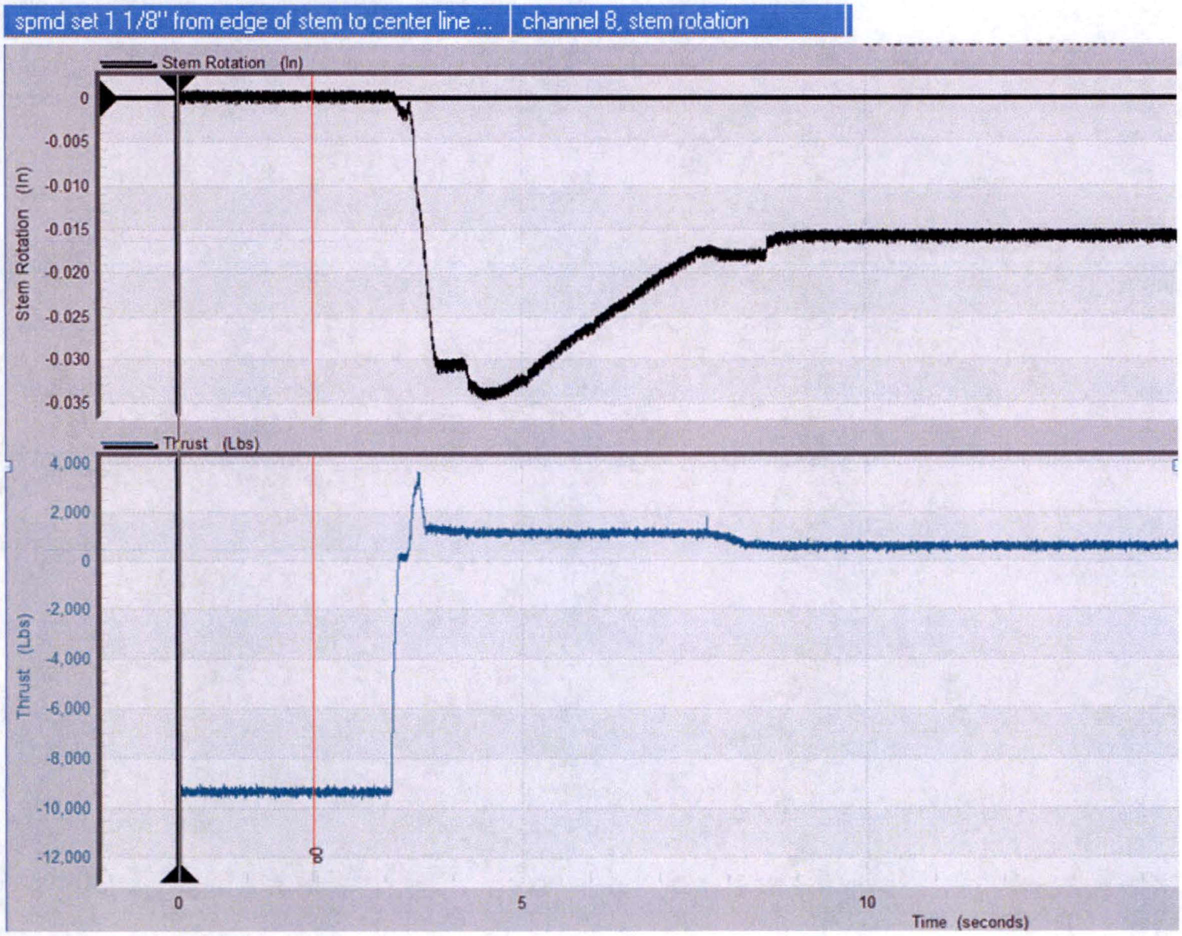
Stem Rotation Check using Spring Pack Measurement Device (SPMD) and stem clamp adapted device – Linear data (inches) can be directly converted into degrees of stem rotation based on effective target circumference.

Picture of Stem Clamp



Example Data:
Stem Dia: 1.75, Stem Radius: 0.875
Target distance from Stem: 1.125
Effective radius @ target: 2.000
Circumference @ target: 12.566”
Measured Movement: 0.034”
Measured Rotation:
360 deg * (0.034” / 12.566”)
0.97 deg (~ 1 degree)

Example data is provided below.



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Attachment 8

Flowserve 10CFR21 Update to the NRC Dated July 11 2017

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Flow Control Division
Anchor/Darling Valves
BW/IP Valves
Edward Valves
Valtek Control Products
Worcester Valves

July 11, 2017

US Nuclear Regulatory Commission
Document Control Desk
11545 Rockville Pike
Rockville MD 20852-2746

Subject: Stem-Wedge Separation of an Anchor/Darling Double Disc Gate Valve at Exelon, LaSalle County Station, Unit 2, February 2017.

Reference: Flowserve, Raleigh 10CFR Part 21 Notification Letter dated February 25, 2013, Wedge Pin Failure of Anchor/Darling DD Gate Valve.

Attachment 1: List of Affected Customers and Plants

Gentlemen:

This is to notify the US Nuclear Regulatory Commission that, in accordance with the provisions of 10CFR Part 21, we have gained additional insight and information concerning the referenced previously reported issue based on a recent incident at the LaSalle County Station, Unit 2 involving a similar valve.

Flowserve has been working with Exelon and nuclear industry groups to investigate and evaluate the stem-wedge separation in a size 12 class 900 Anchor/Darling motor-operated double disc (DD) gate valve. The valve stem was completely separated from the upper wedge, the wedge pin was sheared, the wedge threads stripped away and the pressed-on stem collar was pushed up leaving the valve inoperable. The valve operating thrust and torque is transmitted through the stem-wedge assembly, therefore separation of the stem and wedge will prevent the valve from opening and can adversely affect closing. See Figure 1 for a sketch of the stem-wedge joint.

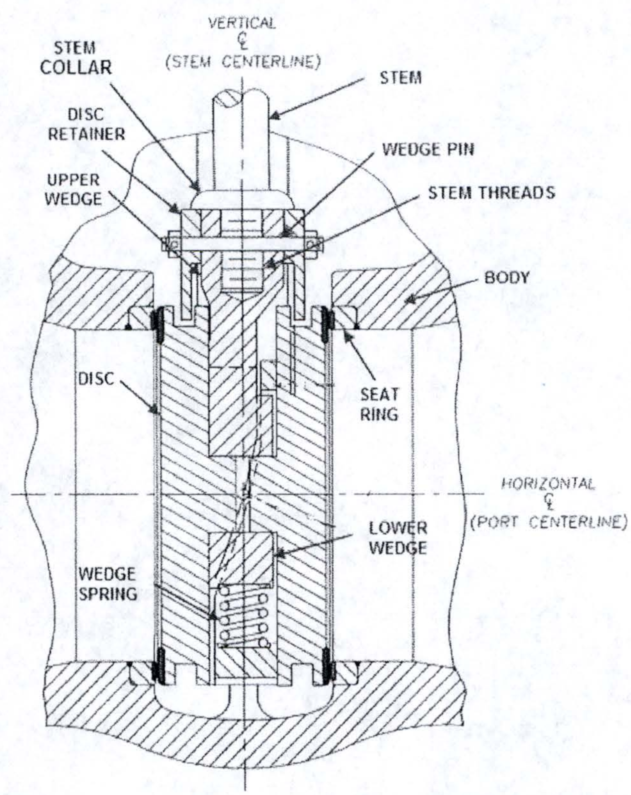
This incident is related to the wedge pin failure of a similar valve reported to the NRC under 10CFR21 on February 25, 2013. A wedge pin sheared on a 10-900 DD at TVA – Browns Ferry although the stem remained engaged in the wedge and the valve could be opened and closed. The conclusion in the evaluation of that incident was that wedge pin shear could lead to stem-wedge joint degradation and eventual stem-wedge failure similar to this incident at LaSalle.

Evaluation of this event added an element not addressed in the previous evaluation regarding the limitation of a pressed-on stem collar to support the actuator thrust and maintain the stem-wedge preload.

Review of the LaSalle incident concluded repeated valve cycles at high actuator loads eventually wore the wedge threads to the point of failure in shear during a valve closing cycle and subsequent separation of the stem from the wedge. Before thread failure the wedge pin sheared which allowed stem to wedge movement with accompanying wedge thread wear and degradation. In additional the pressed-on collar was pushed up out of position, which would reduce or eliminate any existing preload in the joint. Wedge pin failure is attributed to both limited preload on the stem threaded section and exposure to actuator torques higher than the limit of the pin material. Since stem-wedge preload can be reduced or removed by a stem thrust which exceeds the stem-wedge joint capability, high thrust can be a precursor for wedge pin shear for applications with wedge pins that cannot independently withstand the actuator stem torque. The capability to maintain the preload is much less for stems with pressed-on collars than for stems with integral collars.

The scope remains the same as the previous notification, Anchor/Darling type DD gate valve with a threaded stem to upper wedge connection, typically size 2-1/2 inch and larger, operated by an actuator that applies torque on the stem to produce the required valve operating thrust. Note that most size 2 valves utilize a tee head stem connection, however while addressing the original wedge pin issue a few size 2 valves were discovered that have threaded stem connections.

Figure 1
Typical Double-Disc Gate Valve Trim



Valve evaluations and actions resulting from the previous notification are applicable and still apply. This notification includes additional information for maintaining the stem preload that was not addressed previously. The actuator thrust as well as the torque must be reviewed to insure the preload is maintained.

A loose connection is the result of inadequate stem thread preload whether not applied initially during assembly or not maintained during operation. The initial stem preload can be reduced if the stem closing thrust in service is high enough to cause local yielding of the joint. Stems with integral collars typically have allowable thrusts which do not govern the thrust limit of the valve however a stem with a pressed-on collar, supplied with many of the originally supplied valves, has a thrust limit which is less than the typical maximum allowed thrust values previously determined by weak-link or maximum thrust analyses.

Industry groups, such as BWROG, are determining appropriate corrective actions and priorities based on valve application. Consideration should be given to the following Flowserve recommendations:

- Torque the stem into the wedge to the maximum joint capacity.
- Replacement stems should have integral collars in lieu of press-on.
- Replacement wedge pins are manufactured from high strength material.
- Verify the actuator stem thrust is less than the maximum allowed to maintain the stem preload.

Attachment 1 is a list, based on our records, of customers, utilities and nuclear plants which were supplied with Anchor/Darling DD Gate valves with motor actuators on contracts with Section III and/or 10CFR21 imposed. This list added a few sites not included on the list provided with the original notification.

Flowserve plans to provide each of the customers identified in Attachment 1 with a copy of this notification letter.

Please do not hesitate to contact us if you have questions or require additional information.

Respectfully submitted,

7/11/2017 7/11/17.

Joseph Carter
Manager, Quality Assurance
Flowserve Corporation, FCD
Raleigh, NC
919-831-3220

Mark Cowell
Engineering Specialist
Flowserve Corporation, FCD
Raleigh, NC
919-831-3377

ATTACHMENT 1

ANCHOR/DARLING DOUBLE DISC GATE VALVES WITH THREADED STEMS AND MOTOR ACTUATORS	
AE / UTILITY	NUCLEAR PLANT
B&W	THREE MILE ISLAND 2
BECHTEL	ANO 1, CALLAWAY, MILLSTONE, SSES*, WOLF CREEK
CFE	LAGUNA VERDE
COM ED	DRESDEN, LASALLE, QUAD CITIES
CPL	BRUNSWICK, ROBINSON
DOMINION	SURRY
DUKE	CATAWBA, OCONEE
DUQUESNE LIGHT	BEAVER VALLEY*
EBASCO	MILLSTONE
ENTERGY	GRAND GULF, NINE MILE, WATERFORD
EXELON	PEACH BOTTOM
FPL	CRYSTAL RIVER, ST. LUCIE
GE	BROWNS FERRY, BRUNSWICK, CHINSHAN, CLINTON, COLUMBIA, CONFENTES
GE	COOPER, DUANE ARNOLD, FITZPATRICK, FORT CALHOUN, FUKISHIMA
GE	GRAND GULF, HATCH, KUOSHENG, LAGUNA VERDE, LASALLE, LIMERICK
GE	NINE MILE, PEACH BOTTOM, PERRY, PILGRIM, RIVER BEND, SHIMANE
GPC	HATCH
GPU	OYSTER CREEK
GULF STATES	RIVER BEND
ILL POWER	CLINTON
INDIANA MICH POWER	COOK
MAINE YANKEE	MAINE YANKEE
NEU	MILLSTONE
NIAGARA MOHAWK	NINE MILE
NORTHEAST NUC	MILLSTONE
NPPD	COOPER
NSP	MONTICELLO, PRARIE ISLAND
NYPA	FITZPATRICK
ONT HYDRO	BRUCE
PG&E	DIABLO CANYON
PHILA ELECTRIC	PEACH BOTTOM
PPL	SSES
PROGRESS ENERGY	ROBINSON
SCE	SAN ONOFRE
SCE&G	VC SUMMER

SNC LAVALIN	BRUCE
TPC	CHINSHAN, KUOSHENG, LUNGMEN
TVA	BROWNS FERRY
VEPCO	NORTH ANNA, SURRY
VERMONT YANKEE	VERMONT YANKEE
WESTINGHOUSE	COOK, DIABLO CANYON, GINNA*, INDIAN POINT, KANSAI ELECTRIC,
WESTINGHOUSE	KORI 1, NORTH ANNA, POINT BEACH, PRAIRIE ISLAND, RINGALS, KEWAUNEE,
WESTINGHOUSE	ROBINSON, SALEM*, SEQUOYAH*, SURRY, TAKAHAMA*, TURKEY POINT*,
WESTINGHOUSE	WISC-MICH POWER*
*Sites added from previous notification	

FLOWSERVE

Flow Control Division
Edward Valves

fax 1:42p
2:06p

Fax

To: US NRC Document Control Desk	**From:** Flowserve Corp
Fax: 301-816-5151	**Pages: 6 including cover**
Phone: 301-816-5100	**Date:** July 11, 2017
Re: 10 CFR Part 21 Notification Letter of February 25, 2013	

☐ **Urgent** ☐ **For Review** ☐ **Please Comment** ☐ **Please Reply** ☐ **Please Recycle**

● **Comments:**

Attachment 9

Flowserve Memo from Mark Cowell Dated June 27 2017, "Stem-Wedge Separation Evaluation – Anchor/Darling Double Disc Gate Valve"

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FLOWSERVE®

Flow Control Division
Anchor/Darling Valves
BW/IP Valves
Edward Valves
Valtek Control Products
Worcester Valves

STEM-WEDGE SEPARATION EVALUATION
Anchor/Darling Double Disc Gate Valve

SUBJECT: Stem-Wedge Separation at Exelon – LaSalle County Station, Unit 2. Anchor/Darling Valve Size 12-900 Double Disc Gate Valve with SMB-4 Motor Actuator. Darling Valve Drawing 94-13499 and SO E5307-8.

DESCRIPTION: Exelon – LaSalle Unit 2 reported separation of the stem and upper wedge on valve 2E22-F004 during refueling outage L2R16 (February 2017). The stem was completely removed from the wedge with the wedge pin sheared and wedge threads completely stripped. The valve operating thrust and torque is transmitted through the stem-wedge assembly. Separation of the stem and wedge will prevent the valve from opening and can adversely affect closing. See Figure 1 for a sketch of the stem-wedge joint.

This incident is related to the wedge pin failure of a similar valve reported to the NRC under 10CFR21 on February 25, 2013. A wedge pin sheared on a 10-900 DD at TVA – Browns Ferry although the stem remained engaged in the wedge and the valve could be opened and closed. The conclusion of that evaluation was that wedge pin shear can lead to stem-wedge joint degradation and eventual stem-wedge failure similar to this event.

Evaluation of this event added an element not addressed in the previous evaluation regarding the limitation of a pressed on stem collar to support the actuator thrust and maintain the stem-wedge preload.

SCOPE: The same as the original notification, Anchor/Darling type double disc gate valves with threaded stem to upper wedge connections, typically size 2.5 and larger, operated by actuators that produce stem torque. During review of the valve population a few size 2 valves have been discovered that have a threaded connection. An added note is that valves with stems that have pressed on collars are of particular interest because of the possible thrust effect on maintaining the stem-wedge thread preload.

ROOT CAUSE: Repeated valve cycles and high actuator loads eventually wore the wedge threads to the point of failure in shear during valve closing and subsequent separation of the stem from the wedge. Before thread failure the wedge pin sheared which allowed stem to wedge movement with accompanying wedge thread wear and degradation. Wedge pin failure is attributed to both limited preload on the stem threaded section and exposure to actuator torques higher than the limit of the pin material. Since stem-wedge preload can be reduced or removed by a stem thrust which exceeds the stem-wedge joint capability, high thrust can be a precursor for wedge pin shear for applications with wedge pins that cannot independently withstand the actuator stem forces. The capability to maintain the preload is much less for stems with pressed on collars than for stems with integral collars.

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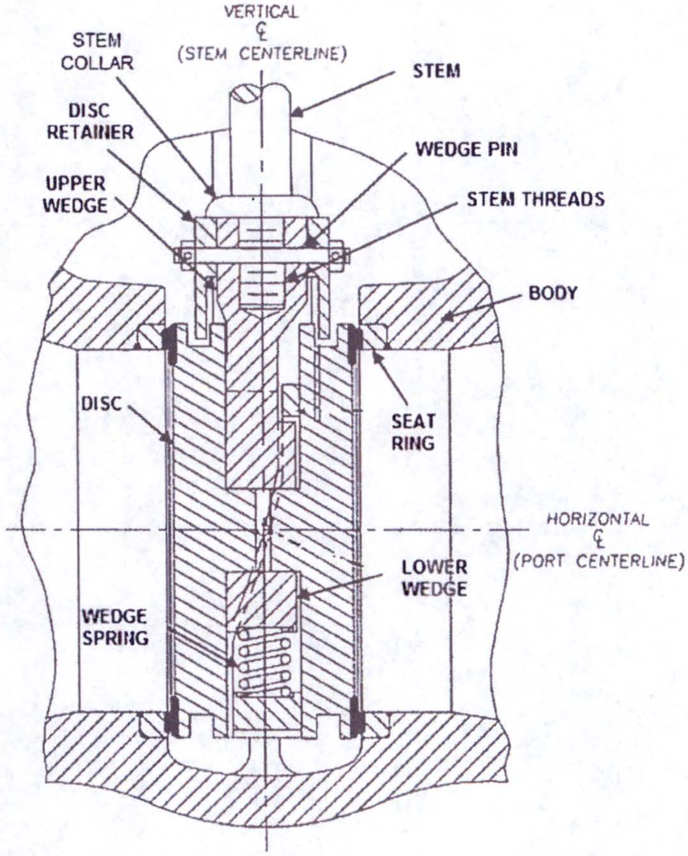
Figure 1
Typical Double Disc Gate Valve Trim



RECOMMENDATIONS:

1) Preload the joint by torqueing the stem into the upper wedge during assembly to a value greater than the actuator output torque before installing the wedge pin. This is the same recommendation as provided under the previous notification. It is further recommended to torque the stem to the maximum capability of the joint to provide additional margin and account for the stem thrust.

2) If stems are replaced use stems with integral collars. Consider stem replacement using stems with integral collars if the valves are disassembled.

3) If wedge pins are replaced use high strength material such as hardened martensitic / 17-4PH stainless or inconel. Consider pin replacement if the valves are disassembled.

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4) Verify the actuator stem thrust is less than the maximum allowed to maintain the stem preload. The stem-wedge connection was not historically evaluated for maintaining stem thread preload. The joint must be addressed in detail in weak-link or maximum thrust evaluations.

EVALUATION: Exelon contracted a detailed evaluation of the LaSalle 2E22-F004 stem-wedge failure. The report concluded the stem separated from the wedge due to shear failure of degraded wedge threads. The degradation was the result of multiple valve high load cycles after the threaded connection became loose which allowed relative motion at the threads and subsequent thread wear and degradation. The increasingly damaged threads eventually reduced the load capacity of the wedge threads until the threads sheared during a closing operation.

A precursor to stem thread damage is shear failure of the wedge pin. If the wedge pin has sufficient strength to withstand the net force of the actuator torque, then joint integrity will be maintained irrespective of stem preload. An evaluation and description of wedge pin failure in an Anchor/Darling DD gate valve is provided in the previous notification.

The actuator stem torque and thrust is reacted by the wedge pin, the stem threads and the stem collar. The net force on the wedge pin is the actuator torque/thrust less the portion of these loads supported by the threads and collar. A loose stem-wedge connection can reduce the reactions of these components increasing the load on the pin, and if the pin cannot handle the actuator forces without the support of the threads and collar then pin failure is possible.

A loose connection is the result of inadequate stem thread preload whether not applied initially during assembly or not maintained during operation. The initial stem preload can be reduced if the stem closing thrust in service is high enough to cause local yielding of the joint. The loose joint results in loss of friction at the threads and at the stem collar, and increased load on the wedge pin. Stems with integral collars typically have allowable thrusts which do not govern the thrust limit of the valve however a stem with a pressed on collar, supplied with many of the originally supplied valves, have a thrust limit to maintain the stem preload which is less than typical maximum allowed thrust values.
Since the stem power threads are generally more efficient than the stem-wedge-collar threads the actuator stem thrust may exceed the stem preload force when applying an actuator stem torque which approaches the preload installation torque. This can cause confusion believing a stem preload torque greater than the actuator stem torque is sufficient to maintain joint integrity under all conditions. Adequate margin to account for the effect of the actuator thrust component on the stem preload should be considered.

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EFFECTS ON PREVIOUS RECOMMENDATIONS:

Valve evaluations resulting from the previous notification are applicable and still apply. This evaluation adds criteria for maintaining the stem preload that was not addressed previously. The actuator thrust as well as the torque must be reviewed to insure the preload is maintained.

Valves with Wedge Pins that can Support the Actuator Torque without a Preload:
If the wedge pin can handle the maximum actuator torque without a joint preload the joint will remain functional independent of preload. The stem threads will support the actuator thrust and prevent pin loading from the thrust. This applies to stems with pressed on or integral collars.

Valves with Wedge Pins that cannot Support the Actuator Torque without a Preload:

1) If a known preload was not applied during assembly, the wedge pin is susceptible to shear failure and the valve must be monitored and/or inspected as addressed in the BWROG report.

2) If the stem was preloaded to a known value which was less than the actuator output torque than the preload and the pin may provide enough support to prevent pin shear. This will require an analysis for each applicable application. The thrust limit addressed in case (3) below must be included in the analysis.

3) If the stem was preloaded to a known value which was greater than the actuator output torque then the actuator thrust must also be reviewed and be less than the maximum allowable thrust to maintain the joint preload, i.e. not yield any sections of the joint in the load path. For stems with integral collars this allowable thrust is generally similar to the maximum allowable for other critical sections of stem however stems with pressed on collars have yield strength limits which are less than are typical for other sections of the stem. The maximum joint thrust to maintain the preload must be determined for each application.

VALVE ASSEMBLY WEAK LINK / MAX THRUST EVALUATIONS:

As part of Generic Letter 89-10 reviews many critical MOVs were evaluated by the utilities to determine the maximum stem thrust / torque that could be applied to the valve by the actuator based on some acceptance criteria such as survivability or maintaining operability under various conditions. Part of many of the evaluations included detailed analysis provided by Flowserve. The analyses included determining the weakest valve component(s), the weak link, and the maximum allowed thrust / torque load the component(s) can withstand based on the acceptance criteria.

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The Flowserve report included a limited analysis of the stem-wedge connection which basically addressed the stem thread shear strength. The Flowserve analyses did not include a review of the wedge pin or stem collar, nor the thrust effects on the joint preload. The maximum allowed thrust can be less than previously reported considering these sections, depending on the specific design and limit criteria. Existing weak-link or maximum thrust evaluations should be reviewed then revised or supplemented as necessary to fully address the stem-wedge joint. The joint should be fully analyzed if the thrust values are used as normal design limits; however, additional analysis may not be required if the maximum thrust is for an abnormal, one-time event.

CONCLUSION: The wedge stem threads failed due to previously undetected wedge pin shearing and a loose threaded joint. The wedge pin did not have sufficient strength to support the loads on the joint without an adequate preload. The threads degraded through repeated valve cycles of a loose joint without a functioning wedge pin until the threads could not support the stem thrust. The joint preload cannot be maintained if the stem thrust exceeds the capability of the stem-wedge connection which can be limited for a stem with a pressed on collar. Many previous weak-link / maximum stem thrust evaluations did not account for joint preload and the limitations of a pressed on stem collar.

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Simplified Recommendations / Schedule for Part21 Applicable MOVs

NOTE: This attachment should be used if susceptibility screening reviews including wedge pin shear analysis were previously performed.

Valves subject to the actions below meet the following Part 21 applicability screening criteria:

Anchor Darling Double Disc Gate Valves as small as Size 2 with threaded and pinned stem / upper wedge connections and subjected to valve actuator torque (e.g. Limitorque motor actuator) and meet one of the following exclusive conditions.

a. Valve was manufactured before 1996
b. Valve was manufactured after 1996 but the maximum applied actuator torque (including historical values) exceed the Flowserve published stem-wedge pre-torque values
c. Valve was manufactured after 1996 and is equipped with a pressed-on stem collar whose thrust capacity is less than maximum applied actuator thrust (including historical values). This evaluation requires Flowserve Valve Engineering support.

Valves may be removed from susceptibility using one of the following two methods

1. Stem-Disc Wedge Pin Shear Capability Analysis (Attachment 4)
2. Stem-Disc Assembly Repair / Replacement (Attachment 6)

Program Risk / Priority	**Recommended Actions and Interval**	**Comments**
Applicable GL96-05 MOVs with symptoms of active stem-wedge connection degradation (i.e. UNSAT stem rotation check and/or unresolved diagnostic test anomalies)	Evaluate the degraded condition for Operability. Perform Method e. at the first available opportunity (i.e. first outage where intrusive inspection/repair can be performed within next 2 years).	Satisfactory Operability Evaluation required until inspection can be performed, otherwise Licensee shall comply with Tech Spec required actions for an INOP MOV until repaired.
All applicable High / Medium Risk GL96-05 MOVs with multiple design basis post-accident strokes (e.g. Open and Close) Category A (See Note 1)	Repair using Method e. at the next available refueling / maintenance outage (within 2 years).	

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All remaining applicable High and Medium Risk GL96-05 MOVs. Category B (See Note 1)	Perform Method e. within 2 years; OR Perform Method c. (diagnostic test) or Method d. (internal inspection) every 2 years until the issue is permanently repaired using Method e. within 2 RFO (4 years).	
All remaining applicable Low Risk GL96-05 MOVs. Category C (See Note 1)	Perform Method e. within 2 years; OR Perform Method c. (diagnostic test) or Method d. (internal inspection) every 2 years until the issue is permanently repaired using Method e. within 3 RFO (6 years).	
Applicable Critical Non-GL96-05 MOVs with symptoms of active stem-wedge connection degradation (i.e. UNSAT stem rotation check and/or unresolved diagnostic test anomalies)	Perform Method e. within 2 years (at Owners Discretion). AND Perform Method c. every 2 years until the issue is permanently repaired using Method e.	Sites should perform Operational Decision Making (ODM) to defer repair or justify operational risk of not repairing
Applicable Critical Non-GL96-05 Valves with no symptoms of stem/wedge connection degradation.	Perform Method e. within 8 years (at Owners Discretion); AND Perform Method c. every 2 years until the issue is permanently repaired using Method e.	Sites should perform Operational Decision Making (ODM) to justify operational risk of not repairing
Applicable GL96-05 MOVs which are no longer considered susceptible (i.e. Priority 5)	Perform Method b. (Stem Rotation Checks) in conjunction with established GL96-05 periodic diagnostic testing requirements.	Non-Intrusive Stem Rotation Checks provide an additional level of assurance that the threaded stem/wedge connection is structurally intact.
Note 1- Categories shown above correspond to those listed in NRC Letter to NEI, "Response From the Nuclear Regulatory Commission Regarding the Anchor Darling Double Disc Gate Valve Industry Resolution Plan", Dated July 31 2017		

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Attachment 11

NRC Letter to NEI Dated July 31 2017

Response from the Nuclear Regulatory Commission regarding the Anchor Darling Double Disc Gate Valve Industry Resolution Plan

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Attachment 11

July 31, 2017

Greg Krueger
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SUBJECT: RESPONSE FROM THE NUCLEAR REGULATORY COMMISISON REGARDING THE ANCHOR DARLING DOUBLE DISC GATE VALVE INDUSTRY RESOLUTION PLAN

Dear Mr. Krueger:

This letter is to acknowledge receipt of your letter dated July 14, 2017 (ADAMS Package Accession No. ML17209A018), as well as to provide confirmation of the Nuclear Regulatory Commission's (NRC's) understanding of topics raised in your letter and at the June 29, 2017, public meeting.

It is the NRC's understanding that the Nuclear Energy Institute (NEI) is coordinating an industry response, and a potential commitment to, an initiative to address the possibility of stem/disk separations in Anchor/Darling double-disc gate valves. The NRC also understands that the proposal for such actions is not complete, but it is likely to include the following:

1. Industry identification of the population of Anchor/Darling double-disc gate valves at each facility;
2. Determination of valves that are susceptible to stem/disk separation based on the ability of the valve actuator to cause wedge pin failure; and
3. Repair/replace susceptible valve internals with components that are not subject to this failure mode.

Additionally, the NRC understands that repair/replacement of valve internals will be prioritized based on risk and valve function as follows:

Category A – valves that are high or medium risk and traverse multiple times to perform their safety function. Repair next outage/within 2 years;

Category B – valves that are high or medium risk and only traverse once, open or closed, to perform their safety function. Repair at next outage or pass diagnostic test during the next outage and repair within 2 outages/4 years; and

Category C – valves that are low risk. Repair at next outage or pass diagnostic test during each of the next 2 outages and repair within 3 outages/6 years.

The NRC indicated that it would monitor the industry's efforts in developing a voluntary initiative to address these valves while the staff continues to develop a generic communication to address this issue in the absence of a suitable voluntary initiative with regulatory commitments.

With regard to the industry efforts to develop a voluntary initiative, the NRC seeks a better understanding of the following:

1. The industry commitment response strategy. The NRC seeks to understand whether each utility will commit to the potential initiative and when the NRC would be informed of such commitment. As noted in the July letter, industry is scheduled to communicate this to the NRC by August 4, 2017;
2. Whether the details of the initiative will be provided to NRC on the docket. If proprietary material is provided, it may be withheld from public disclosure in accordance with Title 10 of the *Code of Federal Regulations* 2.390, "Public inspections, exemptions, requests for withholding;" and
3. Whether the initiative, as provided to the NRC, would include:
    a. Proposed repair/replacement plan (i.e., what actions will be taken to repair the valves including the components to be replaced);
    b. Proposed schedule for repairs. As part of this response, NRC would need to understand industry's justification for including valves required to open to perform their safety function in Category B;
    c. Proposed methodology for determining valve risk ranking; and
    d. Proposed methodology for determining valve susceptibility (i.e., the method by which the susceptibility of the wedge pin failure will be determined).

The NRC currently does not have either a commitment that all plants will implement the initiative or a sufficient understanding of the information identified above which would determine the adequacy of the initiative. The NRC is currently developing a Bulletin to request information that would address the NRC's concerns. The Bulletin may be issued to all operating plants as early as mid-September. The staff anticipates that the type of information required to assess the need for further regulatory action would include the following items:

1. Identify the population of Anchor/Darling double-disc gate valves present at the facility. This would include providing relevant information such as size, system, and safety function (open/close) of the valve.
2. For each of the valves identified in item 1, provide the methodology and results of an analysis of the risk ranking of each valve (i.e., high, medium, low).
3. For each of the valves identified in item 2, provide the methodology and results of an analysis to determine whether each valve is susceptible to wedge pin failure.
4. For each of the valves identified in item 3, describe the repairs that have been completed or are planned and why those repairs are sufficient to address the issue under consideration.
5. For each of the valves identified in item 3, provide a schedule for accomplishing the proposed repairs and describe why the proposed schedule is acceptable.

In keeping with the principles of good regulation, if industry can effectively and efficiently address the overall safety concerns with the Anchor/Darling double-disc gate valves, the NRC will re-evaluate the need to pursue generic communication via Bulletin. In either case, the NRC will provide an independent review of industry's corrective actions for this issue.

If you have questions concerning this letter please contact John Lubinski of my staff at John.Lubinski@nrc.gov or 301-415-3298.

Sincerely,

/RA/

Brian E. Holian, Acting Director
Office of Nuclear Reactor Regulation

SUBJECT: RESPONSE FROM THE NUCLEAR REGULATORY COMMISISON REGARDING THE ANCHOR DARLING DOUBLE DISC GATE VALVE INDUSTRY RESOLUTION PLAN DATED: JULY 31, 2017

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