UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
OFFICE OF NEW REACTORS
WASHINGTON, DC 20555-0001

December 10, 2015

NRC INFORMATION NOTICE 2015-13: MAIN STEAM ISOLATION VALVE FAILURE EVENTS

ADDRESSEES

All holders of an operating license or construction permit for a nuclear power reactor under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those that have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

All holders of and applicants for a power reactor early site permit, combined license, standard design certification, standard design approval, or manufacturing license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of recent operating experience involving main steam isolation valve (MSIV) failures at U.S. nuclear power plants. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

LaSalle County Station, Unit 2

The MSIVs at LaSalle Unit 2 are Wye-pattern[1] globe valves, model 1612JMMNTY, manufactured by Rockwell International (now owned by Flowserve); the valves are equipped with spring return air actuators.

On August 5, 2014, the Unit 2 'C' inboard MSIV failed shut because of stem-to-disk separation. Exelon Generation Company, LLC, the licensee for LaSalle, Unit 2, performed inspections of the valve internals that revealed that the stem-to-disc separation was the result of a failure mechanism that was previously identified at another plant and by the valve vendor. Specifically, the failed valve stem and stem-disk were constructed of different materials with different thermal

[1] The terms "Y" pattern and "Wye-pattern" are used somewhat interchangeably for globe valves. For the MSIVs at LaSalle Unit 2, the name the manufacturer uses is Wye-pattern. This terminology is consistent with the February 10, 2015, NRC Inspection Report, referenced in the description of circumstances for LaSalle.

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coefficients. In addition, the thread size was insufficient to maintain the appropriate preload of the threaded connection between the valve stem the stem disk.

Over a number of operating cycles, uneven heating of the stem and stem-disk resulted in a fracture of the stem, and a loss of preload on the threaded connection. Continued operation introduced fretting wear to the stem threads with the combined effect resulting in the stem-to-main disk separation.

In 1989, the valve vendor addressed this failure mechanism by modifying the valve design to increase the thread size, replacing the stem-disk anti-rotation pin with a welded collar, and adding a Belleville washer to maintain the stem to stem-disk threaded connection preload.

In 2003, the licensee identified the need to monitor the condition of the 16 MSIVs installed in LaSalle, Units 1 and 2. In 2007, the licensee installed the vendor-recommended modification in 7 of the 16 MSIVs at the LaSalle site—3 for Unit 1 and 4 for Unit 2. In 2008, in an attempt to consolidate maintenance activities, the licensee deferred installation of the upgrade on the remaining valves until the valves required corrective maintenance. The licensee later determined that the process for deciding to defer the upgrade for the remaining valves was deficient.

Following the MSIV failure in Unit 2 in August 2014, the licensee carried out corrective actions that included the installation of the vendor-recommended upgrade to the remaining MSIVs, per the manufacturer's recommendation. At this time, all of the MSIVs in both units have been upgraded.

To address the deficiency associated with deferring the installation of the upgraded design on all the MSIVs, the licensee put in place a new risk management process, and reviewed previously made decisions to defer other configuration changes using the new decisionmaking process.

Licensee Event Report (LER) 3742014001, dated October 3, 2014 (Agencywide Documents Access and Management System [ADAMS] Accession No. ML14276A264) provides additional details. Further information also appears in NRC Inspection Reports 05000374/2014004 and 05000374/2014005, dated October 31, 2014 (ADAMS Accession No. ML14304A708), and February 10, 2015 (ADAMS Accession No. ML15042A250). ADAMS is accessible through the NRC's public Web site at http://www.nrc.gov, under NRC Library.

Shearon Harris Nuclear Power Plant, Unit 1

The MSIVs at Shearon Harris Nuclear Power Plant (hereafter referred to as "Harris") are "Y" pattern globe valves, model 1612GJMMTY, manufactured by Rockwell International (now owned by Flowserve). They are bi-directional, and of a balanced design that results in a low pressure drop. The MSIVs are operated by an air-to-open, spring-to-close actuator model SA-A032 manufactured by R.A. Hiller (now owned by Rotork).

On April 21, 2012, Carolina Power and Light Company (now Duke Energy Progress), the licensee for Harris, performed a normal shutdown for refueling. During this time, the "B" and "C" MSIVs failed to close from the main control board. As directed by the Harris abnormal operating procedure, instrument air was isolated from the air-to-open actuators. The "B" MSIV closed in 1 hour and 14 minutes (37 minutes after isolating instrument air), and the "C" MSIV closed

in 4 hours and 37 minutes (4 hours and 7 minutes after isolating instrument air). The NRC sent a special inspection team to the site on May 7, 2012.

Harris has developed an "Air-Operated Valve Reliability Program" that patterns itself after the Joint Owners Group (JOG) Air-Operated Valve Program (ADAMS Accession No. ML010950310) that was developed by the nuclear industry to supply recommended requirements for ensuring that air-operated valves (AOVs) are capable of meeting their intended safety function. The JOG AOV program classifies valves that are important to safety into two categories. Category 1 AOVs are defined as those valves both safety-related and nonsafety-related, that serve an active function and have high safety significance. Category 2 AOVs are defined as safety-related and active, but do not have a high safety-significance. Valves classified as Category 1 require periodic diagnostic testing.

In 2001, the licensee incorrectly classified the Harris MSIVs as Category 2 AOVs based on a probabilistic safety analysis (PSA) that considered only the containment isolation function of the MSIVs. In 2003, the licensee updated their PSA model and recognized that the MSIVs were also important for steam generator (SG) tube rupture and main steam line break design-basis events. The 2003 PSA update concluded that the MSIVs meet the definition for Category 1 valves because they are safety-related, active components that have a high safety-significant function. However, the licensee did not update their AOV program to reclassify the Harris MSIVs as Category 1.

During a review of maintenance history, the licensee found that, since 1986, the valves had not been disassembled for corrective maintenance, nor was there a periodic preventative maintenance task to visually inspect the condition of the valve internals. The licensee determined that the root cause for the MSIVs' failure to close was long-term corrosion and oxidation of the valve piston rings—a condition that could have been detected earlier with proper periodic maintenance. The corrosion caused the piston rings to swell, resulting in the rings expanding outward against the body bore. The contributing causes identified by the licensee included the lack of appropriate diagnostic testing, and several missed opportunities to identify the valve degradation before the April 2012 failures.

As corrective actions to prevent recurrence, the licensee replaced the valve piston rings with upgraded rings made of material less susceptible to corrosion, and implemented a diagnostic testing program of the MSIVs.

Additional details are given in LER 4002012001, dated June 20, 2012 (ADAMS Accession No. ML12172A382). Further information appears in NRC Special Inspection Report 05000400/2012008, dated July 12, 2012, (ADAMS Accession No. ML12194A281) and NRC Inspection Report 05000400/2012009, dated November 1, 2012, (ADAMS Accession No. ML12306A439).

Vogtle Electric Generating Plant, Unit 1

The MSIVs at Vogtle Electric Generating Plant, Unit 1 (hereafter referred to as "Vogtle, Unit 1"), are hydraulically opened Rockwell Equiwedge (double wedge) gate valves, with an Edward A290 hydraulic actuator. The stem of the MSIV is manufactured of ASME SA564 Grade 630 PH heat treated to 1,100 degrees Fahrenheit (F) (593 degrees Celsius (C)), which is a 17–4 PH (precipitation hardening) age-hardenable martensitic stainless steel.

During a Vogtle, Unit 1 startup on October 7, 2012, plant operators noticed that the differential temperatures across the four reactor coolant system loops were not balanced. The reactor was shut down to cold shutdown conditions for troubleshooting. Southern Nuclear Operating Company, Inc., the licensee for Vogtle, Unit 1, determined that the stems for both the loop 2 and 3 outboard MSIVs were sheared approximately 2 inches (5 centimeters) above the stem-to-disc connection point.

The licensee determined that the root cause of the MSIV failures was temperature aging embrittlement of the stem material. The stem material became thermally embrittled over time due to the normal operating temperature (above 500 degrees F or 260 degrees C) of the steam lines and material service age. IN 1992-60, "Valve Stem Failure Caused by Embrittlement," dated August 20, 1992, provides additional operating experience on embrittlement. The contributing causes identified by the licensee were inadequate procedural guidance for valve operation and response practices and strategy in the event of a bound disc. Specifically, the licensees' procedures did not give instructions to limit the magnitude of force applied to the valve stems while attempting to open the MSIVs.

The licensee took corrective actions, including replacing the valve stems for the affected MSIVs, and performing ultrasonic testing for the remaining Unit 1 MSIVs to verify that the valve stems were intact.

Additional details are given in LER 4242012005, dated November 29, 2012 (ADAMS Accession No. ML12339A190). Further information appears in NRC Integrated Inspection Reports 05000424/2012005, dated March 14, 2013 (ADAMS Accession No. ML13073A427) and 05000425/2012005, dated February 1, 2013, (ADAMS Accession No. ML13032A277).

St Lucie Plant, Unit 1

The MSIVs at Saint Lucie Plant (hereafter referred to as "St Lucie") are air-operated Schutte and Koerting, Co (now Ametek, Inc.) valves, model M70-00656-V.

In 2012 in support of an extended power uprate, Florida Power and Light Company, the licensee for St Lucie, replaced and upgraded the internals of the valves to ensure they could withstand the impact stresses associated with spurious closure at the higher steam velocities. However, the existing valve bodies were retained. A new electro-hydraulic actuator (Enertech) replaced the previous pneumatic actuator. A complicated project management approach was required to coordinate the various engineering, design, quality assurance services, and field installation services provided by several different contractors.

On March 12, 2013, Unit 1 tripped on a thermal margin/low pressure transient signal. After the trip, the licensee determined that with the MSIV positioned to "OPEN," the valve did not pass enough flow to maintain steam header pressure, and that steam header pressure could only be maintained with the MSIV bypass valve in service. The licensee cooled down the Unit 1 reactor to inspect the MSIVs. An internal inspection revealed that the "B" MSIV had a spindle-to-disc separation. The "A" MSIV was also damaged, but not to the point of spindle-to-disc separation.

The licensee determined that the new tail links installed as part of the 2012 modification did not meet design specifications. They were oversized. The oversized tail links did not allow the valves to fully backseat, leaving the disc partially in the flow stream when the valve was in the open position. This exposed the valves to unintentional dynamic loading, which ultimately resulted in the failure of internal parts.

The licensee identified two root causes. The first was that the tail links did not meet the design specification dimensional drawings. Shop inspections and dimensioning and field quality assurance inspections did not identify the tail link discrepancies. The second root cause was that the engineering change package did not verify that the modified valves would open fully to the backseat. Although multiple engineering groups reviewed the package, it did not contain specific instructions to assure the valve was fully open to the backseat.

The licensee took corrective actions that included restoring both MSIV tail links to design specification dimensional requirements, revising MSIV maintenance procedures to ensure the valves open completely following repair activities, verifying the acceptability of all post-modification requirements provided by the MSIV contractor, and providing training about this event for maintenance and engineering personnel.

Additional information is given in LER 3352013001, dated May 10, 2013 (ADAMS Accession No. ML13142A200). Further information is available in NRC Integrated Inspection Report 05000335/2013003 and 05000389/2013003, dated July 30, 2013 (ADAMS Accession No. ML13211A161).

BACKGROUND

MSIVs have safety functions that help provide assurance of the safe operation of a nuclear power plant. In particular, MSIVs are located in each main steam supply line downstream of the main steam safety valves and power-operated relief valves. They are fully open during power operations and typically designed to close within 3 to 5 seconds to isolate steam flow from either direction. MSIVs are containment isolation valves which have a fail-shut safety function. In addition, MSIVs are designed to mitigate SG tube rupture and main steam line breaks both upstream and downstream of the MSIVs.

The quality assurance criteria in 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” apply to the design, manufacture, construction, and operation of safety-related structures, systems, and components (SSCs), including MSIVs. For example, Criterion III, “Design Control,” in 10 CFR Part 50, Appendix B, states, in part, that measures shall be established for the selection and review for suitability of application of materials, parts, equipment, and processes that are essential to the safety-related functions of SSCs. In addition, licensees are required by 10 CFR 50.65, “Requirements for monitoring the effectiveness of maintenance at nuclear power plants,” to monitor the performance of SSCs in a manner sufficient to give reasonable assurance that they are capable of fulfilling their intended functions.

Generic Safety Issue 158, "Performance of Safety-Related Power-Operated Valves Under Design Basis Conditions," was identified by the NRC after reactor operating experience and research results on power-operated valves (POVs) indicated that testing methods in use at the time were insufficient to demonstrate consistent performance of these valves under design-basis conditions. Regulatory Issue Summary (RIS) 2000-003, “Resolution of Generic Safety Issue 158: Performance of Safety-Related Power-Operated Valves under Design Basis Conditions” (ADAMS Accession No. ML003686003) provides a summary of the NRC’s historical concerns associated with POVs, including motor-operated valves (MOVs), solenoid-operated valves (SOVs), AOVs, and hydraulically operated valves (HOVs). RIS 2000-003 includes an attachment that lists attributes of a successful POV design capability and long-term periodic verification program. For example, one attribute of a successful POV program is to apply

feedback from plant-specific and industry information, including test data, to all applicable safety-related POVs.

RIS 2000-003 describes the program established by an industry group—the Joint Owners Group on Air-Operated Valves (JOG AOV)— to ensure that AOVs are capable of meeting their intended safety-related/risk-significant functions. The JOG AOV program offers guidance to verify valve performance at design conditions and long-term periodic verification of safety-related AOVs categorized as high risk-significant. For safety-related, low-risk-significant AOVs and AOVs that are not safety-related but are determined to be high risk-significant, the JOG AOV program also provides guidance for verifying valve functionality. The NRC documented its comments on the JOG AOV program and its implementation in a letter dated October 8, 1999 (ADAMS Accession No. ML020360077). Although the program was noted to have some limitations, the NRC staff recognized that industrywide implementation of this program would achieve a uniform level of consistency that would provide increased confidence in the design-basis capabilities of high risk-significant AOVs in nuclear power plants. As indicated in RIS 2000-003, plant-specific and industry information related to AOVs could be applied to other POVs (such as MSIVs with HOV actuators).

Related NRC Generic Communications

Additional operating experience addressing MSIV issues is available in the following NRC Generic Communications:

- Bulletin 1971-01, “Niagara Mohawk Power Corporation,” dated November 24, 1971
- IN 1981-28, “Failure of Rockwell-Edward Main Steam Isolation Valves,” dated September 3, 1981
- IN 1982-23, “Main Steam Isolation Valve (MSIV) Leakage”, dated July 16, 1982
- IN 1983-54, “Common Mode Failure of Main Steam Isolation Nonreturn Check Valves,” dated August 11, 1983
- IN 1985-21, “Main Steam Isolation Valve Closure Logic,” dated March 18, 1995
- IN 1985-84, “Inadequate Inservice Testing of Main Steam Isolation Valves,” dated October 30, 1985
- IN 1986-81, “Broken Inner-External Closure Springs on Atwood & Morrill Main Steam Isolation Valves,” dated September 15, 1986
- IN 1986-81 S1, “Broken External Closure Springs on Atwood & Morrill Main Steam Isolation Valves,” dated January 11, 1988
- IN 1988-51, “Failures of Main Steam Isolation Valves,” dated July 21, 1988
- IN 1988-59, “Main Steam Isolation Valve Guide Rail Failure at Waterford Unit 3,” dated August 9, 1988
- IN 1990-79,” Failures of Main Steam Isolation Check Valves Resulting in Disc Separation,” dated December 20, 1990
- IN 1994-08, “Potential for Surveillance Testing to Fail to Detect an Inoperable Main Steam Isolation Valve,” dated February 1, 1994
- IN 1994-44, “Main Steam Isolation Valve Failure to Close on Demand Because of Inadequate Maintenance and Testing,” dated June 16, 1994
- IN 1995-53, “Failures of Main Steam Isolation Valves as a Result of Sticking Solenoid Pilot Valves,” dated December 1, 1995

DISCUSSION

The operating experience in this IN, specifically the key contributors, demonstrates that deficiencies in licensee processes and procedures can contribute to the failure of MSIVs. For example, at LaSalle, a deficient process for deferring maintenance led to an MSIV failure. At Harris, a lack of diagnostic testing and several missed opportunities to identify MSIV degradation as a result of misclassifying MSIVs contributed to the failure of MSIVs to shut. At Vogtle, adequate procedural guidance to minimize the effects of thermal embrittlement of valve stems and other susceptible components (including minimizing the applied forces, monitoring and trending valve performance, identifying age-related degradation through periodic visual inspections, and performing early corrective or preventative maintenance actions) might have prevented the MSIV failures. Finally, at St Lucie, deficiencies in quality assurance processes during the design phase compounded by deficient post-modification test and engineering change processes contributed to MSIV degradation.

In RIS 2000-003, the NRC stated that it would continue to work with industry groups on an industrywide approach to provide timely, effective, and efficient resolution of the concerns regarding POV performance. The NRC continues to monitor licensees' activities and operating experience to ensure that POVs are capable of performing their specified safety-related functions under design-basis conditions. The NRC will continue to evaluate industry performance in this area to include inspection results and operating experience to ensure adequate protection of the public health and safety.

The NRC expects that addressees will review the information in this IN for applicability and consider actions, as appropriate, to avoid similar problems. Suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

CONTACT

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contacts listed below or to the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Note: NRC generic communications may be found on the NRC's public Web site, http://www.nrc.gov, under NRC Library/Document Collections.

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