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

February 26, 2018

NRC INFORMATION NOTICE 2018-02: TESTING AND OPERATIONS-INDUCED DEGRADATION OF 3-STAGE TARGET ROCK SAFETY RELIEF VALVES

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, or manufacturing license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." All applicants for a standard design certification, including such applicants after initial issuance of a design certification rule.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to make addressees aware of recent operating experience related to Target Rock Model 0867F 3-stage safety relief valves (SRVs). Operating experience has shown that limited flow testing of these valves can result in damage to internal valve components. This damage can be exacerbated when the valves are re-installed in the plant following testing and subjected to normal plant operating conditions, including steam flow-induced vibrations. The resultant internal damage has affected valve operability at low steam pressure. It is expected that addressees will review the information for applicability to their facilities 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.

DESCRIPTION OF CIRCUMSTANCES

Pilgrim Nuclear Power Station

On February 8, 2013, and January 27, 2015, severe winter storms caused loss of offsite power (LOOP) events at Pilgrim Nuclear Power Station (Pilgrim). These LOOP events resulted in complicated reactor trips, with operators using various systems to lower plant pressure. In each event, operators noted an unexpected plant response from one of the plant's four main steam SRVs (Target Rock Model 0867F 3-stage valves) while using the valves to reduce pressure. During the 2013 event, the "A" SRV did not properly open when it was manually actuated at low plant pressure (i.e., below 300 psig). Similarly, during the 2015 event, the "C" SRV did not properly open when manually actuated at low plant pressure. In each case, operators were able to control plant pressure by manually cycling the "B" and "D" SRVs.

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Subsequent to the plant reaching cold shutdown following the 2015 event, the licensee removed SRVs "A" and "C" from the plant and sent them—along with a third valve which had been removed from the plant in 2013—to an offsite testing facility for limited flow testing. The valves were replaced with spare Model 0867F SRVs, and the plant restarted on February 8, 2015. During limited flow testing at the offsite test facility, the valves consistently opened when exposed to steam pressure at the lift setpoint (approximately 1100 psig) but did not fully close. The valves were disassembled to allow inspection of the main stage internal components. This inspection revealed: (1) damage to the threaded connection between the valve stem and the main piston caused by axial displacement of the main piston; (2) fretting damage to the walls of the main cylinder caused by impingement of the main piston rings; (3) loss of torque on the lock nut and deformation of its locking tab; and (4) shortening of the free height of the main valve spring. The damaged threads and axial displacement of the main piston created a gap between the stem and piston shoulders, allowing the piston to wobble and/or rotate within the cylinder. During operation, plant vibrations caused the rings on the loose piston to fret against and eventually wear grooves in the walls of the main cylinder. These grooves affected piston movement and valve operation at low plant pressure during the 2013 and 2015 Pilgrim events. On March 16, 2015, Curtiss Wright, parent company of Target Rock, issued a report in accordance with 10 CFR Part 21, "Reporting of Defects and Noncompliance" (Part 21), indicating that Model 0867F 3-stage SRVs are susceptible to internal damage that is caused by limited flow testing (Agencywide Document and Management System (ADAMS) Accession No. ML15077A422).

The NRC chartered a special inspection team in February 2015 to evaluate the licensee's performance in response to the LOOP event on January 27, 2015. Following the inspection, NRC staff issued a finding of low to moderate (White) significance for the licensee's failure to take appropriate corrective actions for a significant condition adverse to quality associated with the "A" SRV during the 2013 LOOP. The licensee's failure to take corrective action to preclude repetition resulted in the failure of the "C" SRV during the January 27, 2015, LOOP event. The NRC staff subsequently published a special inspection report on May 27, 2015 (ADAMS Accession No. ML15147A412). On September 1, 2015, the NRC staff issued the final determination and a notice of violation to Pilgrim (ADAMS Accession No. ML15230A217).

During an April 2015 refueling outage, Pilgrim replaced all four of their Model 0867F 3-stage SRVs with Model 7567F 2-stage Target Rock SRVs. Curtiss Wright issued interim 10 CFR Part 21 reports for Model 0867F SRVs on May 1, 2015 (ADAMS Accession No. ML15134A017), and June 30, 2015 (ADAMS Accession No. ML15187A172). In these reports, the vendor described how valve internals could be damaged by excessive velocities and impact forces resulting from limited flow testing. In the June 2015 report, Target Rock described the root causes of internal valve damage, along with its plan for redesigning the valve and its testing requirements in order to limit future testing and operations-induced damage. Target Rock also indicated that three other nuclear plants at two sites had Model 0867F 3-stage SRVs installed. The two facilities are the Edwin I. Hatch Nuclear Plant (Hatch), Units 1 and 2, with 11 Model 0867F valves installed in each unit, and the James A. Fitzpatrick Nuclear Power Plant (Fitzpatrick), with three Model 0867F valves installed out of a total of 11 SRVs.

Edwin I. Hatch Nuclear Plant, Units 1 and 2

During a February 2016 refueling outage, Hatch, Unit 1, removed its 11 3-stage SRVs for lift setpoint testing required under technical specification surveillance requirement 3.4.3.1 and the licensee's inservice testing program. The valves were tested at the NWS Technologies testing

facility on March 30, 2016. All of the valves properly opened during limited flow testing, but three of the 11 valves failed to properly close following their second cycling on the test stand.

Two of the three valves that failed to properly close were disassembled, at which time inspectors noted severe internal degradation similar to that found in the SRVs removed and tested by Pilgrim. The licensee for Hatch contracted an independent engineering firm to evaluate any impact of the damage on valve operability. The engineering analysis concluded that the potential for valve binding in the open direction was low despite the damage noted in the Hatch, Unit 1, SRVs. The analysis noted that the fretting wear grooves created by the main piston rings in the main guides of the Hatch, Unit 1, valves were not as steep and deep as those in the Pilgrim valves. Based on the valve condition and analysis, the licensee determined that the Hatch, Unit 1, SRVs would have been able to perform their design function to open and close over their operational range (down to 150 psig) when installed in the plant, and that the SRVs still installed in Hatch, Unit 2, were operable but in a degraded/nonconforming condition due to the potential for in-service vibration wear.

The NRC dispatched a special inspection team to Hatch on April 4, 2016. The team reviewed all aspects of the Hatch operating experience, as well as the licensee's rationale for the actions it took following review of the Pilgrim events and the vendor's Part 21 reports. The NRC inspectors identified no significant performance deficiencies. Hatch Unit 2 performed a six day mid-cycle maintenance shutdown on May 21, 2016, (14 months into their 24-month operating cycle) to replace, test, and inspect the 11 SRVs. Both Hatch Units 1 and 2 were returned to operation with refurbished 3-stage Target Rock SRVs that had undergone the vendor recommended modified testing and inspection requirements discussed in the June 30, 2015, Part 21 interim report. This included removing the requirement to perform a final limited flow cycling of the valve upon reassembly and checking installed valves for evidence of de-shouldering by measuring the gap between the stem and main piston shoulders. The special inspection report was published on June 10, 2016 (ADAMS Accession No. ML16162A631).

James A. Fitzpatrick Nuclear Power Plant

The licensee for Fitzpatrick removed two of its three Model 0867F 3-stage Target Rock SRVs in June and July of 2016. One of these valves exhibited degradation similar to that seen at Pilgrim and Hatch, although the fretting wear in the main cylinder was not as severe. The third 3-stage SRV was replaced in January 2017 and did not exhibit any degradation similar to Pilgrim and Hatch. All three 3-stage SRVs were replaced with 2-stage Target Rock SRVs.

Vendor Corrective Actions

In its June 30, 2015, interim Part 21 report, Target Rock recommended that licensees with Model 0867F 3-stage SRVs installed in their plants assess the valves for the potential of fretting-induced damage and inspect valves as needed. The impacted licensees (Hatch and Fitzpatrick) responded as described above. The interim Part 21 report also recommended a revised method for performing limited flow testing on Model 0867F 3-stage SRVs intended for installation at a plant. The revised method involved additional verifications of the integrity of valve internals following limited flow valve cycling. Valves are to be checked for thread damage, stem to piston shoulder gap, main spring height, and lock nut torque. Following satisfactory inspection and retorqueing of the valve internals, the valve can be leak checked, then reinstalled in the plant without the need to cycle the valve again via limited flow testing. Much of the previous valve damage that led to operational challenges was initiated by this final valve cycling

prior to installation, which could cause the main piston and lock nut to lose torque and become loose on the stem. Valves were being reinstalled in this condition without any further inspection, creating the conditions for fretting-induced damage to the main cylinder wall.

On February 3, 2017, Target Rock issued a final Part 21 report (ADAMS Accession No. ML17039A569) to inform its customers of design changes to the Model 0867F 3-stage SRV. Target Rock evaluated the effectiveness of the changes during limited and full-flow valve testing between August and November of 2016. Target Rock recommends this new design as a long-term solution to all utilities that currently have installed or plan to install Model 0867F 3-stage SRVs in their plants.

BACKGROUND

Valve Design and Actuation

Figure 1 of this document shows a Target Rock Model 0867F 3-stage SRV in the closed position. Additional arrows and labels have been added to show location of the lock nut, lower piston ring, stem shoulder, and gagging device.

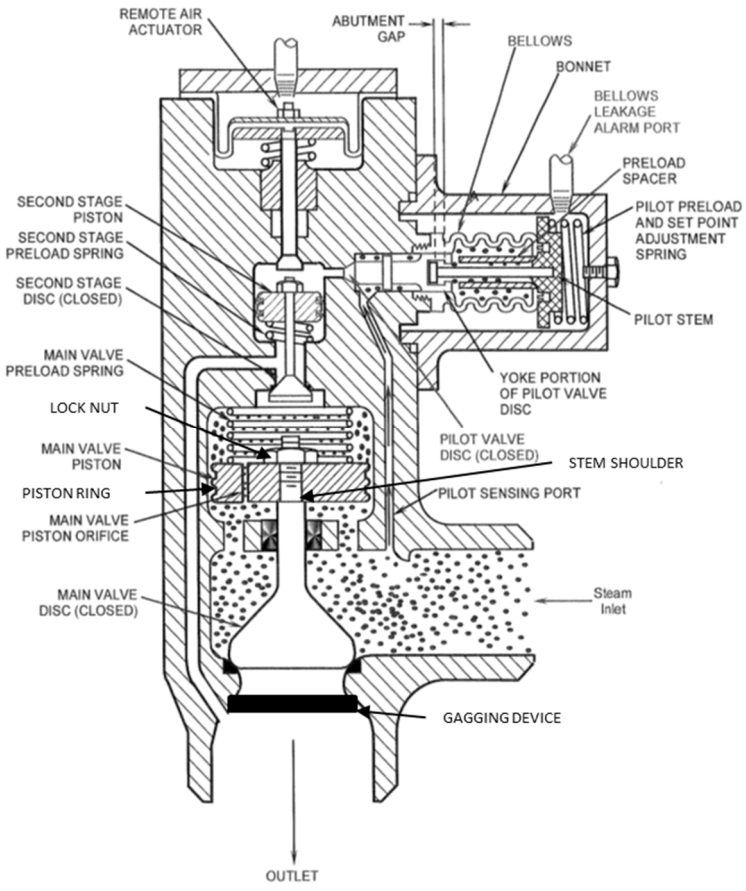

Figure 1: Target Rock Model 0867F 3-Stage SRV

When installed in the plant, the SRV actuates in the pressure relief mode by sensing system pressure at the pilot valve. When pressure reaches the valve setpoint, the metal sensing

bellows expands against the pilot preload spring and opens the pilot valve. This allows steam from inside the bellows to act on top of the second stage piston. The steam pressure causes the second stage piston to compress the second stage preload spring, which unseats the second stage disc. This relieves steam pressure from the top of the main piston through a vent path to the SRV outlet. When pressure is relieved from the top of the main piston, system pressure acting on the underside of the piston through orifices drilled in the main guide is enough to overcome the closing force of the main valve spring. The main piston is threaded onto the stem of the main disc. As the piston pulls the stem upward in its cylinder, the main disc unseats and pops open, thus relieving main steam pressure through the SRV tailpipe (outlet). During the Pilgrim events, SRVs were being used at lower plant pressures in pressure control mode. In this mode, operators manually open the valves from a switch in the control room, as needed, to lower plant pressure. The switch sends a signal to the solenoid, which moves the remote air actuator to unseat the second stage disc, causing the main piston to reposition and open the main disc, as described above.

Root Cause and Method of Damage

In its initial and interim Part 21 reports, Target Rock concluded that valve internal degradation is initiated during limited flow testing at offsite testing facilities. Limited flow testing of the Model 0867F 3-stage SRV exposes the valve internals to excessive velocities and impact forces. The dynamic loads during testing can far exceed those which the valves experience during an in-plant actuation. This is mainly due to the presence of the gagging device, which is a plate with a small orifice inserted just downstream of the main disc to block off most of the steam flow (see Figure 1 of this document). The gag is necessary to ensure sufficient inlet pressure to fully open the valve in testing. It also minimizes the amount of potentially radioactive steam exhausted from the valve during testing. However, by blocking the exhaust path through the valve outlet, the gag causes a reaction force with the underside of the main disc as the valve begins to open. The added force caused by differential pressure across the main piston creates a higher than normal opening force on the main valve assembly. This extra opening force causes the main piston to reach a higher velocity upon valve actuation, which results in excessive impact force when the main spring becomes fully compressed and arrests valve motion. The impact force leads to damage to valve internal components, such as that discovered when valves from Pilgrim, Hatch, and Fitzpatrick were disassembled.

Degradation to valve internals—such as plastic deformation of valve threads, loss of lock nut torque, and de-shouldering of the stem and main piston—allows the piston to wobble and/or rotate inside its cylinder. When a valve in this condition is reinstalled in the plant, steam flow-induced vibrations can cause the main piston rings to fret against the cylinder liner and form grooves over time. If these grooves become deep enough, and develop a steep ramp angle, they can impede valve motion when the damaged valve is actuated (see Figures 2 and 3 of this document). The likelihood of impeding valve motion is greater at low plant pressures, where the differential pressure across the main piston is less. Fretting can also cause wear on the piston rings themselves, allowing steam to leak, which further impacts valve actuation. Finally, a shortened main spring can lead to lack of sufficient driving force to reseat (close) the SRV following actuation.

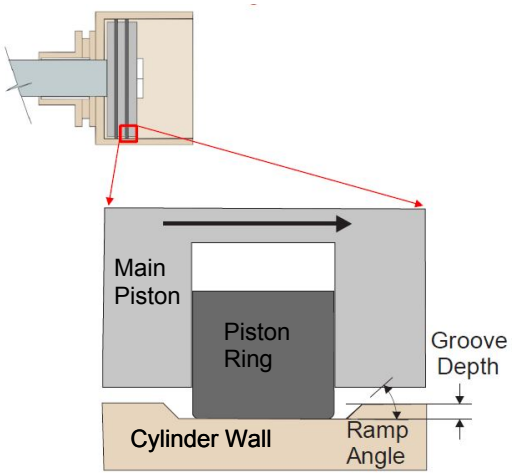

Figure 2: Expanded Diagram of Groove Formed by Piston Ring Fretting

Figure 3: Photo of Grooves Caused by Fretting of Cylinder Wall

Description of Valve Redesign

In 2016, Target Rock implemented design changes on its Model 0867F 3-stage SRVs that reduce main piston velocity and impact forces during limited flow testing. The design changes slow the rate at which steam flows into the underside of the main piston upon valve actuation. This, in turn, lowers the driving force behind the main piston, which slows its velocity during actuation and subsequently reduces impact forces when valve motion is arrested. The design changes also include a modification to the primary pilot seat in order to ensure that valve actuation times continue to satisfy American Society of Mechanical Engineers *Boiler and Pressure Vessel Code* requirements.

DISCUSSION

In the design of boiling water reactors, main steam SRVs support safety functions of both the pressure relief system and the emergency core cooling system (ECCS). In the pressure relief system, SRVs lift at their design setpoints to prevent overpressurization of the nuclear system. This protects the nuclear system process barrier from failure, which could result in the uncontrolled release of fission products. In the ECCS, certain SRVs will lift upon failure of the high pressure coolant injection system in order to reduce plant pressure and allow the low pressure ECCS to protect the reactor during a small break loss of coolant event.

Target Rock SRVs have been in use in the nuclear industry in the United States for several decades. The original SRV was a 3-stage model introduced in the early 1970s. Reliability issues with this model led to the introduction of a 2-stage model in the mid-1970s. The 2-stage SRVs were susceptible to setpoint drift caused in part by corrosion bonding of the pilot valve seat and disc. Target Rock reintroduced the 3-stage SRV in 1998, and modified the design again in 2008 with the expectation that users of the valve would convert back to the 3-stage model based on improved setpoint performance.

Since 2011, there have been anecdotal instances in which Model 0867F valves were inspected during testing and found to have internal damage, such as grooves worn into their main cylinders. However, the primary cause of operability issues for Model 0867F valves between 2011 and 2015 was pilot valve leakage, which is a well-known and monitored phenomenon.

Increased scrutiny following inoperability of Pilgrim's "C" SRV during the plant's complicated scram in 2015 led to the discovery of more severe internal degradation of valve internals.

Target Rock took action to notify the industry of the operating experience at Pilgrim using the process defined in 10 CFR Part 21. As they identified the root cause of valve damage and operational failures, Target Rock updated stakeholders with interim reports which recommended improved limited flow testing techniques, and notified industry of the availability of an improved valve design.

CONTACT

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

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Note: NRC generic communications may be found on the NRC public Web site, https://www.nrc.gov, under NRC Library.

NRC INFORMATION NOTICE 2018-02, "TESTING AND OPERATIONS-INDUCED DEGRADATION OF 3-STAGE TARGET ROCK SAFETY RELIEF VALVES,"
DATED: February 26, 2018

ADAMS Accession No.: ML18029A741 ***concurred via e-mail** **CAC/EPID: A11008/L-2017-CRS-0058**

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