UNITED STATES
NUCLEAR REGULATORY COMMISSION
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April 12, 2019

MEMORANDUM TO: Ho K. Nieh, Director
Office of Nuclear Reactor Regulation

FROM: Craig G. Erlanger, Director ***/RA/***
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

SUBJECT: TARGET ROCK SAFETY RELIEF VALVE SETPOINT DRIFT ISSUE – DOCUMENTATION OF INTEGRATED RISK-INFORMED DECISIONMAKING PROCESS IN ACCORDANCE WITH THE OFFICE OF NUCLEAR REACTOR REGULATION OFFICE INSTRUCTION LIC-504 (EPID L-2018-LRL-0001)

The U.S. Nuclear Regulatory Commission (NRC) staff performed a risk-informed evaluation of the Target Rock safety relief valve (SRV) setpoint drift Technical Specification (TS) compliance issue. The NRC staff recognizes that other agency processes exist to address the TS compliance issue (i.e., enforcement); however, staff elected to use the guidance in the Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-504, Revision 4, "Integrated Risk-Informed Decision-Making Process for Emergent Issues," dated May 30, 2014,[1] to supplement other processes by adding a decisionmaking structure and formal documentation. The purpose of this memorandum is to document the staff's risk-informed evaluation of the issue, the potential agency options, and the recommended path forward based on information available as of April 12, 2019.

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1 Available in the Agencywide Documents Access and Management System (ADAMS) under Accession No. ML14035A143.

1.0 EXECUTIVE SUMMARY

Target Rock SRVs are currently installed in a majority of the U.S. boiling-water reactors (BWRs) and are used to prevent overpressurization of the reactor coolant system (RCS) during abnormal operational transients. Target Rock SRVs have two main designs: two-stage and three-stage. Over the past decades, two-stage Target Rock SRVs have opened at pressures above the TS requirements. Several BWRs have a majority of SRVs drifting beyond the TS limits. Based on the historic test data, SRV setpoint drift has typically varied between 3 to 10 percent (versus 3 percent typically allowed by TSs), with the highest observed case having a drift of 18.5 percent.

This risk-informed evaluation focuses on addressing the recurring issue of two-stage Target Rock SRVs opening above the TS-required setpoints. Because it is occurring at a number of BWRs, this is considered to be a generic issue. This issue was last addressed by NRC in 1999 in the closeout of Generic Safety Issue (GSI) B-55, "Improved Reliability of Target Rock Safety Relief Valves" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML993620214).

Although licensees have implemented a range of corrective actions (e.g., changed the pilot valve disc material, applied platinum coatings to the pilot valve disc, replaced the two-stage Target Rock SRVs with the improved three-stage Target Rock SRVs, changed the TS-required setpoints, etc.), several BWR licensees continue to experience large numbers of surveillance test failures. These failures have resulted in recurring licensee event reports (LERs) documenting conditions prohibited by TSs and subsequent inspection findings or violations of low safety significance.

The NRC staff's risk-informed evaluation, contained in this document, shows that immediate actions (e.g., shutdown of plants) are not required. However, the staff has concerns with the apparent recurring noncompliance with TSs. The staff considered the following actions for resolving the issue: (1) order, (2) different types of generic communications, (3) industry initiative, (4) no action (status quo), and (5) enforcement discretion. On September 12, 2018,[2] and February 14, 2019,[3] the NRC staff engaged the BWR Owners' Group (BWROG), affected licensees, and other stakeholders in public meetings to understand the industry's status on the technical and compliance issues, proposed solutions, and appropriate schedule for resolution. The BWROG representatives proposed a multi-faceted approach to resolve the issue, including a hardware solution and a licensing solution via a Technical Specifications Task Force (TSTF) traveler. The staff supports the BWROG's current path to resolution with an appropriate level of regulatory action and oversight. As the BWROG finalizes the path to resolution, the NRC staff recommends further engagement with the BWROG, affected licensees, and other stakeholders at future public meetings.

The NRC staff will periodically brief the NRR Executive Team (ET) to effectively manage the level of effort of this issue commensurate with its safety significance and considerable margins to the NRC's safety goals. These will include clear milestones, forecasted staff hours, and tracking cumulative hours spent (inspection and licensing). If a TSTF traveler is approved for a licensing solution, the staff will advise the NRR ET through workload management activities on

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2 The meeting summary is available in ADAMS under Accession No. ML18267A016.
3 The meeting summary is available in ADAMS under Accession No. ML19050A009.

efficiencies to improve upon the 1-year estimated time for approval of a plant-specific license amendment request.

2.0 DESCRIPTION OF ISSUE

2.1 Background

Several BWR licensees continue to experience large numbers of Target Rock SRV TS surveillance test failures for both two-stage and three-stage designs, despite continued corrective actions. Table 1 of Enclosure 2 of this evaluation contains a list of recent Target Rock SRV failures based on the NRC staff's review of LERs submitted from 2007 to 2017 that identified conditions prohibited by the TSs. Based on the review of LERs since 2017, this trend continues into 2019. This review revealed that the units listed in the table experienced recurring (twice or more) issues with the setpoint drift. For the plants experiencing recurring setpoint drift issues, an average of 31 percent of SRVs failed TS surveillance requirements (SRs) that were conducted after the operating cycles. For all failed two-stage Target Rock SRVs, the as-found lift setpoints drifted above the TS-allowed maximum (typically +3 percent), with the most significant instance being a setpoint drift of +18.5 percent. In no case did all the SRVs for a particular unit fail the SR. However, typically the failure of more than one SRV to meet its SR results in the loss of SRV system operability.

In each of the reviewed LERs, the licensees provided safety assessments and concluded that the RCS would remain within the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Service Level C pressure limits.[4] These analyses assumed that the design basis transient occurred with the as-found TS setpoint deviations of the SRVs (other cycle-specific inputs may also have been assumed). Furthermore, some of the licensees have a redundant automatic electronically-actuated SRV lift system, which actuates at a lower pressure and is not affected by mechanical drift. However, irrespective of their safety classification, these systems are not credited by safety analyses and are not part of a limiting condition for operation (LCO) in the TSs for these plants.

Licensees have implemented and refined a range of corrective actions, with varying degrees of success. The industry has identified corrosion-induced oxide bonding to be the cause of the current setpoint drift issue for two-stage SRVs. Some licensees have applied platinum coatings to SRV pilot valve discs, while other licensees have changed the pilot valve disc material to Stellite 21 in an effort to prevent corrosion bonding. Some licensees have enhanced SRV insulation to reduce corrosion and improve reliability. None of these methods have been consistently successful. Other licensees are returning to the modified three-stage Target Rock SRVs, which industry experience has shown to be less susceptible to corrosion bonding-induced upward setpoint drift. NRC Information Notice (IN) 2018-02, "Testing and Operations-Induced Degradation of 3-Stage Target Rock Safety Relief Valves," dated February 26, 2018 (ADAMS Accession No. ML18029A741), identified testing-induced problems

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4 ASME Code, Section III, paragraph NCA-2142.4, defines Level A through Level D service limits. Level A service limits are the service loadings to which the component or support may be subjected in the performance of its specified service conditions. The component or support must withstand Level B service limits without damage requiring repair. Level C service limits permit large deformations in areas of structural discontinuity that may necessitate the removal of the component or support for inspection or repair of damage. Level D service limits permit gross general deformations with some consequent loss of dimensional stability and damage requiring repair.

with three-stage Target Rock SRVs. These problems have resulted in the failure of SRVs to open on demand, and the failure of the SRVs to reclose properly after actuation.

During the public meeting on September 12, 2018, the BWROG representatives indicated that the industry has been focused on the application of platinum as a coating on the pilot discs as a possible solution to the corrosion-induced oxide bonding on the SRVs. In 2017 and 2018, the industry used an Ion Beam Assisted Deposition (IBAD) process to apply the platinum coating. The industry is now autoclave testing a new sputtering application process for platinum and testing additional materials. The sputtering process can be used to apply a thicker coating of platinum, which may improve performance. The BWROG is also testing other coating materials.

During the public meeting on February 14, 2019, the BWROG representatives shared recent developments to improve the performance of the two-stage Target Rock SRVs. During testing, the BWROG used accelerated aging in an autoclave to mimic a full cycle of operation in a reactor. Some new materials show promise, but the BWROG is not getting consistent results in the autoclave testing. Troubleshooting and autoclave testing continues. The BWROG representatives plan to test different thicknesses of sputtered platinum coating on pilot discs to determine if it provides more protection from corrosion bonding. They also stated that they are considering whether to examine a sample of valves in lieu of conducting the TS SRs because conducting TS SRs destroys the evidence. However, this option would require prior NRC approval because the licensees would not be able to meet the TS SR. In addition to the testing, the BWROG representatives stated that they are pursuing development of a TSTF traveler to revise the SRV TSs.

2.2 Safety Relief Valve Design Function

The SRVs are part of the nuclear pressure relief system and, in part, prevent overpressurization of the nuclear process barrier. In addition to providing overpressure protection, a select number of SRVs are used by the automatic depressurization system to rapidly decrease reactor pressure during specific small-break loss-of-coolant accidents (LOCAs) during loss of high-pressure injection scenarios. The setpoint drift issue does not affect the automatic depressurization system function.

The two main designs of Target Rock SRVs are two-stage and three-stage SRVs, which are described in, “General Electric Advanced Technology Manual, Chapter 6.8, Safety Relief Valve Differences.”[5]

One of the key factors in selecting the size and number of SRVs is to ensure that the peak pressure in the primary system does not exceed the ASME Code limits. The SRVs are located on the main steam lines between the reactor pressure vessel (RPV) and the first isolation valve within the drywell at a BWR. Different generations of BWRs use anywhere from 5 to 20 SRVs. The ASME Code specifications require the lowest safety valve setpoint to be at or below RPV design pressure (1,250 pounds per square inch gauge), and the highest SRV setpoint to be set so that the total accumulated pressure does not exceed 110 percent of the design pressure. While some BWRs use a single setpoint for all SRVs, the majority have staggered setpoints.

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5 Available in ADAMS under Accession No. ML11263A362.

2.3 Technical Specification Compliance Considerations

Title 10 of the *Code of Federal Regulations* Section 50.36(b), states, in part:

> Each license authorizing operation of a … utilization facility … will include TSs. The TSs will be derived from the analyses and evaluation included in the safety analysis report, and amendments thereto, submitted pursuant to § 50.34. The Commission may include such additional TSs as the Commission finds appropriate.

Per the regulation in 10 CFR 50.36(c)(2), TSs will include items in the category of LCOs. Paragraph 50.36(c)(2)(i) of 10 CFR states, in part:

> Limiting conditions for operation are the lowest functional capability or performance levels of equipment required for safe operation of the facility. When a limiting condition for operation of a nuclear reactor is not met, the licensee shall shut down the reactor or follow any remedial action permitted by the technical specifications until the condition can be met.

The Standard Technical Specifications (STS) for General Electric BWR/4 and BWR/6[6] plants are contained in Revision 4 of NUREG-1433, "Standard Technical Specifications – General Electric BWR/4 Plants," and Revision 4 of NUREG-1434, "Standard Technical Specifications – General Electric BWR/6 Plants,"[7] respectively. In the STS for BWR/4 plants, LCO 3.4.3 states that, "[t]he safety function of [11] S/RVs shall be OPERABLE." Further, LCO 3.4.3, REQUIRED ACTION A, states that if one [or two] required SRV is inoperable, the licensee must restore that SRV to OPERABLE status within 14 days. In the STS for BWR/6, LCO 3.4.4 states that, "[t]he safety function of [seven] S/RVs shall be OPERABLE, <u>AND</u> [t]he relief function of [seven] additional S/RVs shall be OPERABLE." Further, LCO 3.4.4, REQUIRED ACTION A, states that if one required SRV is inoperable, the licensee must restore that SRV to OPERABLE status within 14 days.

Per the regulation in 10 CFR 50.36(c)(3), TSs will include items in the category of SRs, which are "requirements relating to test, calibration, or inspection to assure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the limiting conditions for operation will be met." The STS for BWR/4 and BWR/6 plants include SR 3.4.3.1 and SR 3.4.4.1, respectively, which both require the licensee to verify the safety function lift setpoints of the required SRVs, including verification that the lift settings are within +/-1 percent.

As shown in Table 1 of Enclosure 2 of this evaluation, several BWR/4 licensees reported failure to meet their license-specific equivalent to SR 3.4.3.1. Specifically, the LERs for a number of BWR plants document repetitive and recurring failures to meet the SR. During refueling outages, licensees remove all of the pilot valves of the SRVs to be tested as per the plant-specific SR. Previously refurbished or new SRV pilot valves with setpoints within TS limits are installed in place of the pilot valves that were removed. Recently removed pilot valves are

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6 The STS for BWR/6 is referenced for generic discussion purposes. Based on the review of the LER from 2007 to 2017, only few instances of SRV setpoint drift at BWR/6 plants have been identified. However, none of these BWR/6s are using Target Rock SRVs.

7 Available in ADAMS under Accession Nos. ML12104A192 and ML12104A195, respectively.

sent to an offsite vendor facility for testing, and the results are normally available only *after* the plant has restarted from a refueling outage. If the post-removal SR test identifies a lift setpoint that exceeds the SR limit on setpoint drift, most licensees declare the affected SRVs inoperable for greater than the TS Action Statement allowed time and assess the safety significance (e.g., did the SRVs support their intended safety function during the past operating cycle). The TSs typically permit no more than one SRV to exceed as-found lift setpoints. However, a number of licensees with two-stage Target Rock SRVs still see a large percentage of the SRV pilots exceeding as-found lift setpoints during each SR.

The SRV setpoint drift can be unpredictable, and it is not clear at what point the SRVs start degrading and are likely to exceed TS limitations during the operating cycle. It is possible for the SRVs to exceed TS limitations early on in the operating cycle. TSs require that LCOs be met at all times in the applicable mode, not just at the time the surveillance test is being performed. In the BWR/4 and BWR/6 STS, SR 3.0.1 states, in part, that "[f]ailure to meet a Surveillance, whether such failure is experienced during the performance of the Surveillance or between performances of the Surveillance, shall be failure to meet the LCO." The STS Bases (ADAMS Accession Nos. ML12104A193 and ML12104A196) for SR 3.0.1 elaborate on the intent of SR 3.0.1 by stating the following:

> Systems and components are assumed to be OPERABLE when the associated SRs have been met. Nothing in this Specification, however, is to be construed as implying that systems or components are OPERABLE when:
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> a. The systems or components are known to be inoperable, although still meeting the SRs or
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> b. The requirements of the Surveillance(s) are known to be not met between required Surveillance performances.

The BWR/4 and BWR/6 STS provide a definition of OPERABILITY, which states:

> A system, subsystem, division, component, or device shall be OPERABLE or have OPERABILITY when it is capable of performing its specified safety function(s) and when all necessary attendant instrumentation, controls, normal or emergency electrical power, cooling and seal water, lubrication, and other auxiliary equipment that are required for the system, subsystem, division, component, or device to perform its specified safety function(s) are also capable of performing their related support function(s).

Furthermore, Section 03.13 of NRC Inspection Manual Chapter (IMC)-0326, "Operability Determinations & Functionality Assessments for Conditions Adverse to Quality or Safety," dated November 20, 2017,[8] contains guidance for the NRC staff regarding operability. Section 03.13 of IMC-0326 states in part, that "[a]n SSC [system, structure, and component] that does not meet an SR must be declared inoperable because the LCO operability requirement(s) are not met." In addition, it states that "[w]hen an SSC capability is degraded to a point where it cannot perform with reasonable expectation or reliability, the SSC should be judged inoperable, even if at this instantaneous point in time the system could provide the specified safety functions."

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8 Available in ADAMS under Accession No. ML16302A480.

Section 03.14 of IMC-0326 defines the "reasonable expectation" standard of operability. Specifically, the guidance of IMC-0326 states:

> The discovery of a degraded or nonconforming condition may call the operability of one or more SSCs into question. A subsequent determination of operability should be based on the licensee's "reasonable expectation," from the evidence collected, that the SSCs are operable and that the OD [operability determination] will support that expectation. Reasonable expectation does not mean absolute assurance that the SSCs are operable. The SSCs may be considered operable when there is evidence that the possibility of failure of an SSC has increased, but not to the point of eroding confidence in the reasonable expectation that the SSC remains operable. The supporting basis for the reasonable expectation of SSC operability should provide a high degree of confidence that the SSCs remain operable. It should be noted that the standard of "reasonable expectation" is a high standard, and that there is no such thing as an indeterminate state of operability; an SSC is either operable or inoperable.

The recurring nature of the Target Rock SRV SR failures, even when licensees have made changes expected to improve performance, might indicate that the SRVs cannot be reasonably expected to meet the SR. Thus, operability during the current cycle of operation is called into question. Operability is further clouded because it is impossible to know at what point during an operating cycle the SRVs experience enough corrosion bonding to prevent their required operation. This reflects an ongoing[9] TS compliance issue caused by the mismatch between the TS-required setpoint and the actual as-found setpoint. As a result, either SRV performance must improve or TS requirements must change to ensure TS-compliant operation.

3.0 RESULTS OF STAKEHOLDER INTERACTIONS

3.1 Public Meeting on September 12, 2018

A public meeting between the NRC and BWROG was held on September 12, 2018. The purpose of the meeting was to discuss the TS noncompliance concerns associated with the two-stage Target Rock SRV setpoint drift issue. During the meeting, the NRC staff conveyed that it considers the repeated failure of SRs a challenge to the reasonable expectation of operability of these valves.

The BWROG representatives gave an overview of actions taken thus far to resolve the issue by its BWROG Target Rock SRV Performance Improvement Committee, and the actions taken thus far to resolve the issue. The BWROG representatives stated that the industry has been focused on the application of platinum as a coating on the pilot discs as a possible solution to the corrosion-induced oxide bonding on the SRVs. The BWROG representatives further stated that in 2017 and 2018, the industry used an IBAD process to apply the platinum coating. The BWROG representatives stated that the industry is now testing a new sputtering application process, which will allow them to apply a thicker platinum coating. They are also testing additional coating materials for improved resistance to corrosion bonding. The BWROG representatives concluded their presentation by stating their plan to engage the affected BWR licensees to better understand the issue and to develop a path forward for resolution.

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[9] For example, this condition was recognized during the NRC staff's closeout of GSI B-55 in 1999. More information on GSI B-55 is provided in Enclosure 1 of this document.

The NRC staff asked a series of questions to better understand the activities the BWROG and industry have taken to address the two-stage Target Rock setpoint drift issue. The BWROG representatives responded with the following clarifying information:

- The industry believes corrosion bonding is the root cause, not delamination.

- The electrical lift function on the pilot valve of the two-stage Target Rock SRVs is neither credited in the safety analyses nor by the TSs by the licensees.

- The sputtering application process for platinum has not been used before on two-stage Target Rock SRVs. Hence, there is no operating experience.

- The sputtering application process is a different way of applying the same surfacing material that has been used before and allows different material thicknesses to be applied.

- If the sputtering application process passes the autoclave testing, it is estimated that the industry can use this process starting in fall 2019. It was stated that the sputtering process would need to be used to apply platinum each operating cycle to reduce corrosion bonding.

- Due to the robust autoclave testing technique, the BWROG has confidence that a material that passes the autoclave testing (sputtered platinum or other materials) would not be adversely affected by the reactor environment.

The NRC staff stated that it is open to accepting solutions that result in alignment between the TSs and SRV performance. The sputtering technique might be an adequate long-term solution; however, it may take more than one cycle to determine the optimal platinum thickness or to confirm that other materials are effective. It was agreed that the NRC staff and BWROG representatives will have a subsequent public meeting to discuss in more detail the path forward for near-term resolution of the TS non-compliance issue with the two-stage Target Rock SRVs.

3.2 Public Meeting on February 14, 2019

The NRC staff had a subsequent public meeting with the BWROG representatives on February 14, 2019. The purpose of the public meeting was to receive an update on the proposed path forward for resolution, including the results of the recent testing of the new sputtering application process. The BWROG representatives provided an overview of their multi-faceted approach to resolve the setpoint drift issue, including both a hardware and licensing solution.

The BWROG representatives stated that a new sputtering application process to deposit platinum on the valve disc could minimize corrosion bonding and improve setpoint drift. The autoclave tests indicated that the sputtering process yields good adhesion and that other materials show promise, but the BWROG is not getting consistent results in the autoclave. The BWROG continues to troubleshoot and test in the autoclave. In 2019, the BWROG plans to test different thicknesses of sputtered-platinum coating to determine if additional thickness provides more protection from corrosion bonding. The BWROG is also considering examining sample valve pilot discs after a cycle of operation *instead of* completing the required surveillance tests.

This is because performing the SR destroys evidence of corrosion bonding. However, valve disassembly for this examination would invalidate any subsequent testing; thus, the licensees could not meet the SR. Therefore, this option would require prior NRC approval.

The BWROG representatives are also developing a proposed TSTF traveler, which would revise the TSs to focus on the demonstration of the safety function of the SRVs rather than the setpoint. The representatives stated that in a review of 26 LERs from 2015 to 2018, they found that the safety function of the SRVs were fulfilled in every case. Thus, the TSTF traveler would revise TS 3.4.3 such that the LCO and SR will be met if the safety function is met. The BWROG representatives stated that it is targeting a pre-submittal meeting with the NRC in the next several months and targeting a submittal of the TSTF traveler in summer 2019.

4.0 RISK-INFORMED EVALUATION

Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," dated January 2018,[10] LIC-504 guidance, and other documents related to risk-informed decisionmaking outline five key risk-informed principles. These principles are:

1. Compliance with existing regulations,
2. Maintenance of adequate safety margins,
3. Demonstration of acceptable levels of risk,
4. Consistency with the defense-in-depth philosophy, and
5. Implementation of defined performance measurement strategies.

Item 1 is discussed in Section 2.3 of the document, in describing the issue and its relationship to TS compliance. It is the ultimate goal of this process to restore compliance with the regulations. The second, third, and fourth items are discussed in the following subsections in Section 4.0. Item 5 is the subject of Section 5.0, which evaluates the various options moving forward.

4.1 Deterministic Evaluation

Licensees perform their deterministic evaluations (to support the LERs) following NRC staff-approved guidance. Before 1990, many plant TSs allowed a setpoint tolerance of ±1 percent. However, because of setpoint drift beyond this tolerance, the BWROG submitted topical report (TR) NEDC-31753P, "BWROG In-Service Pressure Relief Technical Specification Revision Licensing Topical Report," dated February 1990, to assist licensees in increasing the setpoint tolerance, subject to the conditions of the NRC staff's safety evaluation (SE). As stated in the NRC staff's SE, each licensee choosing to implement these TS modifications must provide plant-specific analysis including transient analysis of all abnormal operational occurrences, analysis of the design basis overpressurization event, reevaluation of the performance of high-pressure systems, evaluation of the setpoint tolerance change on plant-specific alternate operating modes, and evaluation of the effect of change in the setpoint tolerance limit on the containment response during a LOCA and the hydrodynamic loads on SRV discharge lines and containment. The NRC approved this topical report by letter dated March 8, 1993.[11] Many plants submitted license amendment requests to increase their upper

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10 Available in ADAMS under Accession No. ML17317A256.
11 Available in the ADAMS Legacy Library under Accession No. 9702070012.

setpoint tolerances to 3 percent. The BWR TSs typically allow an upper tolerance of +3 percent.

Following a similar process, the NRC staff has considered the following items for determining the safety significance for SRVs that exceed the TS setpoint limits:

- ASME Code pressure/service limits on the primary system
- hydrodynamic loads on SRV discharge piping
- fuel impact
- performance of high-pressure injection systems

Events (e.g., design basis transients) that use the SRVs in the safety mode of operation are those that result in a sudden reduction of steam flow and in a rapid reactor pressure increase while the reactor is operating at power. The events typically identified as overpressure events are: generator load reject, loss of condenser vacuum, turbine trip, turbine bypass valve malfunction, closure of main steam isolation valve (MSIV), and pressure regulator malfunction. During these events, sensible and decay heat can be removed through actuation of one or more of the following systems: steam relief system, steam bypass to the condenser, reactor core isolation cooling system, and emergency core cooling system.

Typical design basis events are initiated with the rapid closure of a turbine control valve (TCV), turbine stop valve (TSV) or MSIV. Closing any of these valves results in a rapid pressurization in the RPV, causing a collapse of steam voids that rapidly increases the neutron flux and initiates a reactor scram. For this reason, the reactor trip logic initiates a trip following the closure of a certain number of TCVs, TSVs, or MSIVs (anticipatory trip). If this does not trip the reactor, either a high neutron flux or high RPV steam dome pressure signal will trip the reactor. Note that the RPV steam dome high-pressure trip setpoint is typically below the lowest SRV setpoint. The minimum critical power ratio[12] (one of the TS safety limits) is a measure of how close the fuel is to experiencing dryout conditions where the heat transfer from the fuel surface to the coolant is deteriorated, resulting in an increased fuel surface temperature. Because the reactor scram happens almost immediately, the limiting minimum critical power ratio is expected to occur before SRV opening (at its nominal setpoint). Therefore, even if the SRVs open at a higher setpoint than expected, the specified acceptable fuel design limits would be maintained. Therefore, there is no significant impact with respect to fuel during a design basis event.

For the scenarios described above where the reactor does not scram (i.e., an anticipated transient without scram (ATWS) event), the reactor pressure would rise rapidly, and the SRVs would still be expected to open, although at a pressure higher than their nominal setpoint. However, given that the pressure increase is rapid and there is a very short time between when the valves should open (at their nominal setpoint) versus when they actually open, results of the ATWS analysis would not be expected to be significantly different than if the valves opened at their nominal opening setpoint. Therefore, there is no significant impact on system response to ATWS.

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12 NUREG-1433, Volume 1, Section 1.1, states that the minimum critical power ratio "shall be the smallest critical power ratio (CPR) that exists in the core [for each class of fuel]. The CPR is that power in the assembly that is calculated by application of the appropriate correlation(s) to cause some point in the assembly to experience boiling transition, divided by the actual assembly operating power."

Another issue to consider when SRVs open at higher than expected pressures is the effect on other high-pressure injection systems, such as high-pressure core spray, high-pressure coolant injection, reactor core isolation cooling, and standby liquid control. While the higher RPV dome pressure would reduce the flow from these systems, the effect is expected to be minimal for an overpressure transient. This is due to the fact that, for such an event, the RPV dome pressure rises rapidly and would result in only a small-time delay in the opening of the SRVs (i.e., the time difference between the pressure reaching the nominal setpoint and the actual opening pressure). Once the SRVs open for the first time, the corrosion bonding effect is eliminated (testing history has shown that the subsequent SRV lift will be within the tolerance of the nominal setpoint). In addition, the safety analyses generally assume that there are time delays (approximately 30 to 60 seconds) in starting these high-pressure injection systems, such that flow would not be credited during the time the RPV dome pressure is higher than expected (first few seconds of the event). Licensee LERs regularly revisit the ability of the injection systems and find no impact. Therefore, there is no significant impact on the performance of the high-pressure injection systems.

Regarding the integrity of the RCS pressure boundary and SRV piping, licensee LER evaluations routinely review the RCS pressure boundary integrity and SRV discharge piping integrity. The licensee evaluations have shown that setpoint drift has not been sufficient to result in an RCS pressure boundary exceeding Level C service limits during a design basis event. In addition, it has been demonstrated that, even with setpoint drift as high as 20 percent above nominal setpoint (at a specific facility), hydrodynamic loads in the SRV discharge piping do not exceed Level D service limits. Therefore, there is not a significant concern for exceeding the ASME Code pressure/service limits and hydrodynamic loads on SRV discharge piping from the historic levels of setpoint drift.

4.2 Risk Assessment

In addition to the guidance in LIC-504, the NRC staff used the guidance in RG 1.174, Revision 3, to provide perspective on the risk significance of the two-stage Target Rock SRV setpoint drift issue.

Failure of the two-stage SRVs to open at the TS-specified setpoint is important to accident sequences where an ATWS has occurred, and rapid depressurization of the RCS is required to prevent exceeding TS safety limits. ATWS accident sequences provide an appropriate estimation of the overall risk associated with these failures. Within the ATWS accident sequence grouping, the NRC staff assessed the risk impact of this failure mechanism following an ATWS by using a bounding and separately, a conservative, representation of worst credible outcomes regarding the SRV's reliability in performing its probabilistic risk assessment (PRA) function. This approach obviates the need for a greater level of detail, which would require extensive investigation of the best estimate effect on valve reliability. Thus, a simplified, more efficient, and bounding determination is reached on whether immediate regulatory action is warranted. Such an approach is consistent with typical PRA practice for this type of situation.[13] The results of this analysis were then compared with the acceptance guidelines of RG 1.174 as

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[13] For more information about the terminology used to describe this approach, and the relevance of this approach in addressing level-of-detail uncertainties, see the guidance in NUREG-1855, Revision 1, "Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking," dated March 2017 (ADAMS under Accession No. ML17062A466).

demonstrated in Figures 1 and 2 of Enclosure 3 of this evaluation. The plotted points in Figures 1 and 2 are representative of each of the plants listed in Enclosure 2, Table 1. The failure of SRVs to open during a transient is currently modeled in the plant Standardized Plant Analysis Risk (SPAR) models for initiating events leading to an ATWS, such as loss of condenser heat sink and loss of main feedwater transients. As described earlier in this document, the impact of the valve failure mechanisms is on the valve's initial lift, and therefore, only the reliability of initial lifts required for ATWS sequences are adjusted. Again, the results are plotted on Figures 1 and 2 (Enclosure 3 of this evaluation) derived from Figure 4 of RG 1.174 for changes (increases) in core damage frequency (ΔCDF) versus the base case, conditional on the SRVs not being capable of performing their ATWS function reliably. In this way, they represent the ΔCDF in RG 1.174, as well as the conditional change in CDF (ΔCCDF) in LIC-504. Figure 1 of Enclosure 3 of this evaluation shows the bounding change in the ATWS-related CDF when the probability of failure to open of all SRVs is set to "True" (guaranteed to fail). The ΔCDF is considered small and falls in Region II of the acceptance guidelines defined in RG 1.174. Figure 2 of Enclosure 3 of this evaluation shows another sensitivity of this result by displaying the ΔCDF resulting from a one hundred-fold increase in the SRV failure probability over its nominal (base) value. The increase in ΔCDF is considered very small, provides more flexibility with respect to the baseline CDF, and falls in Region III of the acceptance guidelines defined in RG 1.174. The Figure 3 estimate is considered conservative in that it evaluates the failure by substantially increasing its failure probability beyond what is likely to be observed during actual plant operations.

Current risk assessment guidance in Table 5.2 of IMC-0609, Appendix H, "Containment Integrity Significance Determination Process," provides the methodology for estimating the large early release frequency (LERF) for Mark I containments under ATWS conditions. An estimate of LERF can be obtained by applying a multiplication factor of 0.3 to the CDF value, which means that 30 percent of core damage accidents are likely to lead to large, unmitigated releases from containment.

The results of the analyses indicate that the change in risk related to the issue is small (relative to the criteria in RG 1.174) and immediate action is not warranted. Further, these analyses confirm that the threshold in the LIC-504 guidance associated with taking more immediate action is *not* met. In addition, it is likely that a more realistic analysis, which would require significant effort to produce defensible reliability adjustments, would show an even lower risk impact. The observed levels of setpoint drift appear to meet RG 1.174 provisions for safety margins and defense-in-depth.

4.3 Safety Margins

The safety margin is demonstrated in the deterministic evaluation discussed above. Based on historic levels of setpoint drift, there is (1) margin to overpressure of the RCS, (2) margin to damaging SRV discharge piping, (3) no reduction in margin to fuel design limits, and (4) no adverse impact on the high-pressure injection systems.

4.4 Defense-in-Depth

The deterministic and probabilistic analysis discussed in Sections 4.1 and 4.2 above, also provides perspective on defense-in-depth aspects, while Appendix D of LIC-504 provides specific guidance about assessing the issue's impact on defense-in-depth. In this case, the issue does increase the unreliability associated with a key safety function (reactor pressure control), does introduce new common cause failure mechanisms, but generally does not reduce defense against human errors. The deterministic analysis discusses the relevance of these negative attributes, while the risk assessment highlights that only a portion of the plant's risk profile (contributing accident sequences) are affected by even the bounding SRV reliability assumptions.

Regarding the impact of the issue on barrier integrity, the deterministic evaluation concludes that there is not a significant concern for exceeding the ASME Code pressure/service limits and hydrodynamic loads on SRV discharge piping with overpressure from the observed levels of setpoint drift. Meanwhile, the risk evaluation focuses on the fuel cladding barrier (CDF) and the containment barrier (LERF). Use of the LERF factors from IMC-0609, Appendix H, indicates that the relative ratio of LERF contribution (associated with the increase in ATWS contribution) would not be significant relative to the corresponding baseline LERF ratio typical for Mark I containments.

With respect to the potential impact on multiple layers of defense-in-depth, the independence of the different layers of defense-in-depth is not compromised (i.e., the issue does not simultaneously impair multiple layers of defense-in-depth). In addition, some licensees have a redundant automatic electronically-actuated SRV lift system, which is not affected by setpoint drift. While these systems are not credited by safety analyses, these systems provide additional defense-in-depth.

These observations, combined with the deterministic observations regarding plant response to delayed SRV opening during postulated accidents, as well as the earlier discussions about actions taken to mitigate the effects of SRV setpoint drift, supports the conclusion that the issue does not overly erode defense-in-depth, while the regulatory options discussed later will provide opportunities for regaining some or all of the defense-in-depth.

4.5 Technical Conclusion

The NRC staff's risk-informed evaluation indicates that immediate actions (e.g., shutdown of plants) are not required. Additionally, the staff has not invested the additional effort to conclude that the issue is of very low safety significance relative to the criteria in the LIC-504 guidance, in part because LIC-504 is being used here to guide evaluation and documentation of an issue that resides within another agency process (i.e., enforcement). This conclusion is also consistent with the staff's conclusions during the closeout of GSI B-55 and partly dependent upon the licensee's conclusions in the more than 100 LERs since the closeout of GSI B-55.

5.0 OPTIONS CONSIDERED

Even though the risk-informed evaluation indicates that immediate actions are not necessary, the NRC staff position is that licensees should restore TS compliance in a reasonable timeframe. Historically, licensees have been trying to improve the valve performance by use of several potential solutions that would achieve consistency between the equipment performance and the design basis for the plant. Consistent with LIC-504, the staff is assessing which regulatory tools would be most effective at achieving the desired outcome.

The NRC staff has identified several agency actions that could be taken to reach the desired outcome and has updated the evaluation based on interactions with the BWROG during public meetings. The staff's assessment is discussed below. This is not an exhaustive list.

5.1 Order

The NRC primarily exercises the authority to issue an Order when deemed necessary to either ensure a license comes in to compliance with existing regulations following either a violation or noncompliance (enforcement orders) or when necessary, to protect public health safety and security (safety or security orders). Contents of the Order could include provisions that do the following:

- Shut down the facility (immediate or within a specified time period).
- Replace affected SRV components or amend the TSs.
- Implement corrective actions.

If the NRC staff determines that additional information is needed from licensees in order to determine if an NRC Order or further enforcement action is warranted, the NRC staff may consider issuing a demand for information pursuant to 10 CFR 2.204, "Demand for information."

5.2 Generic Communications

The NRC staff considered using one of the NRC's generic communications products (Bulletin (BL), Generic Letter (GL), Regulatory Issue Summary (RIS), and IN).[14] The staff did not consider using a Security Advisory or Information Assessment Team Advisory because the issue does not involve security- or threat-related information.

Since the closure of GSI B-55 in 1999, the NRC staff has not interacted with licensees on a *generic* basis regarding the SRV setpoint drift issue,[15] other than the issuance of RIS 00-012, "Resolution of Generic Safety Issue B-55, 'Improved Reliability of Target Rock Safety Relief Valves,'" on August 7, 2000, and IN 2006-24, "Recent Operating Experience Associated with Pressurizer and Main Steam Safety/Relief Valve Lift Setpoints," on November 14, 2006 (ADAMS Accession Nos. ML003726865 and ML062910111, respectively). RIS 00-012 notified licensees about the NRC staff's resolution of GSI B-55, and IN 2006-24 discussed the continuing SRV LERs related to setpoint drift issues. The only NRC staff interaction has been on a *site-specific* basis between the regional staff and the individual licensees experiencing recurring issues with SRV setpoint drift issue on an ongoing basis (e.g., LER closeouts being documented as licensee-identified violations).

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14 Management Directive 8.18, "NRC Generic Communications Program," dated December 9, 2015, defines the purpose of the NRC's generic communication products, and defines the process for preparing the products. Directive Handbook (DH) 8.18 provides criteria for the use of each generic communication type, guidance on obtaining approval for a proposed generic communication, and guidance on its preparation, issuance, distribution, and follow-up.

15 While not specific to the Target Rock SRV setpoint drift issue, the NRC did complete an inspection at the Curtiss-Wright Flow Control Company Target Rock Division on March 6–9, 2017 to assess its compliance with 10 CFR Part 21, "Reporting of Defects and Noncompliance," and portions of 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants" (ADAMS Accession No. ML17104A205).

5.2.1 Bulletin

As described in Section III.A.1 of Directive Handbook (DH) 8.18,

(a) A BL is used to request licensee actions and/or information to address significant issues regarding matters of safety, security, safeguards, or environmental significance that also have great urgency. A BL requires a written response [but may NOT request long-term actions or require actions or commitments]. The compensatory actions requested should be commensurate with the urgency of the issue being addressed.

(b) To the extent that circumstances permit, NRC staff will interact with the stakeholders on the issue being addressed.

Contents of a bulletin could include the following provisions:

- Request actions to be taken (e.g., request that licensees identify vulnerable SRVs and proposed actions for resolution of the issue).
- Request information be provided (e.g., request that licensees provide a proposed schedule and action plan for resolution of the issue).
- Request analyses be performed and submitted by a specified time (e.g., request that licensees evaluate previous operating history and maintenance for the vulnerable SRVs, including their safety significance), including request for new or revised commitments based on the results of the analyses.
- Require a response from affected licensees documenting the results of the analyses and the proposed action plan.

5.2.2 Generic Letter

As described in Section III.A.2 of DH 8.18,

(a) A GL addresses either an emergent or routine technical issue with generic applicability for which NRC staff and stakeholders have interacted. A GL may also be issued without extensive prior interaction between the NRC and stakeholders when the NRC has determined a risk-significant compliance matter should be brought promptly to the attention of licensees.

(b) A GL may request information and/or compensatory actions and require a written response from licensees regarding matters of safety, security, safeguards, or environmental significance.

A GL may not request long-term actions or require actions or commitments.

Contents of the GL could include the following provisions:

- Request actions to be taken (e.g., request that licensees identify vulnerable SRVs and proposed actions for resolution of the issue).
- Request information be provided (e.g., request that licensees provide a schedule and action plan for resolution of the issue).
- Request analyses be performed and submitted by a specified time (e.g., request that licensees evaluate previous operating history and maintenance for the vulnerable SRVs, including their safety significance).
- Request new or revised commitments based on the results of the analyses performed and on the proposed corrective actions for timely resolution of the issue.
- Require a response from affected licensees documenting the results of the analyses and actions taken for resolution of the issue.

5.2.3 Regulatory Issue Summary

As described in Section III.A.3 of DH 8.18,

(a) A RIS is used to communicate with stakeholders on a broad range of matters.

(b) A RIS may-

(i) Communicate previous NRC endorsement of an industry-developed resolution of a matter on which the staff has interacted with the industry.

(ii) Communicate previous NRC endorsement of industry guidance on technical or regulatory matters.

(iii) Provide the status of staff interaction with the nuclear industry on a matter.

(iv) Request the voluntary participation of the nuclear industry in staff-sponsored pilot programs.

(v) Inform the nuclear industry of previously established opportunities for regulatory relief.

(vi) Communicate and/or clarify staff technical or policy positions on regulatory matters that have not been communicated or are not broadly understood by the nuclear industry.

(vii) Provide guidance to applicants and licensees on the scope and detail of information that should be provided in license applications to facilitate staff review.

(viii) Communicate any of the following: administrative procedure changes in the implementation of regulations or staff positions; the issuance and availability of regulatory documents (topical reports, NUREG-type documents, regulatory guides; memoranda documenting the closeout of generic safety issues); and changes in NRC internal procedures and organization.

(ix) Request the voluntary submittal of information, which will assist the NRC in the performance of its functions. [In general, a RIS may inform, clarify, or remind licensees about regulatory matters or NRC staff positions.]

(c) A RIS may NOT-

(i) Provide guidance for the implementation of rules and regulations,
(ii) Provide guidance to NRC staff on regulatory or technical matters,
(iii) Require a response, commitments, or action; or be used in lieu of other established agency products.

A RIS could be used to highlight the continuing high level of SRV setpoint drift or to reinforce with industry that there should be alignment between the TSs and the SRV performance. However, the NRC staff would need to consider another option (e.g., enforcement discretion) to address the recurring TS noncompliance issue.

5.2.4 Information Notice

As described in Section III.A.6, of DH 8.18,

(a) An IN communicates recently identified operating experience to the nuclear industry. The results of recently completed research that may affect addressees may also be communicated in an IN. Addressees are expected to review the information for applicability to their facilities or operations and consider actions, as appropriate, to avoid similar problems.

(b) An IN may NOT-

(i) Convey or imply requirements,
(ii) Transmit interpretations of regulations, or
(iii) Request information or action from addressees.

The NRC staff has already issued several INs on SRVs (described in Enclosure 1). The staff could issue an IN to highlight the continuing trend of setpoint drift. One method would be to update IN 2006-24 to include the more recent failures or issue a new IN on the continuing SRV setpoint drift issues. However, an IN cannot request action or information and would, therefore, alone may not be adequate for addressing the long standing setpoint drift and TS noncompliance issue.

5.3 Industry Initiative

The purpose of an industry initiative would be for the industry to recommend a proposed solution to the SRV setpoint drift issue. Although the NRC staff cannot impose this action, the staff can encourage the industry to develop a structured plan to address the issue. This option would resolve the TS compliance issue in the near term; thus, another option would likely be desired if the industry initiative does not lead to timely resolution commensurate with the safety significance. Elements of the plan should include the following:

- Provide an overall assessment of the issue.
- Identify susceptible components.
- Identify actions for timely and effective resolution (e.g., modification to SRVs, license amendment requests to change TSs, and actions to credit pilot actuation of the SRVs) including properly assigned priorities.
- Provide a timely schedule for completion.

The NRC staff would support the industry initiative in the following situations:

- If the industry controls and owns the issue resolution in a timely and effective manner.
- If the NRC retains an appropriate level of oversight of industry actions; inspection elements (Temporary Instruction or Operating Experience Smart Sample) could be used to confirm that the industry's resolution plan was effective and being managed appropriately.

The NRC staff would not support the industry initiative in the following situations:

- If the industry initiative does not contain the specificity for the NRC staff to have confidence that the proposed actions will be effective.
- If the industry initiative does not support a timely and effective resolution.

In the public meetings, on September 19, 2018, and February 14, 2019, the BWROG proposed two possible solutions for the Target Rock SRV setpoint drift issue, which is discussed in detail in Sections 3.1 and 3.2 of this document. The proposed industry initiative includes possible hardware and licensing solutions. Additional testing is necessary to evaluate the effectiveness of the proposed change before pursuing the hardware solution. For the licensing solution, the BWROG is in the process of drafting a proposed TSTF traveler and is working towards submitting the TSTF traveler for NRC approval this summer. If the TSTF traveler is approved by the NRC, affected licensees would need NRC prior approval via license amendment requests to adopt the TSTF traveler. The NRC staff would need approximately 1 year to review these license amendment requests for approval.

Further engagement with the BWROG, licensees, and other stakeholders is necessary to better understand these proposed solutions and finalize the path forward and resolution of the issue in a timely fashion. The resolution proposed by the industry and accepted by the NRC staff would need to be coupled with an appropriate level of regulatory action and oversight (e.g., enforcement discretion).

5.4 No Further Action, Enforcement through Baseline Reactor Oversight Process Inspections

No further action is a possible option; however, while this issue has been determined to date to involve low risk significance, it would allow apparent TS noncompliance for indeterminate time periods to continue. Further action is also warranted because this option would result in a large number of TS operability issues, resulting in requests for notice of an enforcement discretion, an emergency license amendment, or both. The NRC typically addresses TS compliance issues on a plant-specific basis. However, since this is a generic issue that effects several plants, it may not be the most efficient way to address the issue. Furthermore, this path has not led to consistent progress toward TS compliance in the past.

5.5 Enforcement Discretion

Enforcement discretion allows the NRC staff to not take enforcement action for a specific noncompliance issue. Specifically, this option would allow a licensee to continue to operate if they discover that an SRV lift setpoint exceeds the TS limit for operability during a post-removal surveillance test. Enforcement discretion is not a means for resolving the issue but provides time to licensees to continue to operate while actions are taken to restore compliance.
An enforcement guidance memorandum (EGM) or interim enforcement policy (IEP) could be used as guidance on the enforcement discretion for the regional staff. However, an IEP is considered a policy change; thus, it would require Commission approval.

The NRC staff may consider granting enforcement discretion after an acceptable technical solution, and an appropriate timeframe for resolution is identified and accepted by staff. The enforcement discretion would allow the NRC staff not to take enforcement action for a specific duration to allow the licensees the opportunity to restore TS compliance. There could be a variety of technical solutions for licensees to use. Depending on the technical solution, the duration of the enforcement discretion could be short-term (e.g., months) or long-term (e.g., a couple of refueling outages). As the staff obtains additional information from the BWROG, affected licensees, and other stakeholders on the proposed solution, the staff will evaluate the appropriate duration for the EGM (if this is the recommended option). A RIS should accompany the EGM to address the TS compliance issue and notify licensees of the opportunity for regulatory relief if deemed appropriate.

Guidance provided by EGM or IEP may include the following:

- criteria for allowing the use of enforcement discretion for specific circumstances
- standard language for cover letter descriptions and citations
- severity levels for specific violations to ensure consistency

An EGM or IEP would provide reasonable time for licensees to resolve the issue, such as the following:

- Implement plant modifications to improve SRV performance to ensure SRVs consistently meet TS LCOs throughout the operating cycle.

- Amend plant TSs to align the analysis and TSs to match the SRV performance.

Following additional public meetings with the BWROG and the industry, the NRC staff will have a better understanding of industry's solution before issuance of an EGM or IEP. The viability of any resultant exercise of enforcement discretion would be influenced by the soundness of the technical approach and duration of the period before compliance could be reached. Based on the risk-informed evaluation of the issue in Section 4.0 of this document, and the compliance question in Section 2.3 of this document, the NRC staff would consider an EGM if the licensee proposed an adequate and timely technical solution. The staff considers a period of up to two refueling cycles to be a reasonable timeframe, if the option for enforcement discretion is the recommended path forward.

6.0 RECOMMENDATION

The NRC staff recommends the following for a path to resolution of the issue:

- The NRC staff supports the BWROG's current path to resolution. The staff will provide an appropriate level of regulatory oversight. Further engagement with the BWROG, affected licensees, and other stakeholders in public meetings is necessary to understand the industry's proposed licensing and hardware solutions and appropriate schedule for resolution.

- Based on the proposed industry solution, the NRC staff will explore and select appropriate option(s) (e.g. enforcement discretion, generic communication, etc.) suitable to restore TS compliance in a manner and reasonable timeframe commensurate with the safety and risk significance of the issue.

Based on guidance and direction from NRC management and the results of additional discussions with the industry, the NRC staff will update this document accordingly. Once the NRC staff selects a recommended path forward, the staff will evaluate the option for backfit considerations in accordance with 10 CFR 50.109, "Backfitting."

Enclosures:
1. History of Issues with Target Rock Safety Relief Valves
2. Target Rock Safety Relief Valve Operating Experience
3. Acceptance Guidelines for Change in Core Damage Frequency in Regulatory Guide 1.174

SUBJECT: TARGET ROCK SAFETY RELIEF VALVE SETPOINT DRIFT ISSUE—DOCUMENTATION OF INTEGRATED RISK-INFORMED DECISIONMAKING PROCESS IN ACCORDANCE WITH THE OFFICE OF NUCLEAR REACTOR REGULATION OFFICE INSTRUCTION LIC-504 (EPID L-2018-LRL-0001) DATED APRIL 12, 2019

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HISTORY OF ISSUES WITH TARGET ROCK SAFETY RELIEF VALVES

Overview of Design Changes

The earlier 1970s design of the three-stage Target Rock safety relief valve (SRV) had a history of spuriously opening and failing to reseat. This led to the introduction of a two-stage SRV, which was a modification of the three-stage SRV designed to eliminate the spurious opening and blowing down problem. Beginning in 1978, two-stage SRVs were installed in several boiling-water reactors (BWRs). However, during surveillance testing, it was discovered that a number of two-stage SRVs experienced setpoint drift and did not open within technical specification (TS) limits. The setpoint drift issue of concern is unique to the Target Rock two-stage SRVs. Several two-stage Target Rock SRV variants were developed and tested with limited success. Target Rock reintroduced a three-stage SRV variant in 1998 and modified the design again in 2008, with the expectation that users of the Target Rock two-stage SRVs would convert to the 2008, three-stage model (Model No. 0867F) based on the improved performance. However, experience has shown that limited flow testing of Model 0867F Target Rock SRVs can result in damage to internal valve components affecting valve operability at low steam pressures. Loose manufacturing tolerances for the pilot valves were also identified as the cause for low setpoint drift. As a result, Target Rock has developed a design change that has been verified, through analysis and qualification testing, to ensure testing on the available limited flow test facilities will not damage the three-stage SRVs.

Previous Safety Assessments

In response to both industry and U.S. Nuclear Regulatory Commission (NRC) concerns about the Edwin I. Hatch Nuclear Plant, Unit 1 event, in late 1982, the BWR Owners' Group (BWROG) established the SRV Setpoint Drift Committee. On November 10, 1983, the SRV Setpoint Drift Committee, accompanied by representatives from General Electric (GE) and Target Rock, met with the NRC staff to discuss the results of the program. GE concluded that two-stage SRV drift resulted from two unrelated causes:

a. sticking of the pilot valve disk in its seat, a corrosion-induced mechanism

b. binding of the pilot valve stem if clearances between the stem labyrinth seal and its guide bushing are too small

Based on the available data at that time, GE concluded that binding of the pilot valve stem was the predominant issue. To reduce the occurrence of setpoint drift, GE recommended a revised maintenance procedure be followed that primarily addresses drift resulting from stem binding. GE Service Information Letter (SIL) 196, Supplement 14, describes the revised recommended maintenance procedure. By letter dated June 22, 1984, the BWROG transmitted a proprietary topical report, NEDE-30476, "Setpoint Drift Investigation of Target Rock Two-Stage Safety/Relief Valve (Final Report)," issued February 1984, to the NRC staff that documented the information presented at the meeting on November 10, 1983. However, after the meeting, additional as-found SRV test data revealed that setpoint drift resulting from pilot disk sticking was occurring more frequently than was previously believed.

Based on the additional data, the NRC staff concluded that the revised maintenance procedure described in NEDE-30476 is a necessary part of resolving the two-stage SRV setpoint drift concern, but it is not sufficient by itself. Setpoint drift resulting from pilot stem binding causes a delay in valve opening; however, the SRV will usually open within 5 percent of the nominal setpoint. Drift resulting from pilot disk sticking is frequently much more severe and has been more than 10 percent above the nominal setpoint.

To resolve issues with the two-stage and three-stage SRVs, the NRC opened Generic Safety Issue (GSI) B-55, "Improved Reliability of Target Rock Safety Relief Valves." After having followed the BWROG program and the programs of individual licensees for a number of years, the NRC staff was confident that the necessary resources were being allocated by all licensees involved to adequately address the setpoint drift issue. The staff agreed with the then-current approaches being pursued by the BWROG and by the individual BWR licensees.

To assist in evaluating whether additional improvements needed to be made to the two-stage SRVs, beyond those already being pursued, the NRC staff performed a bounding assessment, assuming that there will continue to be occurrences of significant setpoint drift. GSI B-55 considered two types of event sequences involving failures of the valves to open. The first involves inadequate emergency core cooling system flow when SRVs fail to open in the automatic depressurization system mode. However, since the automatic depressurization system mode of operation is independent of the mechanical setpoint, setpoint drift does not affect these event sequences. The second type of event sequence involves system overpressurization. The most severe overpressurization event is a main steam line isolation followed by failure of the reactor to scram (i.e., anticipated transient without scram (ATWS)). As discussed in NUREG-1000, Volume 1, "Generic Implications of ATWS Events at the Salem Nuclear Power Plant," for a typical BWR/4, the peak analyzed pressure for this event is approximately 1,300 pounds per square inch gauge (psig), which is well below the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code service Level C limit of 1,500 psig. This analysis assumes that all SRVs open at the correct setpoints; however, even with significant setpoint drift, there is substantial margin. Sensitivity studies of the BWR ATWS analysis input parameter (provided in GE proprietary report NEDE-24222, "Assessment of BWR Mitigation of ATWS, Volume 11," issued December 1979) show that the effect of a significant decrease in SRV capacity still results in the peak pressure not exceeding the service Level C limit. Therefore, the setpoint drift that had been observed at the time of GSI B-55 would not result in a significant loss of margin in the system pressure boundary integrity.

The above safety case supported the NRC staff's finding that no additional improvements, other than those already being pursued as discussed in GSI B-55, were needed. However, in GSI B-55, the NRC staff also considered that, because the plant TS require these valves to remain operable within the allowed setpoint tolerance, licensees would take necessary corrective actions. The GSI B-55 closeout memorandum, dated December 17, 1999 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML993620214), specifically concluded the following:

> In conclusion, the staff finds that the BWR Owners Group and the individual licensees have significantly improved the performance of Target Rock SRVs, as demonstrated by plant-specific operational experience and test data. As stated above [in Attachment to the memorandum dated December 17, 1999], the inadvertent actuation problems which had existed with the three-stage SRVs have been corrected, and there is substantial margin in the reactor coolant

> system pressure boundary to accommodate bounding values of setpoint drift for the two-stage SRVs. Further, there are adequate regulatory mechanisms for requiring any further improvements necessary in the future. The staff is also satisfied that the BWR Owners Group and the licensees are pursuing the setpoint drift issue with appropriate resources necessary to continue to improve performance as needed. Therefore, based on the accomplishments and ongoing activities by the licensees and the BWR Owners Group regarding Target Rock safety/relief valves, the staff is recommending that GSI B-55 be closed.

In addition to GSI B-55, the NRC also issued several generic communications on SRVs over the years, including NRC Information Notice (IN) 2006-24 and IN 2018-02. The NRC issued IN 2006-24, "Recent Operating Experience Associated with Pressurizer and Main Steam Safety/Relief Valve Lift Setpoints," on November 14, 2006 (ADAMS Accession No. ML062910111). The NRC staff noted there were 11 licensee event reports (LERs) in 2001, 17 LERs in 2002, 9 LERs in 2003, 6 LERs in 2004, 14 LERs in 2005, and 8 LERs in 2006 (as of August). The staff's evaluation of the LERs for 2005 and 2006 revealed that the safety significance of individual events was generally low or minimal since the as-found valve setpoints were within the ASME tolerance limit or within the accident analyses. Recently, the staff issued IN 2018-02, "Testing and Operations-Induced Degradation of 3-Stage Target Rock Safety Relief Valves," dated February 26, 2018 (ADAMS Accession No. ML18029A741), to make the licensees aware of recent operating experience related to redesigned Target Rock three-stage SRVs (Model 0867F).

TARGET ROCK SAFETY RELIEF VALVE OPERATING EXPERIENCE

Table 1: Recent Failures of Target Rock Safety Relief Valves (SRVs)[1]

Licensee	# of SRVs	10-year % failed	Summary of Target Rock SRV Surveillance Test (ST) Performance over Last 10 Years[2]
Browns Ferry Nuclear Plant, Unit 1	13	27.7%	Failed 4 times in 10 years (10 SRVs, 3 SRVs, 2 SRVs, 3 SRVs). One ST passed.
Browns Ferry Nuclear Plant, Unit 2	13	19.2%	Failed 3 times in 10 years (4 SRVs, 7 SRVs, 4 SRVs). Passed ST 3 times in a row between 2011 and 2015.
Browns Ferry Nuclear Plant, Unit 3	13	30.8%	Failed 4 times in 10 years (7 SRVs, 8 SRVs, 2 SRVs, 3 SRVs). One ST passed.
Brunswick Steam Electric Plant, Unit 1	11	7.2%	Failed 2 times in 10 years (2 SRVs each time). Three STs passed.
Brunswick Steam Electric Plant, Unit 2	11	21.2%	Failed 4 times in 10 years (4 SRVs, 4 SRVs, 3 SRVs, 3 SRVs), including the last 3 in a row. STs in 2009 and 2011 passed.
Cooper Nuclear Station	8	21.4%	Failed 6 times in 10 years (1 SRV, 1 SRV, 2 SRVs, 1 SRV, 5 SRVs, 2 SRVs). One ST passed
James A. FitzPatrick Nuclear Power Plant	11	53.0%	Failed 5 times in 10 years (8 SRVs, 5 SRVs, 5 SRVs, 7 SRVs, 10 SRVs). One ST passed.
Edwin I. Hatch Nuclear Plant, Unit 1[3]	11	41.8%	Failed 5 times in 10 years (3 SRVs, 5 SRVs, 8 SRVs, 5 SRVs, 2 SRVs). [includes data for three-stage SRVs]
Edwin I. Hatch Nuclear Plant, Unit 2[3]	11	32.5%	Failed 6 times in 10 years (5 SRVs, 3 SRVs, 5 SRVs, 8 SRVs, 3 SRVs, 2 SRVs). One ST passed.
Hope Creek Generating Station, Unit 1	14	51.2%	Failed 6 times in 10 years (6 SRVs, 6 SRVs, 6 SRVs, 5 SRVs, 10 SRVs, 10 SRVs). No passed tests.

1. The operating experience summarized in the above table is based on the LERs identified by an ADAMS search and is meant to reflect the generic status; it should not be used for any plant-specific review. Also, the table reflects data for SRV setpoint drift for two-stage Target Rock SRVs with significant ST failures only, except for Edwin I. Hatch Nuclear Plant (Hatch), Units 1 and 2. The table does not reflect the data for the following: (1) other BWRs experiencing a low ST failure rate with two-stage Target Rock SRVs, (2) using different manufacturer SRVs not subject to setpoint drift issue similar to two-stage Target Rock SRVs, or (3) using three-stage Target Rock SRVs (except for Hatch, Units 1 and 2, which includes failure rates for two-stage and three-stage SRVs).
2. Assumed the licensee passed the SRV STs when there was no LER written.
3. Hatch, Units 1 and 2, has already replaced their two-stage SRVs with all three-stage SRVs. This corrective action should resolve the issue going forward.

ACCEPTANCE GUIDELINES FOR CHANGE IN CORE DAMAGE FREQUENCY (∆CDF) IN REGULATORY GUIDE (RG) 1.174

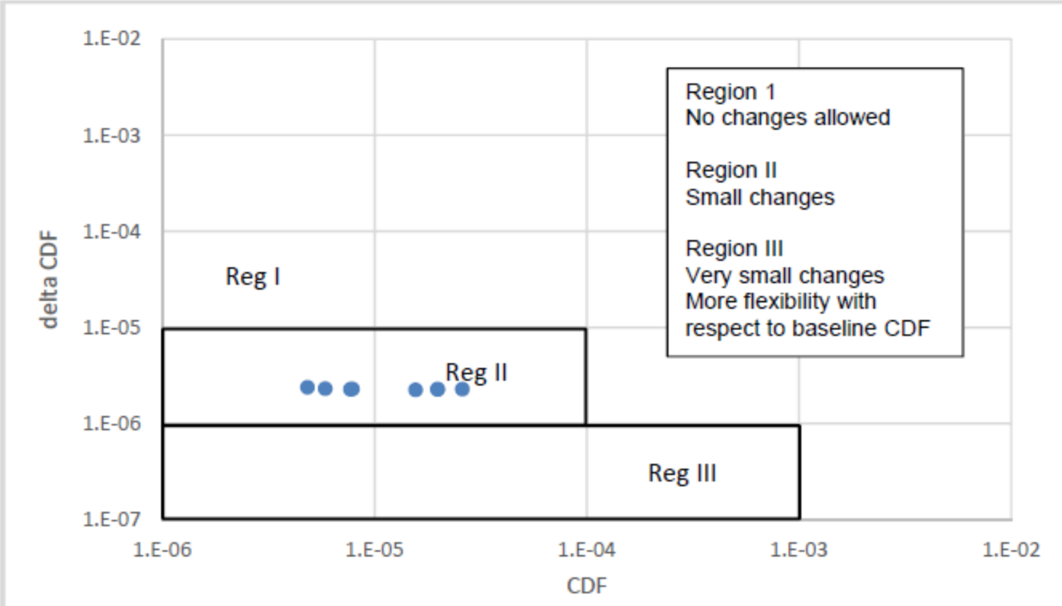

Figure 1: Acceptance Guidelines for ∆CDF in RG 1.174 when Failure=True (Dots represent results of the plant-specific analysis)

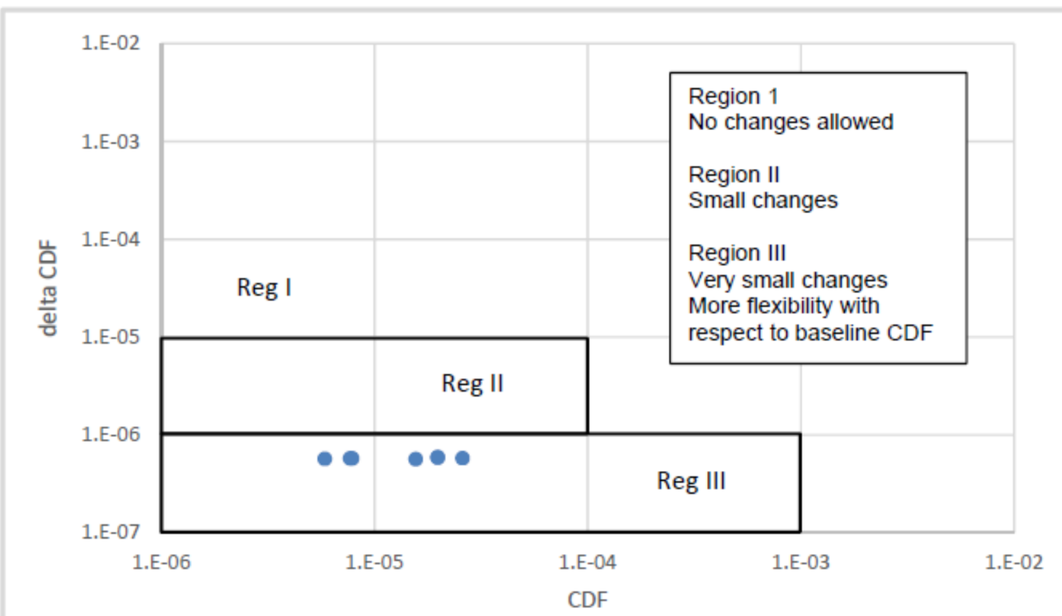

Figure 2: Acceptance Guidelines for ∆CDF in RG 1.174 when Failure=100X nominal (Dots represent results of the plant-specific analysis)

Enclosure 3