<u>DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION</u>

<u>ELECTRIC POWER RESEARCH INSTITUTE TECHNICAL REPORT 3002019621</u>

<u>SUSCEPTIBILITY OF VALVE APPLICATIONS TO FAILURE OF THE</u>

<u>STEM-TO-DISK CONNECTION</u>

1.0 INTRODUCTION

By letter dated April 28, 2021, the Electric Power Research Institute (EPRI) submitted Technical Report (TR) 3002019621, Revision 0, "Susceptibility of Valve Applications to Failure of the Stem-to-Disk Connection," to the U.S. Nuclear Regulatory Commission (NRC) staff for review and approval (Agencywide Document Access and Management System Accession No: ML21126A233). The purpose of this TR is to provide a methodology and basis for operating nuclear plants to apply American Society of Mechanical Engineers (ASME) *Code for Operation and Maintenance of Nuclear Power Plants* (OM Code) Code Case OMN-28, "Alternative Valve Position Verification Approach to Satisfy ISTC-3700 for Valves Not Susceptible to Stem-Disk Separation.".

2.0 REGULATORY EVALUATION

The NRC regulations in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(f)(4), "Inservice testing standards requirement for operating plants," state that throughout the service life of a boiling or pressurized water-cooled nuclear power facility, pumps and valves that are within the scope of the ASME OM Code must meet the IST requirements (except design and access provisions) set forth in the ASME OM Code and addenda that become effective subsequent to editions and addenda specified in 10 CFR 50.55a(f)(2) and (3) and that are incorporated by reference in 10 CFR 50.55a(a)(1)(iv), to the extent practical within the limitations of design, geometry, and materials of construction of the components. The IST requirements for pumps and valves that are within the scope of the ASME OM Code but are not classified as ASME *Boiler and Pressure Vessel Code* (BPV Code) Class 1, Class 2, or Class 3 may be satisfied as an augmented IST program in accordance with 10 CFR 50.55a(f)(6)(ii) without requesting relief under 10 CFR 50.55a(f)(5) or alternatives under 10 CFR 50.55a(z). This use of an augmented IST program may be acceptable provided the basis for deviations from the ASME OM Code, as incorporated by reference in 10 CFR 50.55a, demonstrates an acceptable level of quality and safety, or that implementing the Code provisions would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety, where documented and available for NRC review.

Valves are nominally exercised in accordance with ASME OM Code, Subsection ISTC "Inservice Testing of Valves in Water-Cooled Reactor Nuclear Power Plants", paragraph ISTC-3520, "Exercising Requirements," and all the moving parts of a valve are verified by paragraph ISTC-3530, "Valve Obturator Movement," and paragraph ISTC-3700, "Position Verification Testing." In addition, operating plants will be required to perform the condition noted in 10 CFR 50.55a(b)(3)(xi), "OM condition: Valve Position Indication," which states:

> "When implementing paragraph ISTC–3700, "Position Verification Testing," in the ASME OM Code, 2012 Edition through the latest edition and addenda of the ASME OM Code incorporated by reference in paragraph (a)(1)(iv) of this section, licensees shall verify that valve operation is accurately indicated by supplementing valve position indicating lights with other indications, such as flow meters or other suitable instrumentation to provide assurance of proper obturator position for valves with remote position indication within the scope of Subsection ISTC including its mandatory appendices and their verification methods and frequencies."

The NRC regulations in 10 CFR 50.55a(z), "Alternatives to codes and standards requirements," state that alternatives to the requirements of 10 CFR 50.55a(b) through (h) or portions thereof may be used when authorized by the Director, Office of Nuclear Reactor Regulation. A proposed alternative must be submitted and authorized prior to implementation. The applicant or licensee must demonstrate that:

(1) *Acceptable level of quality and safety.* The proposed alternative would provide an acceptable level of quality and safety; or

(2) *Hardship without a compensating increase in quality and safety.* Compliance with the specified requirements of this section would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

3.0 TECHNICAL EVALUATION

3.1 Background

ASME established a committee in 1911 for the purpose of formulating standard rules for the construction of steam boilers and other pressure vessels. During the early days of nuclear power plant design and construction, it was determined that a special set of rules would be needed. In 1971, ASME published the *Boiler and Pressure Vessel Code* (BPV Code), Section III, "Rules for Construction of Nuclear Power Plant Components," and ASME BPV Code, Section XI, "Rules for Inservice Inspection of Nuclear Reactor Coolant Systems."

ASME BPV Code, Section XI, established the requirements for testing and examination of piping, welds, and repairs. Section XI was later updated in 1973 summer addenda to include test requirements for pumps designated as section IWP and valves designated as section IWV.

Section IWV stated that its object was to test and verify valve operational readiness on a continuing basis. There were three major tests for Category A (valves with a seat leakage limit) and Category B (valves with no leakage limit):

1) IWV-2104, "Exercising," in the definition section states, "Exercising is the demonstration based on direct or indirect visual or other positive indication that the moving parts of a valve function satisfactorily." IWV-3410(2)(b), "Valve Exercising Test," which states, "The necessary valve stem or disk movement shall be established by exercising the valve while observing either an appropriate indicator which signals the required change

of valve stem or disk position, or indirect evidence, such as changes in system pressure, flowrate or temperature which reflect stem or disk position."

2) IWV-3300, "Check of Valve Position Indicator," which states, "All valves with remote position indicators, which during power operation are inaccessible for direct observation, shall be visually observed at the same (or greater) frequency as scheduled refueling outages but not less than one observation every two years, to confirm that remote valve indications accurately reflect valve operation."
3) IWV-3420, "Valve Leak Rate Test," which states in part that, "Category A valves shall be leak tested. Tests shall be conducted at the same (or greater) frequency as scheduled outages but not less than once every two years."

As the ASME BPV Code, Section XI, evolved, these three requirements remained the same with the exception that the paragraph IWV-3300 title changed to Valve Position Indicator Verification, and the requirement was simplified to: "Valves with remote position indicators shall be observed at least once every 2 years to verify that valve operation is accurately indicated."

The ASME BPV Code, Section XI, valve exercise requirements can be summed up as:

1) Valve exercise test shall demonstrate that the valve functions satisfactorily (all moving parts are working).
2) Once every two years, there is a need to locally observe the valve to make sure that the valve and indicating lights are operating correctly and the overall condition and performance of the valve moving parts are acceptable.

In June 1975, the Committee on Operation and Maintenance of Nuclear Power Plants (Operation and Maintenance (O&M) Committee) was formed when the N45 Committee was disbanded. The N45 Committee was established by the American National Standards Institute (ANSI) and was officially known as the Committee N45 on Reactor Plants and Their Maintenance. The N45 Committee was chartered to promote the development of standards for the location, design, construction, and maintenance of nuclear reactors and plants embodying nuclear reactors, including equipment, methods, and components. The scope of the O&M Committee was to identify, develop, maintain, and review codes and standards that are considered necessary for the safe and efficient operation and maintenance of nuclear power plants, particularly as they relate to structural and functional adequacy.

By 1981, the O&M Committee had published five standards which were later consolidated into one single publication, ASME/ANSI OM-1987, *Operation and Maintenance of Nuclear Power Plants*, issued on December 15, 1987. The five standards were:

1) OM-1-1981 - Requirements for Inservice Performance Testing of Nuclear Power Plant Pressure Relief Devices (ASME/ANSI OM-1987 Part 1)
2) OM-2-1982 - Requirements for Performance Testing of Nuclear Power Plant Closed Cooling Water Systems (ASME/ANSI OM-1987 Part 2)
3) OM-3-1982 - Requirements for Preoperational and Initial Start-up Vibration Testing of Nuclear Power Plant Piping Systems (ASME/ANSI OM-1987 Part 3)
4) OM-4-1982 - Examination and Performance Testing of Nuclear Power Plant Dynamic Restraints (Snubbers) (ASME/ANSI OM-1987 Part 4)

5) OM-5-1981 - Inservice Monitoring of Core Support Barrel Axial Preload in Pressurized Water Reactors (ASME/ANSI OM-1987 Part 5)

The O&M Committee was given responsibility to review ASME BPV Code, Section XI, and determine where O&M standards could replace current ASME BPV Code, Section XI, requirements. It was determined that pumps and valves were major areas in ASME BPV Code, Section XI, as requiring O&M standards. The ASME/ANSI OM-1987 first addenda was issued on July 14, 1988, as ASME/ANSI OMa-1988. It added the following standards:

1) Part 6 - Inservice Testing of Pumps in Light-Water Reactor Power Plants
2) Part 7 - Requirements for Thermal Expansion Testing of Nuclear Power Plant Piping Systems
3) Part 8 - Start-up and Periodic Performance Testing of Electric Motor Operators on Valve Assemblies in Nuclear Power Plants (place holder due to in preparation)
4) Part 9 - Requirements for Inservice Performance Testing of Radioactive Material Handling Cranes (place holder due to in preparation)
5) Part 10 - Inservice Testing of Valves in Light-Water Reactor Power Plants

It was the development of the ASME/ANSI OMa-1988 addenda where the requirements for valve exercise and position indicator verification gets updated, confusing, and open for interpretation:

1) IWV-2104 is placed in Section 1.3, "Exercising Terminology." - The wording remained the same: "Demonstration based on direct or indirect visual or other positive indication that the moving parts of a valve function satisfactorily."
2) IWV-3410(2)(b) changed to Section 4.2.1.3, "Valve Obturator Movement." - The wording was updated to: "The necessary valve obturator movement shall be determined by exercising the valve while observing an appropriate indicator, such as indicating lights which signal the required change of obturator position, or by observing other evidence, such as changes in system pressure, flow rate, level, or temperature, which reflect change of obturator position." The intent of this change was to allow observation of indicating lights, if equipped, as verification of all the valve moving parts because the exercise test was required to be performed nominally every three months. The indicating lights would be verified to accurately reflect proper valve operation by section 4.1, "Valve Position Verification," once every 2 years.
3) IWV-3300, "Check of Valve Position Indicator," was changed to 4.1, "Valve Position Verification." – The wording was updated to: "Valves with remote position indicators shall be observed locally at least once every 2 years to verify that valve operation is accurately indicated. Where practicable, this local observation should be supplemented by other indications such as use of flow meters or other suitable instrumentation to verify obturator position. These observations need not be concurrent. Where local observation is not possible, other indications shall be used for verification of valve operation." The intent of this change was to locally observe the valve and if practicable supplement the valve operation with other positive means. The two actions need not be concurrent. This was written this way for valves that couldn't be tested or locally observed during normal operation. Performance of valve exercise and the local observation at shutdown conditions usually has no other supplemental indications

(pressure or flow). The intent was to allow local observation and when systems returned to normal, verify proper valve operation via changes in supplemental indicators. However, many have interpreted this to mean go to the valve once every two years and watch the stem go up and down and not having to supplement because it was impracticable due to no dynamic conditions at the time of observance.

The ASME Board on Nuclear Codes and Standards recognized that O&M is the appropriate committee to establish inservice testing (IST) requirements and voted to proceed with making the O&M Standard stand on its own, with the objective of eventual deletion of IST from Section XI of the BPV Code when appropriate. A transition was implemented in which Part 1 (pressure relief devices), Part 4 (dynamic restraints or snubbers), Part 6 (pumps), and Part 10 (valves) of ASME/ANSI OM-1987 were incorporated into ASME OM Code-1990, "Code for Operation and Maintenance of Nuclear Power Plants." The ASME OM Code 1990 Edition was issued on October 15, 1990.

Publication of the ASME OM Code 1990 Edition was reformatted with only one section, "IST Rules for Inservice Testing of Light-Water Reactor Power Plants." Section IST was divided into four Subsections, a mandatory appendix, and four nonmandatory appendices as noted in the following table:

OM Code 1990	Previous OM-1987	OM Code 1990 Title
ISTA		General Requirements
ISTB	Part 6	Inservice Testing of Pumps in Light-Water Reactor Power Plants
ISTC	Part 10	Inservice Testing of Valves in Light-Water Reactor Power Plants
ISTD	Part 4	Inservice Testing of Dynamic Restraints (Snubbers) in Light-Water Reactor Power Plants
Mandatory Appendix I	Part 1	Inservice Testing of Pressure Relief Devices in Light-Water Reactor Power Plants
Nonmandatory Appendix A		Preparation of Test Plans
Nonmandatory Appendix B		Dynamic Restraint Examination Checklist Items
Nonmandatory Appendix C		Dynamic Restraint Design and Operating Information
Nonmandatory Appendix D		Comparison of Sampling Plans for Inservice Testing of Dynamic Restraints

With the format update to the first ASME OM Code 1990 Edition, the following changes were made to the valve testing requirements:

1) Section 1.3 was changed to ISTC 1.3, "Definitions." - The wording remained the same: "Demonstration based on direct or indirect visual or other positive indication that the moving parts of a valve function satisfactorily."
2) Section 4.2.1.3 was changed to ISTC 4.2.3, "Valve Obturator Movement." – The wording remained the same: "The necessary valve obturator movement shall be determined by exercising the valve while observing an appropriate indicator, such as indicating lights which signal the required change of obturator position, or by observing other evidence,

such as changes in system pressure, flow rate, level, or temperature, which reflect change of obturator position."

3) Section 4.1 was changed to ISTC 4.1, "Valve Position Verification." - The wording remained the same: "Valves with remote position indicators shall be observed locally at least once every 2 years to verify that valve operation is accurately indicated. Where practicable, this local observation should be supplemented by other indications such as use of flow meters or other suitable instrumentation to verify obturator position. These observations need not be concurrent. Where local observation is not possible, other indications shall be used for verification of valve operation."

The ASME OM Code is a national, voluntary consensus standard. The NRC mandates the use of editions and addenda to the ASME OM Code in 10 CFR 50.55a, "Codes and standards," through the rulemaking process of "incorporation by reference." With respect to the evaluation of EPRI Technical Report 3002019621, Revision 0, the following is a high level timeline on the need for this report based on the development of the ASME OM Code from 1989:

Date	Description
8/3/1989	Generic Letter (GL) 89-04, "Guidance on Developing Acceptable Inservice Testing Programs," issued to provide clarification on the requirements and reduce alternative request backlog
10/25/1989	NRC staff issues "Minutes of the Public Meetings on Generic Letter 89-04," to provide useful information on how to apply the guidance of GL 89-04
9/8/1992	1989 edition of Section XI was incorporated by reference into paragraph 50.55a(b)
1995	National Technology Transfer and Advancement Act of 1995 P.L. 104-113 requires Federal agencies to use industry consensus standards to the extent practical.
4/1995	NUREG 1482, Revision 0, "Guidelines for Inservice Testing at Nuclear Power Plants," is issued to assist industry in eliminating unnecessary alternative requests.
4/1995	NUREG 1482, Revision 0, Section 4.2.5, "Verification of Remote Position Indication for Valves by Methods Other Than Direct Observation," provides recommendations on how to verify once every 2 years that valve position is accurately indicated emphasizing the point that if remote valve position cannot be verified by local observation at the valve, an acceptable approach is for the licensee to observe operational parameters such as leakage, pressure, and flow that give positive indication of the valve's actual position(s).
1997	NRC staff publishes meeting minutes questions and answers of Public Workshops discussing Inspection Procedure (IP) 73756, "Inservice Testing of Pumps and Valves." Question 2.2.8 - For certain types of valves that can be observed locally, but for which valve stem travel does not ensure that the stem is attached to the disk, the local observation must be supplemented by other indications. If this test is not practicable, such as lack of instruments to observe operating parameters, does this Code requirement apply?

Date	Description
	NRC Response - Yes, when local observation is not possible, the Code requires that other indications must be used. If this is not practical, relief must be requested.
7/31/1998	ASME OM Code 1998 Edition completely reformatted. ISTC 1.3, "Definitions," was changed to ISTC-2000, "Supplemental Definitions." The definition of "Exercising" wording remained the same. ISTC 4.2.3, "Valve Obturator Movement," was changed to ISTC-3530, "Valve Obturator Movement," and the wording remained the same. ISTC 4.1, "Valve Position Verification," was changed to ISTC-3700, "Position Verification Testing," and the wording remained the same.
11/2/2001	ASME OM Code 2001 Edition – Definition of "Exercising" was removed from ISTC-2000, "Supplemental Definitions," and was placed in ISTA-2000, "Definitions," and the wording was changed to read, "Demonstration based on direct visual or indirect positive indications that the moving parts of a component function." By moving this definition from the valve Subsection ISTC to the General Requirements Subsection ISTA and changing the word "valve" to "component," this reduces the clarity even more on evaluating the valve moving parts during an exercise test.
2/26/2010	ASME OM Code 2009 Edition - ISTC-3700, "Position Verification Testing," was revised to add a sentence to read, "Position verification for active motor-operated valves (MOV) shall be tested in accordance with Mandatory Appendix III of this Division." All other wording remained the same.
10/23/2010	A motor-operated valve (MOV) at Browns Ferry experienced a stem-to-disk failure resulting in a red inspection finding. The initial NRC inspection noted that the licensee was mis-applying the requirements of ISTC-3700 for verifying valve operation is accurately indicated at least once every two years (in particular, watching the stem move up and down only). A special independent review team concluded that the ASME OM Code is not clear with respect to the extent to which the ASME OM Code requires certainty in the verification of obturator position during testing.
7/18/2017	The NRC staff worked with the ASME consensus process to clarify and improve the wording in ISTC-3700. After five years, consensus could not be reached. The NRC specified condition 10 CFR 50.55a(b)(xi) to emphasize the provisions in the ASME OM Code, 2012 Edition, Subsection ISTC-3700, "Position Verification Testing:" "Licensees shall verify that valve operation is accurately indicated by supplementing valve position indicating lights with other indications, such as flow meters or other suitable instrumentation to provide assurance of proper obturator position for valves with remote position indication within the scope of Subsection ISTC including its mandatory appendices and their verification methods and frequencies." This condition goes into effect when plants update their IST program to the 2012 or later Editions of the ASME OM Code.
3/16/2021	ASME OM Code developed and issued ASME OM Code Case OMN-28. In lieu of having to perform ISTC-3700 and 10 CFR 50.55a(b)(xi) once every 2 years, Code Case OMN-28 allows performance of this verification to be completed once every 12 years for those valves determined to be not susceptible to stem-to-disk separation.
3/26/2021	The NRC issued a proposed rule in the Federal Register (86 FR 16087) to incorporate by reference the 2020 Edition of the ASME OM Code into 10 CFR

Date	Description
	50.55a. The proposed rule included a revision to 10 CFR 50.55a(b)(xi), as follows: "For valves not susceptible to stem-disk separation, position verification testing specified in ISTC-3700 may be performed on a 10-year interval where the licensee documents a justification, which is made available for NRC review, demonstrating that the stem-disk connection is not susceptible to separation based on the internal design and evaluation of the stem-disk connection using plant-specific and industry operating experience (OE) and vendor recommendations." This proposal was developed by NRC staff working in parallel with the industry consensus staff that developed ASME OM Code Case OMN-28. The NRC staff is currently considering finalizing the rule to adopt OMN-28 in its entirety.
9/2020	EPRI personnel worked with ASME OM Code Committees on the development of Code Case OMN-28. EPRI saw the need for a technical report to assist licensees and NRC inspectors in evaluating valve susceptibility to stem-to-disk separation. Thus, TR 3002019621, Revision 0, was created and issued.

3.2 TR 3002019621, Revision 0 Summary

TR 3002019621, Revision 0, reviews information to determine whether specific valve designs are susceptible to separation of the stem and disk. In particular, the TR reviews various valve stem-to-disk connection designs and evaluates their performance over 43 years of operating experience (OE) for susceptibility to separation under different operating conditions. It also discusses verification methods that can be used to provide indication that the stem-to-disk connection is intact for various valve types. It does not recommend supplemental verification intervals but does provide some information that may be useful in determining an interval. In addition, the TR discusses several NRC generic communications that are associated with valve failures due to stem-to-disk separation.

Key findings of this TR include:

1) A total of 226 stem-to-disk failures were identified over a period of 43 years from 1977 through 2019 for an average failure rate of 5.3 failures per year. This failure rate included safety-related and non-safety-related valves. It is understood that safety-related valves may have more rigor with respect to design and preventive maintenance activities which may yield smaller failure rates. However, the purpose of this TR was to examine all failures to better understand the susceptibility of specific stem-to-disk connection designs to stem-to-disk separation under specific operating conditions. A table listing all the stem-to-disk failures is provided in Attachment A located at the end of the TR report.
2) Ten common stem-to-disk connection designs were identified.
3) There are several methods that can be used to provide direct indication that the stem-to-disk connection is intact for various valve types.
4) There are several lessons that the industry has learned over the years related to minimizing the potential for stem-to-disk separation. These lessons should be incorporated into plant processes and procedures as appropriate.

3.3 Ten Common Stem-to-Disk Design Evaluation

3.3.1 Keyed

This design is typically found in butterfly valves where the disk is keyed to the stem. The TR did not identify any failures of this nature thus considering this design to be not susceptible to stem-to-disk separation. The TR does emphasize the need to have maintenance procedures that provide guidance on key installation and appropriate position retention techniques for example staking of the keys.

The NRC staff completed its own review of industry OE events from the Institute of Nuclear Power Operations (INPO) Industry Reporting Information System (IRIS) database and found the following:

INPO Event ID	Event Title	Failure Comments
178025	2/4/1999 - Failure of Essential Service Water System butterfly valve SWN-41-2B	10" Clow butterfly MOV that failed to close. Apparent cause was excessive clearances on the disk and keys allowing the shaft to place force on shaft alignment pins. These pins were not designed to absorb the force and they sheared allowing the disk to float on the shaft and eventually hung up when trying to close.
184845	2/23/2000 - Failure of Essential Service Water System butterfly valve SWN-41-4B	10" Clow butterfly MOV that failed to close. Apparent cause was excessive clearances on the disk and keys allowing the shaft to place force on shaft alignment pins. These pins were not designed to absorb the force and they sheared allowing the disk to float on the shaft and eventually hung up when trying to close.
148601	10/2/1994 - Failure of Essential Service Water System butterfly valve	Butterfly MOV failed to open. Apparent cause was a sheared key on the shaft due to over torque or material defect.
149383	11/2/1994 - Failure of Primary Containment Isolation Valve 1VC5	Butterfly air-operated valve (AOV) failed to open. Apparent cause was valve shaft key sheared due to normal aging cyclic fatigue.
169912	12/12/1997 - Failure of Closed/Component Cooling Water System pneumatic valve operator (AOV)	Butterfly AOV that was binding. This was not a key failure. However, it was noted in the failure history description that this valve was disassembled in 1994 to replace a sheared disk-to-stem key.

The NRC staff identified six other OE events involving a sheared key or pin. However, it was not clear if the sheared component was the part connecting the disk to the shaft or the piece that couples the shaft to the actuator or manual handwheel. The keyed design is not totally non-susceptible to failure. However, with proper attention to detail such as key material, dimensions, force being applied, vendor recommendations, and periodic preventive maintenance, this design can be considered not susceptible to disk-to-stem failure.

3.3.2 Socketed/Splined

The socketed design is typically found in ball valves where the end of the stem has a rectangular cross-section that fits into a rectangular hole in the ball. Ball valves are a type of control valve that features a spherical disk inside. This disk has a hole in it that is called a port. When the port is in line with both ends of the valve, the valve is open and allows medium to flow through it easily. When the port is perpendicular to the ends of the valve, the valve is closed, and the fluid flow stops.

A valve with a splined connection on the stem can be found in eccentric plug valves. A plug valve is named so because it features a conically tapered or cylindrical disk that resembles a plug. The plug features one or more passages going sideways through the plug that allow the fluid to pass through them. When the bored passage is in line with the flow, the valve is open and the fluid can flow through it freely. When the plug is turned, the solid part of the plug blocks the flow, hence closing the valve. Plug valves are similar to the ball valve design in operation. Both are considered a rugged design and as noted in the TR, there have been very few failures.

The NRC staff reviewed INPO IRIS database for these types of valve failures and found two additional events:

INPO Event ID	Event Title	Failure Comments
192008	4/24/2001 - Delayed power ascension due to failure of stem in HP Heater and MSR Drains and Vents System ball valve 3HD-269	Dump valve 3HD-269 failed closed due to the valve stem separation from the valve causing an actual high level in heater allowing the disk to float on the shaft and eventually hung up when trying to close.
216819	7/5/2005 - Failure of pin(s) in Essential Service Water System pneumatic valve operator (AOV) that supports Aux. Bldg. Environmental Control System cooler 2CHE18	Ball valve failed closed due to the actuating pin being broken where it connects to the scotch yoke, a slotted arm that converts the linear action of the actuator piston to rotary motion to turn the valve.

The NRC staff agrees that the socketed/splined design has a very low failure rate and can be considered to be non-susceptible to stem-to-disk failure. The NRC staff believes that the scotch yoke design interface should also be included in this category due to its design to convert linear motion to a quarter turn rotating motion. The scotch yoke design can have a spline connection, rectangular cross section connection, pinned, or keyed.

3.3.3 Integral/Single Piece

The integral/single piece design is a stem and disk that are machined from the same bar stock. There is no stem-to-disk connection that can fail. This type of design is typically found in smaller globe and/or plug valves. The TR does identify one stem failure that was due to cycling after a thermal transient which caused the valve internals to tighten leading. The NRC staff agrees that the integral/single piece design has a very low failure rate and can be considered to be non-susceptible to failure. Precautionary considerations include periodic preventive maintenance, vendor recommendations, system conditions, stem material susceptible to embrittlement, and thermal transients.

3.3.4 Threaded and Welded

This design is typically found in gate or globe valves where the stem is threaded into the disk or plug then welded. The TR identified four events which appear to be isolated issues due to design, manufacturing, or maintenance and considers this low failure rate to be essentially non-susceptible to stem-to-disk separation.

The NRC staff reviewed INPO IRIS database for these types of valve failures and found several additional events using the key words “tack weld”:

INPO Event ID	Event Title	Failure Comments
69978	8/16/1988 - Failure of RHR Supp Pool Full Flow Disch Isol Valve MO-2009	Anchor/Darling globe valve that had the stem and the disk breaking apart due to a failed tack weld.
89572	1/7/1990 - Failure of weld in Condensate System globe valve	Velan globe valve that stem nut and plug had separated from the stem due to a broken tack weld.
99364	9/20/1990 - Failure of weld in Closed/Component Cooling Water System globe valve	Velan globe valve disk separated from the stem due to a broken tack weld.
102576	12/6/1990 - Forced normal Rx shutdown due to failure of RHR/LPCI System (BWR) gate valve HV-051-1F068B	Anchor/Darling gate valve (MOV) that had process water enter the threaded area between the valve disk and disk nut causing threads to weaken. The threads eroded and the tack weld failed separating the disk from the stem.
132723	12/29/1992 - Failure of weld in Essential Service Water System globe valve.	Crane globe valve that had vibration cause loss of stem guide retainer and broke the tack weld allowing the stem to unscrew from the disk.
227104	6/7/2007 - Broken Tack Welds on Condensate Pump Recirc/Fill Valve	Broken tack weld on disk plug stem ring allowed the plug to unscrew from the stem.

In addition to the six additional OE involving a gate or globe valve, eleven OE involving check valves that experienced a broken tack weld occurred. It is noted that the TR did not address check valves or relief valves. Check and relief valve failures typically are self-revealing at the time of failure and they rarely have remote position indication which would not require testing per ASME OM Code, Subsection ISTC, paragraph ISTC-3700.

However, the failure rate for valves that rely on a tack weld increases the susceptibility to failure. The NRC staff agrees that this type of valve connection design can be considered to be non-susceptible to failure provided that a preventive maintenance measure be in place that reviews system conditions for vibration, system fluid that could affect the threaded connection (untreated water), verification that the weld (if applied) is sufficient, and follow vendor recommendations.

3.3.5 Captured and Free

In this design, the end of the stem is captured by a sleeve that is threaded into the top of the disk and then welded (or otherwise secured) to the disk. There is a clearance between the stem and the sleeve/disk such that the stem has some axial freedom of movement relative to the disk. This design is used primarily in globe valves.

The NRC staff reviewed the INPO IRIS database for the model valves listed in Appendix A of the TR that had stem-to-disk valve failures and found three additional events:

INPO Event ID	Event Title	Failure Comments
76821	2/15/1989 - Failure of Essential Service Water System globe valve	When attempting to close this globe valve, the valve was found to have a broken stem. Apparent cause was overtorqueing the valve on its previous operation.
109431	5/17/1991 - Failure of Feedwater System gate valve	During inspection of a special hydrostatic pressure test, it was discovered that the valve stem was broken. Apparent cause was excessive force applied during closing. The report states that this is a gate valve, but it is the same Crane model 3652 valve as INPO report # 241014, which is a globe valve.
142351	12/21/1993 - Failure of Main Steam Turbine Bypass Valve	During a plant startup, it was discovered that this valve disk was found broken off and laying inside the valve body. Apparent cause unknown.

The NRC staff agrees with the TR summary that this type of valve design does not appear to have any common issues or themes for failures with the exception that a few of the failures were caused by excessive force used by maintenance personnel to operate the valve. The failure rate for this design can be considered to be very low and essentially not susceptible to stem-to-disk separation. Lessons learned on application of excessive force should be considered.

3.3.6 Bolted

In this design, the end of the stem is threaded, and the disk is rigidly attached to the stem with a clamping nut. There is typically a locking device on the nut, such as a cotter pin, star washer, or weld. This design is used primarily in globe valves.

The NRC staff reviewed INPO IRIS database for the model valves listed in Appendix A of the TR that had stem-to-disk valve failures and found an additional event:

INPO Event ID	Event Title	Failure Comments
207847	12/17/2003 - Auxiliary Feedwater Flow Control	4” globe valve had reduced flow. Inspection of valve found missing cotter pin that secures the hex

INPO Event ID	Event Title	Failure Comments
	Valve Cotter Pin Degradation	nut, pilot plug spacer, and washer on the valve plug which became dislodged and was obstructing flow.

The NRC staff has reviewed the operating experience with this type of valve design and agrees with the TR conclusions that the failure rate is low and that it can be essentially considered to be not susceptible to stem-to-disk separation provided that attention and precautions are made with vendor recommendations and evaluation of system vibration impact on internal connection components.

3.3.7 Captured and Clamped

This design is the same as the captured and free design except that the stem T-head is "clamped" between the sleeve and disk such that the stem T-head cannot move relative to the sleeve/disk in the direction of motion. This design is used primarily in globe valves.

Because there is no axial clearance between the stem and disk (i.e., the stem head is clamped), flow-induced loads imposed on the disk are translated to the stem-to-disk connection. As a result, this design is susceptible to flow induced failures (e.g., due to vibration).

The NRC staff reviewed INPO IRIS database for the model valves listed in Appendix A of the TR that had stem-to-disk valve failures and found an additional event plus some comments:

INPO Event ID	Event Title	Failure Comments
231497	3/25/2008 - Outage impacted due to failure of stem/plug assembly in Primary Containment Isolation Valve 3-FCV-023-0040	Failure of the anti-rotation weld and subsequent fretting failure of the threads. This event is similar to INPO event 231486 listed in the table in Appendix A.
245831	10/23/2010 - AP-913 failure event due to failure of disk and weld in RHR/LPCI System (BWR) globe valve 1-FCV-074-0066	This event was captured in Appendix A table for valve design that is threaded and welded. However, this actually should be placed in the Captured and Clamped category. This is a 24" Walworth globe valve with a T-head stem captured via screw in skirt. The skirt is tack welded to the disk.
522	2/1/1975 - Failure of weld in RHR/LPCI System (BWR) globe valve	This is the same model valve as INPO event 245831. The failure discovery was part of an extent of condition investigation due to a stem-to-disk separation that occurred in 1974 which does not appear in INPO database due to not being in existence. The failure was a Part 21 notification where the recommended fix was to increase the weld holding the skirt. This recommendation was

INPO Event ID	Event Title	Failure Comments
		not applied to the valve in OE 245831 resulting in failure.

The TR notes that about half of the valve failures were due to generic issues with design and/or application. The other half of the OE events involve system vibration that affect valve internal anti-rotation measures or tack welds and staking of components to keep the stem-to-disk intact. The NRC staff agrees that this type of valve connection design can be considered to be non-susceptible to failure provided that a preventive maintenance measure be in place that reviews system conditions for vibration, system fluid that could affect the threaded connection (untreated water), verification that the weld (if applied) is sufficient, and follow vendor recommendations.

3.3.8 Pinned

In this design, which is used in many butterfly designs, the disk is pinned to the stem at the top and a stub shaft or trunnion at the bottom. This design is potentially susceptible to the following key failures:

1) Shear failure of the pins due to flow induced vibration
2) Backing out of the pins due to flow-induced vibration or inadequate locking of the pins (in some cases, one pin may back out and cause the remaining pin or pins to fail in shear)

The TR details that there were 44 failures of this design. The NRC staff reviewed INPO IRIS database for this design and found several events that were considered failures but not necessarily complete failure of the stem-to-disk connection:

INPO Event ID	Event Title	Failure Comments
9582	9/19/1982 - Failure of Essential Service Water System butterfly valve	Found the valve shaft broken and the valve bushings and pins were severely worn.
15155	3/2/1984 - Failure of Essential Service Water System butterfly valve	Valve was discovered leaking by due to worn seal ring and pins.
15765	3/27/1984 - Failure of Containment Leakage Control System butterfly valve	Valve failed leak test. The seat and seal were found damaged with the cause being a dowel pin backing out of the shaft.
26508	4/18/1985 - Failure of Containment Leakage Control System butterfly valve	Valve failed leak test. Disk-to-stem pin found to be loose.
34117	11/27/1985 - Failure of Closed/Component Cooling Water System butterfly valve ACCMVAAA126-A	Valve was not operating correctly and was slamming. Disassembly revealed the shaft pins were missing.

INPO Event ID	Event Title	Failure Comments
41073	6/2/1986 - Failure of Essential Service Water System butterfly valve	Valve was leaking due to worn seats and stem pins.
42125	6/27/1986 - Failure of Containment Spray Discharge to Header Isolation Valve.	Valve was leaking. The valve liner was worn out and the valve disk to shaft taper pin holes were elongated causing the disk to wobble.
42875	7/18/1986 - Failure of Condensate Demin Bypass Valve 2-CP-AOV-3B-VALVE	Valve was leaking. The cause was due to loose taper pins on the disk and worn bearings.
44695	9/11/1986 - Failure of Essential Service Water System butterfly valve 11SW58	Valve disk was found loose on the shaft caused by worn pins due to high silt content of the service water.
52185	4/14/1987 - Failure of Closed/Component Cooling Water System butterfly valve	Valve was leaking caused by a loose taper pin.
79497	4/21/1989 - Failure of Essential Service Water System butterfly valve 2CV14272	Valve was leaking caused by corroded carbon steel dowel pins resulting in a rough surface causing the disk to cock.
85244	9/20/1989 - Failure of Condensate Demin Bypass Valve 2-CP-AOV-3B-VALVE	Valve was leaking caused by loose disk-to-stem dowel pins that were worn.
85948	10/6/1989 - Failure of Essential Service Water System butterfly valve 2CV14251	Valve would not fully close due to roll pins on the disk backing out causing the disk to drop down and misalign.
86035	10/9/1989 - Failure of Essential Service Water System butterfly valve 2CV14222	Valve was leaking past its seat. The seat was damaged due to foreign material. It was later discovered that the foreign material was the dowel pins had dropped out from corrosion.
86489	10/19/1989 - Failure of Primary Containment Isolation Valve 3JCPAUV0002B	Valve had excessive leakage. The cause of the failure was a sheared thrust collar pin causing the disk to be out of alignment.
105976	3/2/1991 - Failure of Essential Service Water System butterfly valve.	Valve leaking past the seat. The cause was corroded pins that hold the valve disk in place.
115087	10/22/1991 - Failure of Primary Containment Isolation Valve EFHV0032	Valve leaking past the seat. The cause was erosion and corrosion of the valve disk.
120628	3/4/1992 - Failure of Primary Containment	Valve leaking past the seat. Apparent cause was wear on the groove pins that hold the disk to the valve stem allowing the disks to move slightly.

INPO Event ID	Event Title	Failure Comments
	Isolation Valve 2-SW-MOV-204B-VALVE	
131853	11/27/1992 - Failure of Aux/Emergency Feedwater Pump Alt Source Suction Valve ALHV0031	Valve leaking past the seat. The cause of the leakage was erosion and corrosion of the valve disk and body.
135491	3/31/1993 - Failure of Essential Service Water System butterfly valve 13SW58	Valve failed to open. The cause was the valve disk and pins were worn out from normal wear being in an untreated service water system.
135553	4/2/1993 - Failure of Essential Service Water System butterfly valve	Valve leaking past the seat. The valve leaked by due to worn bushing guide, valve liner, and shaft pin.
178025	2/4/1999 - Failure of Essential Service Water System butterfly valve SWN-41-2B	Valve would not fully close. The cause was due to excessive clearances between the disk and shaft and the pins that align the disk were found sheared and missing allowing the disk to move along the shaft.
184845	2/23/2000 - Failure of Essential Service Water System butterfly valve SWN-41-4B.	Valve would not fully close. The cause was due to excessive clearances between the disk and shaft and the pins that align the disk were found sheared and missing allowing the disk to move along the shaft.
188776	10/7/2000 - Failure of Essential Service Water System butterfly valve 24SW72	Valve failed to close. Apparent cause was the taper pins that hold the disk to the stem were found eroded.
229886	12/9/2007 - AP-913 high critical component failure and MSPI monitored component failure due to failure of pin(s) in Closed/Component Cooling Water System butterfly valve 2-SW-8.1C	Valve failed to open due to failure of the pins.
234455	10/15/2008 - Failure of pin(s) in Primary Containment Isolation Valve 3CDS*CTV38A	Valve failed to close due to failure of the pins.
308142	7/6/2013 - Power Reduced Due to a Loss of a 500 KV Line on the Distribution Grid	Valve failed to open during power reduction due to pins that hold the valve disk were found broken.
313185	9/21/2014 - Service Water Valve Fails to Stroke Open	Valve failed to open during surveillance. Apparent cause was the shaft had decoupled from the actuator due to a lack of procedural guidance for shaft installation.

INPO Event ID	Event Title	Failure Comments
407707	3/16/2017 - Secondary Containment Isolation Valve Failed to Isolate Reactor Building Ventilation Penetration	The valve failed to isolate due to connection pin between valve disk stem and the valve actuator became detached.
453735	3/31/2019 - Essential Service Water Ultimate Heat Sink Cooling Tower Bypass Valve Decoupling Results in Inoperable Essential Service Water System	Valve discovered to be 90 degrees closed when indication showed it was open. The cause was flow induced vibration caused the actuator to become disconnected to the valve shaft. Investigation noted that two of the valve three disk pins were missing.
466015	9/26/2019 - Local Leak Rate Test Failed Acceptance Criteria	Valve failed its leak rate test. Apparent cause was the leakage path was through one of the taper pins that holds the disk to the shaft.

In addition, the NRC has issued several generic communications over the years related to pin or key issues in butterfly valves. For example, see the following NRC communications:

NRC Inspection and Enforcement Circular 80-12, “Valve-Shaft-to-Actuator Key May Fall out of Place When Mounted below Horizontal Axis”

NRC Information Notice (IN) 1994-67, “Problem with Henry Pratt Motor-Operated Butterfly Valves”

IN 2005-23, “Vibration-Induced Degradation of Butterfly Valves”

As noted in the TR and the follow up NRC staff review of additional OE events found in the INPO IRIS database, the majority of the valve failures involve disk-to-stem pin failures for reasons of normal wear, erosion, corrosion, improper assembly, lack of staking the pins, system vibration, etc. The TR suggests that applying recommended guidance on maintaining pin integrity (e.g., staking or securing the pin) and incorporating into processes and procedures that this type of valve design can be considered not susceptible to stem-to-disk separation. The NRC staff agrees with this assessment however end users should also evaluate and establish preventive maintenance measures such as disassembly, inspect, and refurbish internals until system vibration levels, valve operation, and internal wear rates of components are fully understood. Many of the valve failures noted by NRC staff could be considered “near misses” in that failure of leak rate tests found many of the valve internals were a pin or two from completely not functioning.

3.3.9 T-Head/T-Slot

T-head/T-slot designs have a T-head on the end of the stem that fits into a T-slot at the top of the disk. This design is used primarily in solid and flexible wedge gate valves. This design is relatively rugged, there are no connection devices (such as pins or keys) to fail, and the "loose" connection between the stem and disk makes it unlikely to be susceptible to vibration-related failures. However, Appendix A identifies 45 failures of valves with this design. Many of the failures of this design are attributed to:

1) Corrosion of the material due to being in a raw untreated water system thus reducing the strength
2) Pressure locking or thermal binding (PL/TB)
3) Intergranular stress corrosion cracking, hydrogen embrittlement, forging flaws, backseating, improper heat treatment, excessive closing force yielding excessive unwedging force, manufacturing defects, steam erosion, and wear/out flow erosion.

The NRC staff reviewed INPO IRIS database for this design and found several additional failure events:

INPO Event ID	Event Title	Failure Comments
135378	3/28/1993 - Failure of Essential Service Water System gate valve	Disassembly of the valve during preventive maintenance activity, it was discovered that the disk had separated from the stem. Apparent cause was dissimilar metals coupled with operation in a raw untreated water system.
142368	12/22/1993 - Forced power reduction due to failure of Main Steam Turbine Bypass Valve SP13A3	The valve was not able to fully close. Apparent cause was a poorly designed T-slot which had a very tight fit of the stem T-head eventually leading to a corner of the T-slot to break off and obstructing the valve for full closure.
174968	8/27/1998 - Failure of disk in Essential Service Water System check valve that supports Emergency Power Generator 034-011	The valve stem separated from the disk because the wedge ears were worn off due to corrosion.
236979	4/8/2009 - RHR Shutdown Cooling Suction Valve Stem Found Broken	Manual valve operation noted that the disk was remaining closed. Disassembly of the valve found the stem was broken at a reduced cross-sectional area that forms a "T" at the end of the stem that connects to the valve disk.
301298	10/8/2012 - Two Main Steam Isolation Valve Stem Failures Resulting in a Manual Reactor Shutdown	During power ascension, two main steam isolation valves experienced a stem to disk failure due to thermal embrittlement. The stems were sheared above the T-head.
302566	11/26/2012 - Failure of Steam Generator Main Feedwater Inlet Isolation Valve Impacted Outage Schedule	During plant start up, main feedwater inlet isolation valve failed closed due to the wedge had separated from the stem at the T-head.

The TR review of the T-Head/T-Slot design yielded that many of the failures were attributed to those valves operating in an untreated raw water system. The TR recommends that this design of valve in untreated raw water systems should be considered susceptible to stem-to-disk failure unless the stem and disk materials can be verified to be not subject to corrosion in a raw water environment. For the other valve failures not involving operation in an untreated raw water system, the failure rate over a long period of time is relatively low and that they may be considered non-susceptible to failure provided that the other variables such as conditions that could lead to PL/TB, stress corrosion cracking, or embrittlement are monitored and addressed appropriately. The NRC staff is in agreement on this assessment.

3.3.10 Threaded and Pinned

In this design, the stem is screwed into the valve disk or plug and then pinned to the disk/plug. This design is used in many globe valves and in some gate valves. The pin is typically intended only as a locking device and is not designed to react the maximum load applied to the valve0020stem. To ensure the pin is not overloaded, the stem must be properly torqued into the disk, with a preload that exceeds the maximum expected stem load, before installing the pin.

This design is potentially susceptible to the following failures:

1) Failure of the pin due to inadequate joint preload and subsequent unscrewing of the valve stem from the disk/plug
2) Failure of the pin due to inadequate joint preload and subsequent wear of the valve stem threads

The NRC staff reviewed INPO IRIS database for this design and found several additional failure events:

INPO Event ID	Event Title	Failure Comments
15983	4/4/1984 - Forced power reduction due to failure of Feedwater Regulating Valve FCV-1FW-498	Main Feedwater Reg valve was noisy and actuator was twisting. The cause was the stem was separated from its plug.
20755	10/14/1984 - Failure of Aux/Emergency Feedwater Discharge To S/G Isolation Valve MV-09-10, VALVE	Valve failed to open. The stem was separated from the disk. Apparent cause was an over torque event.
30225	8/10/1985 - Failure of Feedwater Regulating Valve FCV-478.	Valve appears to be not closed all the way. Discovered the valve stem to be broken.
107339	4/2/1991 - Failure of Main Steam Turbine Bypass Valve MS-1-PCV-7	During startup valve was leaking. Investigation noted the stem was separated from the disk.
158719	3/19/1996 - Manual reactor scram due to failure of Feedwater Regulating Valve	Plant auto trip due to stem separating from the disk. Apparent cause was torsional stress fracture.
217064	7/23/2005 - Failure of stem in Closed/Component Cooling Water System plug valve 2-3904-A (2A	Temperature control valve was no longer controlling. Investigation noted the stem had separated from the disk.

INPO Event ID	Event Title	Failure Comments
	RBCCW heat exchanger outlet TCV)	
300893	5/28/2012 - Unit 2 Turbine Control Valve #3 Failed to Open	Valve failed to open due to stem separated from the crosshead.
486066	8/12/2020 - Stem Disk Separation of Reactor Building Closed Cooling Water Temperature Control Valve	Temperature control valve failed to control due to a stem to disk separation.

In addition to the events noted in the table for the threaded and pinned design, NRC staff noted several near misses where the pin had sheared but the valve stem had not completely unthreaded itself. These near misses were identified during routine preventive maintenance activities or investigations of erratic behavior. It was noted in the TR that many of the listed failures of this design were due to Anchor/Darling double disk gate valves which were associated with a Part 21 notification.

In addition, the TR noted that many of the failures were associated with valves that were active and controlling a process during normal operation. Failure of this type of valve is identified immediately. Subtracting the number of Anchor/Darling valves and the valve failures of active controlling valves, the failure rate is relatively small and can be considered to be non-susceptible to stem-to-disk failure. The NRC staff agrees with this assessment however end users should evaluate and establish preventive maintenance measures based on vendor recommendations, system conditions, stem material susceptible to embrittlement, and thermal transients.

3.3.11 Hermetically Sealed

In a typical hermetically sealed valve design, the valve disk is not connected to the stem; a diaphragm is used to provide a pressure boundary, and the stem pushes on the diaphragm to move the disk toward the closed position. A spring moves the disk in the open direction when the stem is raised. For these designs, there is no stem-to-disk connection to fail; however, there are other potential failure modes that could cause the valve disk to fail to move for an opening stroke, such as failure of the spring and binding of the disk in the valve body. The TR reviewed INPO IRIS database for one model valve and found no failures.

NRC staff performed an independent review of INPO IRIS database and found no failures. The TR recommends the valve design should be reviewed for failure modes that could cause the valve disk to fail to move with the valve stem, and an operating experience review should be performed to determine the number of such failures that have occurred. Based on these reviews, the valve design can be classified as susceptible or not susceptible. The NRC staff agrees with this approach.

4.0 Limitations and Conditions

The EPRI TR used INPO IRIS database to identify valve stem-to-disk failures over a period of 43 years from 1977 through 2019. A total of 226 failures were identified by searching key words:

- Stem failure
- Stem separation
- Stem-to-disk failure
- Valves

The NRC staff review of the EPRI TR and search for additional valve failures in the INPO IRIS database yielded many more failures and/or near-miss events. The NRC staff believes that the failure rate is much higher than noted in the TR for the following reasons:

1) The early years of data input to the INPO database yielded inconsistent event entries. Some events had very little content with no details on the cause of the event.
2) Some events narrative was captured in attached documents which could lead to being passed over on key word searches.
3) Not all non-safety related valve failures are entered into the database.
4) The rules for data entry changed many times over the years.
5) Many events capture the failure and state that additional information will be entered at a later date and it doesn't happen.
6) Many valve failures were attributed to the de-coupling of the actuator to the valve stem. For this TR, it doesn't seem that these were counted as failures.
7) Valves that are found in the failed mode or fail when preventive maintenance is performed may not be entered into the database.
8) NRC staff search on other key words yielded several additional failure events. Some events could be missed due to a misspelling of a word. Sometimes a partial key word search is effective.

The EPRI TR was developed to support ASME OM Code Case OMN-28, which allows the test interval of ISTC-3700 to be extended from 2 years to once every 12 years for those valves that have been determined to be not susceptible to stem-to-disk separation. The Code Case defines a valve not susceptible to stem-disk separation as a valve with a documented justification that the stem-disk connection has been determined to not be susceptible to separation based on the internal design, service conditions, applications and evaluation of the stem-disk connection using plant-specific and industry operating experience, and vendor recommendations.

The NRC staff finds the use of EPRI TR 3002019621 to be acceptable as part of the implementation of ASME OM Code Case OMN-28 with the following conditions:

1) Each valve that has been determined to be not susceptible to stem-to-disk separation shall have a documented justification entered in their IST Program Plan.
2) For those valve designs that rely on a weld to secure the stem-to-disk connection and operate under high system vibration conditions, additional justification for relying on the welded connection shall be completed. This may be in the form of a structural analysis (weak link) or disassembly and inspection after a number of years of service that evaluates the connection condition.

3) For butterfly valves that have a pinned connection, the TR makes a statement that if end users apply lessons learned detailed in vendor and NRC information notices, then this design type can be considered to be not susceptible to stem-to-disk separation. The NRC staff agrees with this assessment in general. However, end users shall also evaluate and establish preventive maintenance measures such as disassembly, inspection, and refurbish internals until system vibration levels, valve operation, and internal wear rates of components are fully understood.
4) For valves that are high failure rate valve types (Captured and Clamped, Pinned, T-Head/T-Slot, Threaded and Pinned) and have been determined to be not susceptible to stem-to-disk separation, local observation during the required valve exercise shall be completed at least once every 2 years looking for any abnormal operation of the actuator to valve stem interface. Valve position indication testing as described in ASME OM Code Case OMN-28 may remain at the 12-year interval.

5.0 Conclusion

EPRI TR 3002019621 represents a comprehensive study on the failure rate of various valve designs in operating nuclear power plant facilities over a period of 43 years. The study provides many lessons learned and recommends actions to preclude future valve failures. Based on the evaluation above, the NRC staff finds the use of EPRI TR 3002019621, with the conditions listed above, to be acceptable as part of the implementation of ASME OM Code Case OMN-28.

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