AREVA

MRP-227-A Applicant/Licensee Action Item #7 Analysis for Arkansas Nuclear One Unit 1

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Revision 1

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AREVA Inc.

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
Rev. 0	All	Initial Issue
Rev. 1	All	Bracketing Updated

Contents

Nomenclature

Acronym	Definition
A/LAI	Applicant/Licensee Action Item
ANO	Arkansas Nuclear One
ANO-1	Arkansas Nuclear One Unit 1
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BWRVIP	Boiling Water Reactor Vessel and Internals Program
CASS	Cast Austenitic Stainless Steel
CMTR	Certified Material Test Report
CRA	Control Rod Assembly
CRGT	Control Rod Guide Tube
CSS	Core Support Shield
EFPY	Effective Full Power Year
EPRI	Electric Power Research Institute
FIV	Flow-Induced Vibration
I&E	Inspection and Evaluation
IE	Irradiation Embrittlement
IMI	Incore Monitoring Instrumentation
LOCA	Loss of Coolant Accident
LR	License Renewal
MRP	Materials Reliability Program
NDE	Non-Destructive Evaluation
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
PH	Precipitation-Hardenable
PT	Dye Penetrant Testing
PWR	Pressurized Water Reactor
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RT	Radiographic Testing
RV	Reactor Vessel
SCC	Stress Corrosion Cracking
SER	Safety Evaluation Report

Acronym	**Definition**
SSE	Safe Shutdown Earthquake
TE	Thermal Aging Embrittlement
U.S.	United States
UT	Ultrasonic Testing
VT	Visual Testing

ABSTRACT

The purpose of this document is to summarize the analyses performed for the applicable component items at ANO-1 to complete applicant/licensee action item #7 from MRP-227-A for ANO-1. The summary includes a discussion of the purpose, the methodology utilized, a summary of the background, evaluation inputs, evaluation, and conclusion for each component item, and an overall conclusion.

1.0 INTRODUCTION AND PURPOSE

The Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) developed inspection and evaluation (I&E) guidelines in document MRP-227-A (1) for managing long-term aging of pressurized water reactor (PWR) reactor vessel (RV) internal components. Specifically, the I&E guidelines are applicable to RV internal structural components; they do not address fuel assemblies, reactivity control assemblies, or welded attachments to the RV. The I&E guidelines concentrate on eight aging degradation mechanisms and their aging effects, such as loss of fracture toughness. The I&E guidelines define requirements for inspections that will allow owners of PWRs to demonstrate that the effects of aging degradation are adequately managed for the period of extended operation. These guidelines contain mandatory and needed requirements and an implementation schedule for nuclear units employing B&W nuclear steam supply systems (NSSS) currently operating in the United States (U.S.).

MRP-227-A includes a safety evaluation report (SER) prepared by the US Nuclear Regulatory Commission (NRC). The U. S. NRC staff determined whether the guidance contained in the report provided reasonable assurance that the I&E guidelines ensured that the RV internal components will maintain their intended functions during the period of extended operation. From the determination, seven topical report conditions and eight plant-specific applicant/licensee action items (A/LAIs) were contained in the SER to alleviate issues and concerns of the NRC staff. The plant-specific A/LAIs address topics related to the implementation of MRP-227 that could not be effectively addressed on a generic basis in MRP-227. The seventh A/LAI (A/LAI #7) addresses NRC staff concerns regarding thermal aging embrittlement (TE) and irradiation embrittlement (IE).

During the performance of this A/LAI, four component items were identified as requiring further aging management for ANO-1 based on material type. A fifth component item, the vent valve bodies, were also identified as being fabricated from cast austenitic stainless steel (CASS); however, they were not evaluated based on the assumption that the vent valve bodies in the [ ] at ANO-1 have a ferrite content of 20% or less. For the B&W fleet, all originally installed vent valve bodies are American Society of Testing and Materials (ASTM) A351 Grade CF-8 castings, [ ] The B&W fleet was supplied with [ ] in the 1970s or 1980s. Some vent valve assemblies at some units [ ] However, the [ ] could have used the [ ] It is currently [ ] at ANO-1 contain [ ] AREVA's records were reviewed and [ ] This QADP contained a certified material test report (CMTR) for the [ ] that reported the material to be ASTM A351 Grade CF-8 casting, [ ] Given that all reviewed records [ ] at ANO-1 are ASTM A351 Grade CF-8 castings, [ ] it is likely that all currently installed vent valve bodies at ANO-1 are below the 20% screening criteria for thermal embrittlement. However, this cannot be definitively confirmed unless the specific vent valve bodies currently installed at ANO-1 are known.

Therefore, Entergy commits to record the serial numbers and heat numbers stamped on the vent valve bodies currently installed in the ANO-1 RV internals when the core barrel assembly is removed during the initial MRP-227 inspections. This information will support confirmation that the vent valve bodies [ ] at ANO-1 have a ferrite content of 20% or less.

The four component items applicable to A/LAI #7 for ANO-1 are listed below:

- Control Rod Guide Tube (CRGT) Spacer Castings (Grade CF-3M)
  - Screened as potentially susceptible to TE, but not IE
- Incore Monitoring Instrumentation (IMI) Guide Tube Spiders (Grade CF-8)
  - Screened as potentially susceptible to IE, but not TE
- Vent Valve Retaining Rings (Type 15-5 precipitation-hardenable [PH])
  - Screened as potentially susceptible to TE, but not IE
- Select Original Vent Valve Locking Device Parts (Type 431)
  - Screened as potentially susceptible to TE, but not IE

The purpose of this document is to summarize analyses performed for these four component items for Entergy Operations, Inc.'s (hereafter referred to as Entergy) Arkansas Nuclear One (ANO) Unit 1 (ANO-1). This document will fulfill the A/LAI for these component items; that is, to develop a plant-specific analysis for ANO-1 to demonstrate that the component items will maintain their functionality during the period of extended operation, considering the loss of fracture toughness due to TE and/or IE (whichever is applicable).

The methodology used to evaluate all four components items is similar and is illustrated in Section 2.0. Each component item has its own section (CRGT Spacer Castings – Section 3.0, IMI Guide Tube Spider Castings – Section 4.0, Vent Valve Retaining Rings – Section 5.0, and Select Original Vent Valve Locking Device Parts – Section 6.0).

Information considered by AREVA to be proprietary is marked with brackets: **[ ]**

2.0 METHODOLOGY

The purpose of this section is to provide various potential methodologies and identify the ultimate methodology used to evaluate the component items for ANO-1.

2.1 *WCAP-17096 Methodology Applicability*

WCAP-17096 (2), including proposed edits (3), provides a methodology for developing evaluation procedures to assess the functional impacts of degradation in component items with "observed relevant conditions." As will be discussed below, the basis for why these components are not expected to fail [ ] is generally part of the methodology used herein to justify that these component items will be expected to maintain their functionality through the period of extended operation. Therefore, the WCAP-17096 methodology [ ] then using the WCAP-17096 methodology may be needed (if replacement of affected component items is not preferred).

2.2 *MRP-227-A Suggested Methodologies*

As described in A/LAI #7, to address the NRC staff concerns regarding TE and IE of potentially susceptible materials, applicants/licensees are required to perform a plant-specific analysis or evaluation demonstrating that certain component items will maintain their functionality during the period of extended operation. Per MRP-227-A, possible acceptable approaches may include, but are not limited to:

- Functionality analyses for the set of like components or assembly-level functionality analyses, or
- Component level flaw tolerance evaluation justifying that the MRP-227 recommended inspection technique(s) can detect a structurally significant flaw for the component in question, taking into account the reduction in fracture toughness due to IE and TE; or

- For CASS, if the application of applicable screening criteria for the component's material demonstrates that the components are not susceptible to either TE or IE, or the synergistic effects of TE and IE, then no other evaluation would be necessary. For assessment of CASS materials, the licensees or applicants for license renewal (LR) may apply the criteria in the NRC letter of May 19, 2000, "License Renewal Issue No. 98-0030, Thermal Aging Embrittlement of Cast Stainless Steel Components" (4) as the basis for determining whether the CASS materials are susceptible to the TE mechanism.

2.3 *Methodology Utilized for ANO-1*

An analysis was performed for each of the four component items, generally per the methodology below:

- Identify appropriate inputs for the evaluation, [ ]
- Utilize available information to determine if failure is likely or unlikely to occur
- Determine effect of failure on functionality
- Conclude whether components are expected to maintain their functionality through the period of extended operation

3.0 CRGT SPACER CASTINGS

This section summarizes the analysis performed of the ANO-1 CRGT spacer castings to fulfill A/LAI #7 from MRP-227-A.

3.1 *Background*

MRP-227-A provides I&E guidelines for the various component items including the CRGT spacer castings, which are considered a "Primary" item in MRP-227-A. The I&E guidelines specify applicability, effect and mechanism, expansion link, examination method/frequency, and examination coverage.

3.1.1 Description of the Component Item

This section contains an abbreviated description, including a short description of the functionality, consequence of failure, and operating experience of the component items.

The plenum assembly (upper internals) contains 69 vertical CRGT assemblies that are welded to the plenum cover plate and bolted to the upper grid. Inside of each guide housing is a brazement subassembly consisting of ten parallel spacer castings brazed to twelve perforated vertical rod guide tubes and 4 pairs of vertical rod tube guide sectors. There are a total of 690 spacer castings in the ANO-1 RV internals. The CRGT spacer castings are made from ASTM A 351-65, Grade CF-3M castings.

During normal operation, most of the control rod assembly (CRA) is positioned within the CRGT. In the event of a reactor trip or a rod movement command from the control room, the CRAs pass through the path provided by the brazement into, or out of, the fuel assemblies. The outer pipe portion of the CRGTs is the structural support for the rod guide brazement, and also provides a structural connection between the upper grid assembly and the plenum cover in the upper internals.

There are openings in the lower region of the pipe to allow some of the fluid entering the CRGT assembly from the core to exit to the plenum region. The remainder of the CRGT assembly has [ ]

The function of the CRGT spacer castings is to provide structural support and alignment to the [ ] vertical rod guide tubes and [ ] vertical rod guide sectors within each CRGT assembly. The CRA consists of a control rod spider and control rods that travel vertically within the rod guide brazement. [ ] The CRA is guided by the brazement subassembly over the entire range of the vertical withdrawal path. In addition, the rod guide tubes limit reactor coolant cross-flow on the control rods to limit flow-induced vibration. The spacer castings do not have a core support function; however, they do have a safety function relative to control rod alignment, insertion, and reactivity issues. Degradation of the spacer castings could result in degradation in the unit shutdown capability by hindering the insertion of the control rods into the core in the normal anticipated time.

Appendix A of MRP-227-A indicates that the failure of CASS materials due to TE in the PWR RV internals has not been reported. Additionally, no known failures of CASS materials due to embrittlement have been reported in the industry.

3.2 *Evaluation Inputs*

This section will describe the quantitative inputs for the evaluation, such as flaw size, degraded material properties, and stresses.

3.2.1 Flaw Size

As indicated by the MRP-227-A process, the CRGT spacer castings are not screened as potentially susceptible to service induced flaws (i.e., irradiation-assisted stress corrosion cracking [IASCC], SCC, or fatigue). Therefore, the following section will focus on the potential for flaws in the 'as-built' condition from the manufacturing process. The non-destructive evaluation (NDE) methods used to examine the component items prior to their in-service time at ANO-1 are summarized below.

Review of the available CMTRs for the CRGT spacer castings indicated [ ] However, it is reasonable to assume that the CRGT spacer castings used in-service at ANO-1 had [ ] and therefore [ ]

3.2.2 Degraded Material Properties

[ ] of the CRGT spacer castings at ANO-1 exceed the screening criteria for TE and are therefore considered potentially susceptible. For the potentially susceptible CRGT spacer castings, the time to reach saturation in the reduction of impact properties was investigated. It was determined that a saturation value of impact energy, and correspondingly fracture toughness, [ ] Therefore, for the susceptible CRGT spacer castings (with high ferrite contents exceeding the screening criteria), [ ]

3.2.3 Distortion Evaluation

An evaluation was performed to determine the amount of distortion allowed that will still permit the control rod spider to freely pass through the brazement sub-assembly. The acceptance criterion was then used in an analysis of the brazement subassembly to evaluate the conditions required to lead to a restricted guide path. The brazement subassembly analysis only evaluated the [

]

The conclusion of the analysis was [

]

3.3 *Evaluation*

The results of the methodology utilized are organized into several conclusions as discussed in the following sections.

3.3.1 Failure is Unlikely

The CRGT spacer casting material is expected to be [ ]

Therefore, for the susceptible CRGT spacer castings (with high ferrite contents exceeding the screening criteria), the reduction in fracture toughness due to thermal aging (i.e., TE) [ ] In 2012 and 2013, two B&W units performed visual testing (VT)-3 examinations of the CRGT spacer castings, per the guidance in MRP-227-A. These visual examinations with 100% coverage of accessible surfaces at each of the four CRGT spacer casting screw locations revealed no recordable indications. Furthermore, no known failures of CASS materials due to embrittlement have been reported in the industry. This is confirmation that the [ ]

Due to the [ ] being present in the material [ ]

Therefore, due to the CRGT spacer casting material [ ] for the CRGT spacer castings, and [ ] failure of the CRGT spacer casting material during the period of extended operation is unlikely.

3.3.2 Effect of Failure on Functionality

[ ] However, the postulated occurrence is not considered a credible scenario as described previously.

The reported stress distribution reinforces the premise that [ ] is not expected. Not only must a [ ] but it must [ ] Analysis also leads to the conclusion that a [ ] In particular the stresses in the [ ] Therefore, there is no rational reason why [ ] This data directly reinforces the premise that the [ ]

Drop-time testing of the control rod assemblies is performed at the beginning of each cycle per the technical specification surveillance requirement. Historically, the rod drop-times are somewhat uniform and are easily within this limit. When an unusual drop-time is encountered, the utility normally investigates the possible cause. To date, slow trip times have always been linked to unusual fuel bow or issues with the control rod drive mechanism. Additionally, the safety analysis already considers that the maximum worth rod may not trip on demand.

The redundant features of the [ ] The rod guide tubes and rod guide sectors have [ ] In addition, [ ] due to the CRGT spacer casting geometry and [ ] and are not a credible risk.

3.4 *Conclusions*

Cast austenitic stainless steel materials are known to be potentially susceptible due to TE after exposure at PWR RV internals temperatures for long periods of time, especially those containing higher levels of ferrite and molybdenum. Studies show that saturation of reduction of room temperature impact energy, and correspondingly fracture toughness, [ ] The CRGT spacer casting material that does not exceed the screening criteria is not considered potentially susceptible to TE.

Additionally, the [ ] for the CRGT spacer castings [ ] The stress analysis of the spacer castings [ ]

An analysis of the brazement sub-assembly, including [

] the monitoring of control rod drop times is a normal surveillance requirement. It is currently a requirement that abnormal control rod drop times must be investigated. [ ]

The function of the brazement sub-assembly, of which the CRGT spacer castings are a part, is currently monitored by periodically verifying the control rod movement and control rod drop-time. In addition, the aging management plan has implemented a new visual examination to verify that critical regions of the spacer casting have not failed due to random original defects. The combination of the original licensing basis surveillance, that has not been altered, and the additional visual verification of intact spacer castings demonstrate that, in the unlikely event of degradation, it could be detected.

Based on the discussion above, it is concluded that the CRGT spacer castings will maintain functionality during the period of extended operation.

4.0 IMI GUIDE TUBE SPIDER CASTINGS

This section summarizes the analysis performed of the ANO-1 IMI guide tube spider castings to fulfill A/LAI #7 from MRP-227-A.

4.1 *Background*

MRP-227-A provides I&E guidelines for the various component items including the IMI guide tube spider castings, which are considered a "Primary" item in MRP-227-A. The I&E guidelines specify applicability, effect and mechanism, expansion link, examination method/frequency, and examination coverage.

4.1.1 Description of the Component Item

This section contains an abbreviated description, including a short description of the functionality, consequence of failure, and operating experience of the component items.

The IMI guide tube spider castings are part of the lower internals assembly. Fifty-two IMI guide tube assemblies provide support and protection for the IMI along the path from the RV bottom head IMI nozzles, through the lower internals, and into the instrument tubes in the fuel assemblies.

The IMI guide tube spider castings are ASTM A351-65 Grade CF-8 material and resemble a four eared butterfly nut. The IMI guide tube spider casting has a center hub with four integral "L" shaped legs extending outward. The inner diameter of each IMI guide tube spider casting center hub is chrome plated. Each of the 52 IMI guide tube spider castings is custom machined to fit within the lower grid rib section.

Each of the four IMI guide tube spider casting legs is fillet welded to the walls of the lower grid rib section. The welds are a stainless steel filler metal (ER 308/308L). The tip at the upper end of the IMI guide tube slides inside the chrome-plated center hub of the IMI guide tube spider casting. The relatively [ ] while providing [ ] to accommodate the axial expansion of the IMI guide tube.

The lower end of the IMI guide tube is solidly welded to the flow distributor head (in some locations with the use of gussets) with additional support provided at its midsection via a threaded guide tube nut to the IMI guide support plate.

The function of the IMI guide tube spider casting is to provide lateral restraint for the IMI guide tube and the function of the spider fillet welds is to hold the IMI guide tube spider casting in place. The IMI guide tube provides the continuous protected guide path for the in-core monitoring instrumentation from their entry into the RV through the RV instrumentation nozzles to the entrance into the fuel assembly instrument guide tube.

[ ] Loss of function of the in-core monitoring instrument guide path would be a sufficient misalignment at the fuel assembly instrument tube entrance to prohibit entry of the in-core instrument. In addition, failure of the guide path could result in wear of the IMI sheath due to flow-induced vibration (FIV) and therefore would be considered a loss of function.

Appendix A of MRP-227-A indicates no cracking has been reported in the PWR RV internals as being attributed to embrittlement for CASS materials. Cast stainless steels are also used extensively in pressure-boundary components such as piping components, valve bodies, and pump casings. However, no cases of embrittlement requiring corrective action have been reported in the industry as of 2015.

4.2 *Evaluation Inputs*

This section will describe the quantitative inputs for the evaluation, such as flaw size, degraded material properties, and stresses.

4.2.1 Likelihood of Fabrication and Service-Induced Flaws

Review of the available CMTRs for the IMI guide tube spider castings indicated they [ ] Information regarding [ ] deemed acceptable by the American Society of Mechanical Engineers (ASME) Code for castings in pressure boundary applications. Additionally, service-induced flaws such as those resulting from SCC, IASCC, and fatigue, were evaluated and not expected for the ANO-1 IMI guide tube spider castings.

4.2.2 Driving Force for Crack Extension

A structural analysis evaluated the design configuration for the ANO-1 IMI guide tube spider castings and considered two loading configurations:

- Case 1: steady state reactor coolant flow with accelerations from safe shutdown earthquake (SSE) and loss of coolant accident (LOCA) events
- Case 2: [ ]

This structural analysis shows that stress in the ANO-1 IMI guide tube spider castings is [ ] In summary, loads capable of driving a [ ] Loads from [ ]

4.2.3 Irradiated Fracture Toughness

The IMI guide tube spider castings retain sufficient fracture toughness to be best characterized by elastic-plastic measures of fracture toughness. Two elastic-plastic measures of fracture toughness are used in this report: J_{Ic} and J at a crack extension of 2.5 mm (hereafter "$J_{2.5mm}$"). The parameter J characterizes the crack driving force based on an integration of loading work per unit volume (e.g., strain energy density for elastic bodies) around a crack front. J_{Ic} characterizes the crack driving force just prior to the onset of significant stable tearing crack extension. $J_{2.5mm}$ characterizes the crack driving force required to achieve a crack extension of 2.5mm.

4.2.3.1 Fracture Toughness Characterized by J_{Ic}

There is a paucity of fracture toughness data available for CASS material, particularly in the [ ] relevant to the ANO-1 IMI guide tube spider castings. No measured fracture toughness properties were identified in this task for CF-8 materials irradiated in light water reactors. Reference (5) reports fracture toughness properties (measured at room temperature) for a CF-8 material irradiated at 325°C in a fast-breeder reactor between roughly 0 and 12 dpa. The Reference (5) data are summarized in Figure 54 of Reference (6) as "CF-8 (Burke et al.)", including an additional measurement at 19 dpa. A lower bound to this data determined per engineering judgment suggests that the [

] based on fracture toughness categorizations described in Reference (6).

Figure 61 of Reference (6) shows that for irradiated materials [

]

The key point from this discussion is that the ANO-1 IMI guide tube spider casting [

]

4.2.3.2 Fracture Toughness Characterized by $J_{2.5mm}$

The NRC has adopted $J_{2.5mm}$ = 255 kJ/m^2 as a conservative criterion for piping materials to differentiate between non-significant and potentially significant reduction in fracture toughness for CASS subject to thermal aging embrittlement (4). A joint Boiling Water Reactor Vessel and Internals Program (BWRVIP)/MRP Working Group on CASS has compiled information of $J_{2.5mm}$ for irradiated CF-8 materials as a function of neutron exposure. Most of this $J_{2.5mm}$ data is from the same CF-8 testing from which J_{Ic} was discussed in Section 4.2.3.1 and shows that $J_{2.5mm}$ = 255 kJ/m^2 is not reached until about 3.3 dpa. In addition, the BWRVIP/MRP Working Group reported example calculations of $J_{2.5mm}$ for RV internals components with large flaws. These calculations show that a crack driving force of $J_{applied}$ = 255 kJ/m^2 is unlikely to be achieved in RV internals components, adding further conservatism to the use of $J_{2.5mm}$ = 255 kJ/m^2.

[ ] (the lower bound estimate for $J_{2.5mm}$ = 255 kJ/m^2) [ ] There is also margin between $J_{applied}$ = 255 kJ/m^2 and RV internals loading conditions.

The key point from this discussion [ ] the NRC's conservative screening criterion of $J_{2.5mm}$ = 255 kJ/m^2. Thus, the reduction in fracture toughness due to IE is not considered significant.

4.3 *Evaluation*

The results of the methodology utilized are organized into several conclusions as discussed in the following sections.

4.3.1 Likelihood of Failure

Three parameters must be considered to evaluate the likelihood of failure due to reduced fracture toughness: 1) likelihood for flaw to be present, 2) driving force for crack extension and 3) material fracture toughness. Considering each of these parameters in turn, it is unlikely that an ANO-1 IMI guide tube spider casting will fail due to irradiation embrittlement.

1. It is not likely [ ] (Section 4.2.1).
2. The dominant driving force for flaw extension in the ANO-1 IMI guide tube spider casting [ ] as a flaw would grow, the driving force [ ] (Section 4.2.2).
3. The ANO-1 IMI guide tube spider castings [ ] relative to [ ] austenitic stainless steel and the NRC's conservative screening criterion of $J_{2.5mm}$ = 255 kJ/m^2 (Section 4.2.3).

The worst effect of reduced fracture toughness is expected [ ] in the IMI guide tube spider casting. The flaw extension would be [ ] The unlikely, but more severe, case of [ ] IMI guide tube spider casting leg is evaluated in Section 4.3.2.

4.3.2 Impact of Fractured Spider Casting on Functionality

The structural and FIV analyses evaluated a series of [ ] of IMI guide tube spider castings [ ] The structural analysis results show that stresses [ ] and accelerations from SSE and LOCA [ ] When [ ] the structural analysis results show that the maximum stress [ ] Thus, [ ] on the same IMI guide tube spider casting. The FIV analysis results show that [ ] Based on these analysis results, [ ] IMI guide tube spider casting [ ] on that IMI guide tube spider casting.

The function of the IMI guide tube spider castings is to provide lateral restraint for the IMI guide tubes and the function of the fillet welds is to hold the IMI guide tube spider casting in place. Significant degradation of the IMI guide path (potentially due to contributions from degraded IMI guide tube spider castings) could result in misalignment at the fuel assembly instrument tube entrance, prohibiting free entry or withdrawal of the IMI itself, or could result in wear of the IMI.

[ ] is not expected to affect the function of the IMI guide tube spider casting for the following reasons:

1. The IMI guide tube spider casting provides [

   ]

2. The FIV analysis shows degraded configurations of the IMI guide tube spider casting [ ] In addition, this analysis [ ] of the IMI guide tube [ ] of the IMI guide tube spider casting.

4.4 *Conclusions*

The ANO-1 IMI guide tube spider castings are [ ] from ANO-1 IMI guide tube spider casting fabrication records. An ANO-1 specific neutron fluence evaluation [ ] However, [ ] that the ANO-1 IMI guide tube spider castings [ ]

1. It is not likely that [ ] in the IMI guide tube spider casting.
2. The dominant driving force for flaw extension in the ANO-1 IMI guide tube spider casting [ ]
3. The ANO-1 IMI guide tube spider castings retain [ ] relative to [ ] the NRC's conservative screening criterion of $J_{2.5mm}$ = 255 kJ/m^2.

[ ]

Therefore, the IMI guide tube spider castings are expected to perform their function for the period of extended operation.

5.0 VENT VALVE RETAINING RINGS

This section summarizes the analysis performed of the ANO-1 vent valve retaining rings to fulfill A/LAI #7 from MRP-227-A.

5.1 *Background*

MRP-227-A provides I&E guidelines for the various component items including the vent valve retaining rings, which are considered a "Primary" item in MRP-227-A. The I&E guidelines specify applicability, effect and mechanism, expansion link, examination method/frequency, and examination coverage.

5.1.1 Description of the Component Item

This section contains an abbreviated description, including a short description of the functionality, consequence of failure, and operating experience of the component items.

ANO-1 has eight vent valves installed in the core support shield (CSS) cylinder. Each vent valve is mounted in a vent valve mounting ring (also called vent valve nozzle) which is welded into the CSS cylinder. For all normal operating conditions, the vent valve is closed but in the event of a pipe rupture in the RV inlet pipe, the valve will open to permit steam generated in the core to flow directly to the break, and will permit the core to be flooded and adequately cooled after emergency core coolant has been supplied to the RV. Each valve assembly includes two retaining rings with varying thicknesses that have integral threaded bosses at both ends to accept the jackscrews. They are fabricated from AMS 5658 Type 15-5 PH stainless steel in the H1100 condition.

The function of the retaining rings is to retain the vent valve body in the vent valve nozzle. The consequence of failure of a retaining ring or portion of a retaining ring is loss of support function for the valve body [

] Failure of a retaining ring or portion of a retaining ring [

]

As of the evaluation date, there is no known cracking or failures of the vent valve retaining rings; there are several known instances of more susceptible types of PH stainless steel materials (e.g., Type 17-4 PH) in other components and systems failing.

5.2 *Evaluation Inputs*

This section will describe the quantitative inputs for the evaluation, including inputs such as flaw size, degraded material properties, and stresses.

5.2.1 Flaw Size

Per the MRP-227-A process, the vent valve retaining rings are not screened as potentially susceptible to service-induced flaws (i.e., IASCC, SCC, or fatigue). Therefore, the focus of this section is the potential for [

]

Review of available CMTRs for the vent valve retaining rings indicated [

] Information regarding actual observed flaw sizes [

]

5.2.2 Degraded Material Properties

[

]

The fracture toughness of the vent valve retaining ring material is expected to be

[ ] is a

reasonable lower bound. In comparison, this fracture toughness is [

] after long-term irradiation exposure.

5.2.3 Stresses

A stress analysis considering all portions of the retaining rings [

]

(as discussed in Section 5.3.1) the available information indicates that the stresses

during [

]

5.3 *Evaluation*

The results of the methodology utilized are organized into several conclusions as discussed in the following sections.

5.3.1 Failure is Unlikely

For the originally and continuously installed vent valve retaining rings at ANO-1, [ ] during the period of extended operation. It is assumed that the originally and continuously installed vent valve retaining rings at ANO-1 [ ] Additionally, as of the publication of MRP-227-A, there is no known cracking of the vent valve retaining rings. This confirms that the stresses sustained [ ] especially given the majority of the retaining rings at ANO-1 are expected [ ] Furthermore, the expected lower bound fracture toughness value is [ ] To date, there are no confirmed cracking of austenitic stainless steel component items in PWR RV internals due solely to IE. Due to the improbability of [ ]

Based on the discussion above, failure of the vent valve retaining rings is not expected during the period of extended operation.

5.3.2 Effect of Failure on Functionality

While failure of the vent valve retaining rings is not expected, this section describes the outcome, should a vent valve retaining ring fail, on the two functions of the vent valve retaining ring.

One of the functions of the vent valves is to relieve pressure in the interior of the core support assembly during a cold leg large break LOCA. The retaining rings, if damaged due to TE (cracked, fractured material, surface irregularities, etc.), could eventually lead to [ ] If this happened, the vent valve nozzle in the CSS which [ ] the vent valve assembly would [ ] Therefore, it is likely that degradation of the vent valve retaining ring material due to TE will not affect the function of the vent valve during a cold leg large break LOCA.

An additional function of the vent valves is to [ ] The event would be detectable [ ] For initial operation of the early B&W plants the Nuclear Regulatory Commission (NRC) had imposed a [ ] for the possibility of one vent valve being in the failed open position. This penalty was removed as experience demonstrated that a failed open vent valve was highly improbable as confirmed by the refueling exercise and visual surveillance program.

5.4 *Conclusions*

The vent valve retaining rings are not expected to fail during the period of extended operation based on the following: [

]

In the unlikely event that failure of the vent valve retaining rings does occur, it is not expected to impair the function of the vent valve to relieve pressure in the interior of the core support assembly during a cold leg large break LOCA. Should failure of the vent valve retaining rings fail and cause, [

] it would be detectable [

]

Therefore, the vent valve retaining rings are expected to perform their function for the period of extended operation and in the unlikely event of failure, the primary vent valve functions is not expected to be impaired and the secondary vent valve function that could possibly be impaired would be detectable.

6.0 SELECT ORIGINAL VENT VALVE LOCKING DEVICE PARTS

The vent valve locking devices were not included in the MRP-227-A I&E guidelines; however they were screened and evaluated in the response to Applicant/Licensee Action Item #2 for ANO-1.

As of February 2015, the four vent valves near the outlet nozzles have modified locking devices (7); therefore both the modified and original locking devices were evaluated in Applicant/Licensee Action Item #2 for ANO-1. Engineering evaluation and assessment was performed after consideration of screening parameters, failure, modes, effects, and criticality analysis (FMECA), and severity categorization, for select original and modified vent valve locking device parts in Applicant/Licensee Action Item #2 for ANO-1, including two component items fabricated from martensitic stainless steel. The [

] (both fabricated from martensitic stainless steel) within the original vent valve locking device are within the scope of LR for ANO-1 and require aging management.

6.1 *Background*

ANO-1 has eight vent valves installed in the CSS cylinder. Each vent valve is mounted in a vent valve mounting ring (also called vent valve nozzle) that is welded into the CSS cylinder. Each vent valve consists of a hinged disc, a valve body with sealing surfaces, a split-retaining ring and fasteners (that retain and seal the perimeter of the valve assembly), and an alignment device (to maintain the correct orientation). For all normal operating conditions, the vent valve is closed but in the event of a pipe rupture in the RV inlet pipe, the valve will open to permit steam generated in the core to flow directly to the break, and will permit the core to be flooded and adequately cooled after emergency core coolant has been supplied to the RV.

In the original vent valve locking devices, the [

] The spring holds the pressure plate up so that it engages the [ ] and prevents the jackscrew from turning. Other than the "U" cover and cap screws, the component items of the locking device are [ ]

The function of the vent valve jackscrew is to maintain the retaining rings position and to prevent the retaining rings from backing out of the mounting ring groove in the CSS nozzle. The function of the top and bottom retaining rings is to retain the vent valve body in the CSS mounting ring.

6.2 *Evaluation*

The following section contains a discussion of the applicable degradation mechanism and effect of failure on functionality for select original vent valve locking device parts [ ] fabricated from martensitic stainless steel (Type 431).

6.2.1 Degradation Mechanism

The vent valve assembly has a fluence [ ] therefore, [

]

6.2.2 Effect of Failure on Functionality

The primary function of the vent valve assembly is to support core cooling during a cold leg large break LOCA. [

] The purpose of this section is to discuss how the [ ] could affect the primary or [ ] of the vent valve assembly.

Each vent valve assembly has two jackscrews, which each have a locking device

[ ]

In the event [ ] jackscrews turning [ ] the vent valve body [ ] In this scenario, the primary function of the vent valve assembly (support core cooling during a cold leg large break LOCA) likely would be maintained, [ ] However, this event could be detected [ ]

If [ ] the associated jackscrew could [ ] This is because it is necessary for [ ] The [ ] turning of one jackscrew on a vent valve assembly could result in a [ ] This scenario of [ ] was considered in an evaluation discussed as part of internal correspondence at B&W to address [ ] in the late 1970s at other B&W units. This correspondence indicated that the [ ] and that such [ ] would not affect the function [ ]

6.3 *Conclusion*

Failure of the martensitic stainless steel parts evaluated in this section could result in the failure of the vent valve jackscrew locking device, [ ] jackscrew locking devices in a vent valve assembly failed, the primary function of the vent valve assembly (to support core cooling during a cold leg large break LOCA) likely would be maintained. If [ ] jackscrew locking device in a vent valve assembly fails, [ ] If [ ] jackscrew locking devices in a vent valve assembly fail, [ ] be detected [ ]

7.0 OVERALL CONCLUSIONS

A/LAI#7 is applicable to CRGT spacer castings, IMI guide tube spider castings, vent valve retaining rings, and select original vent valve locking device parts for ANO-1.

Based on the extensive evaluations summarized above, failure during the period of extended operation was found to be improbable for the CRGT spacer castings, vent valve retaining rings, and IMI guide tube spider castings. In the unlikely event of a failure occurring for these component items, the intended function of the component items is expected to be maintained or the failure will be detectable.

For the applicable original vent valve locking device parts, the evaluation concluded that failure of one or both of the original locking devices on a vent valve assembly would not impact the primary function of the vent valve assembly (to support core cooling during a cold leg large break LOCA). If [ ] original jackscrew locking device in a vent valve assembly fails, [ ] locking devices on a vent valve assembly could impact [ ] but this event will be detectable and there would be no safety consequences.

8.0 REFERENCES

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