North Anna SLRA

RAI B2.1.35-1:

Settlement Monitoring: Service Water Valve House (Settlement Marker SM-28)

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Discussion

- Settlement of SM-28 has slightly exceeded 75% of the TRM 3.7.7 allowable value.
- A Condition Report (CR) has been submitted. There is no immediate challenge to the functionality of plant equipment. Based on data, settlement of SM-28 is projected to remain below the 100% allowable settlement limit of TRM 3.7.7 until at least 2036.
- The current planned corrective action is to increase the allowable settlement of SM-28 by adjusting piping expansion joint tie-rods (discussed in RAI B2.1.35-1 response).
- The CR response is consistent with RAI B2.1.35-1 response and other information provided.

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RAI B2.1.7-1: Pitting and Crevice Corrosion in Reactor Vessel Internals

SLRA Treatment

- Loss of material due to pitting and crevice corrosion was not identified as an aging effect requiring management for NAPS stainless steel or nickel alloy reactor vessel internals components
  - NUREG-2192 (SRP-SLR), Section 3.1.2.2.9 (as amended by SLR-ISG-2021-01-PWRVI), references EPRI MRP-227 Revision 1-A for applicable aging mechanisms for PWRVI components
  - The following are the only aging mechanisms identified: SCC, IASCC, fatigue, wear, neutron irradiation embrittlement, thermal aging embrittlement, void swelling and irradiation growth or component distortion, and thermal- or irradiation-enhanced stress relaxation or irradiation-enhanced creep
  - Wear is the only loss of material mechanism identified

SLRA Treatment (continued)

- EPRI MRP-191 Revision 2 identifies the same aging mechanisms for PWRVI components as those identified in MRP-227 Revision 1-A
- MRP-175 Revision 1 screening criteria used to evaluate other mechanisms; PWRVI components found not susceptible to any others
- Westinghouse expert panel review of MRP-191 Revision 2, as it applies to NAPS RVI components, identified no other aging degradation mechanisms
- NUREG/CR-7153, EMDA Vol. 2, also validates that localized corrosion of stainless steels, including CASS, is well studied and not a concern in modern LWR water chemistries
- Disposition of SRP Table 3.1-1 Item 087 for NAPS is the same as for Surry Power Station (SPS), which was found acceptable by the Staff in the SPS SER, Section 3.1.2.1.1

Conclusion

- Relevant industry documents applicable to NAPS RVI components have been reviewed and applied, and
- Loss of material due to pitting and crevice corrosion is not identified as an aging effect requiring management
- Thus, SRP Table 3.1-1 Item 087 is not applicable
- GALL-SLR AMP XI.M2, Water Chemistry, is credited for aging management, but only for SCC mechanisms

NUREG 2192 Table 3.1-1 Excerpt

Table 3.1-1 Summary of Aging Management Programs for Reactor Vessel, Internals, and Reactor Coolant System Evaluated in Chapter IV of the GALL-SLR Report

New, Modified, Deleted, Edited Item	ID	Type	Component	Aging Effect/Mechanism	Aging Management Program (AMP)/TLAA	Further Evaluation Recommended	GALL-SLR Item
			reactor coolant				
	087	PWR	Stainless steel, nickel alloy PWR reactor internal components exposed to reactor coolant, neutron flux	Loss of material due to pitting, crevice corrosion	AMP XI.M2, "Water Chemistry"	No	IV.B2.RP-24 IV.B3.RP-24 IV.B4.RP-24
	088	PWR	Stainless steel; steel with	Loss of material due to	AMP XI.M2,	No	IV.A2.RP-28

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SLR-ISG-2021-01-PWRVI – XI.M16A Excerpt

2. ***Preventive Actions***: The program relies on PWR water chemistry control to prevent or mitigate aging effects that can be induced by corrosive aging mechanisms [e.g., loss of material induced by general, pitting corrosion, crevice corrosion, or stress corrosion cracking or any of its forms (SCC, PWSCC, or IASCC)]. Reactor coolant water chemistry is monitored and maintained in accordance with the Water Chemistry Program, as described in GALL-SLR Report AMP XI.M2, "Water Chemistry."

3. ***Parameters Monitored or Inspected***: The program manages the following age-related degradation effects and mechanisms that are applicable in general to RVI components at the facility: (a) cracking ~~induced by~~due to SCC, PWSCC, IASCC, or fatigue/cyclic loading; (b) loss of material ~~induced by~~due to wear; (c) loss of fracture toughness ~~induced by~~due to thermal aging and neutron irradiation embrittlement; (d) changes in dimensions due to void swelling or distortion; and (e) loss of preload due to thermal and irradiation-enhanced stress relaxation or creep.

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RAI B2.1.15-1:

Diesel-Driven Fire Pump Engine Coolant Heat Exchanger

SLRA Treatment

- Diesel-driven fire pump engine and skid-mounted subcomponents were originally addressed in SLRA as an active assembly, not subject to AMR per 10 CFR 54.21(a)(1)(i)
  - Active status is consistent with NUREG-2192, Table 2.1-6 item 55. Equipment performance is managed via Maintenance Rule
  - Similar component was recently questioned at Peach Bottom and active status was accepted in RAI response, documented in SER 2.3.3.14.2
  - Dominion believes Table 2.3-2 excerpt is applicable to diesel generators, not fire pump diesel engines, which typically have integral subcomponents
- Staff noted that the engine coolant HX had experienced a tube failure in 2017; RAI questioned ability of active component testing to identify degradation prior to failure
- Dominion proposed new commitment #49 for periodic replacement in RAI response. Therefore, the HX is not subject to AMR per 10 CFR 54.21(a)(1)(ii).

NUREG-2192 Table 2.1-6 & 2.3-2 Excerpts

Table 2.1-6 Typical Structures, Components, and Commodity Groups, and 10 CFR 54.21(a)(1)(i) Determinations for Integrated Plant Assessment

Item	Category	Structure, Component, or Commodity Grouping	Structure, Component, or Commodity Group Meets 10 CFR 54.21(a)(1)(i) (Yes/No)
50	Pumps	Emergency Service Water Pumps	Yes (Casing)
51	Pumps	Submersible Pumps	Yes (Casing)
52	Turbines	Turbine Pump Drives (excluding pumps)	Yes (Casing)
53	Turbines	Gas Turbines	Yes (Casing)
54	Turbines	Controls (Actuator and Overspeed Trip)	No
55	Engines	Fire Pump Diesel Engines	No
56	Emergency Diesel Generators	Emergency Diesel Generators	No

Table 2.3-2 Examples of Mechanical Components Screening and Basis for Disposition

Example	Disposition
Diesel engine jacket water heat exchanger and portions of the diesel fuel oil system and starting air system supplied by a vendor on a diesel generator skid	These are "passive," "long-lived" components having intended functions. They are subject to an AMR for SLR even though the diesel generator is considered "active."

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Peach Bottom SER Excerpt

In RAI 2.3.3.14-3, the staff requested the applicant to verify whether the fire protection components listed below are within the scope of subsequent license renewal and whether they are subject to an AMR. The staff also requested justification for components excluded from the scope of subsequent license renewal and are not subject to an AMR:

- diesel engine jacket water heat exchanger and portions of the diesel fuel oil system and starting air system supplied by a vendor on a diesel generator skid including heat exchanger and muffler

In a May 23, 2019 letter, the applicant provided the results of the scoping and screening process for the fire protection system component types listed above. The applicant indicated that the components in the diesel engine fuel oil system and diesel engine muffler are included under the component type piping, piping components in SLRA Table 2.3.3-14 with AMR results in SLRA Table 3.3.2-14. The diesel engine starting air system and jacket water heat exchange system are subcomponents in the diesel-driven fire pump engine, which are integral to the active diesel engine assembly. The applicant indicated that the diesel engine starting air system and jacket water heat exchange system are not subject to an AMR. The staff confirmed that the diesel engine for diesel-driven fire pump subcomponents do not meet the AMR criteria of 10 CFR 54.21(a)(1)(i).

The fire pump diesel engines include various components necessary to support engine operation. Many of these components are either located internal to the engine or are physically mounted on the engine. These components are considered integral subcomponent parts of the active diesel engine assembly. Fire hose connections and standpipe risers are included under

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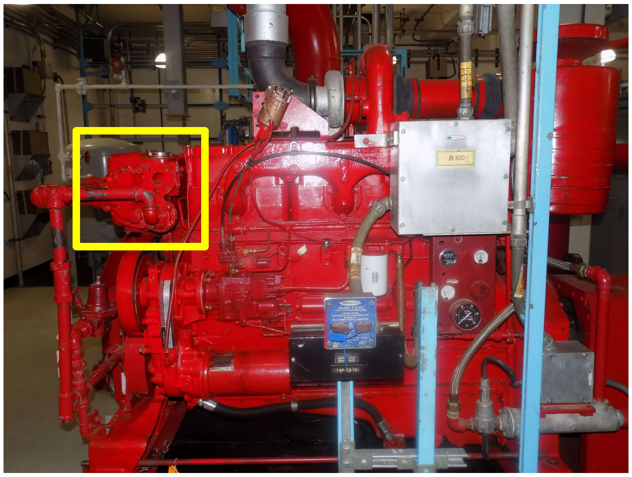
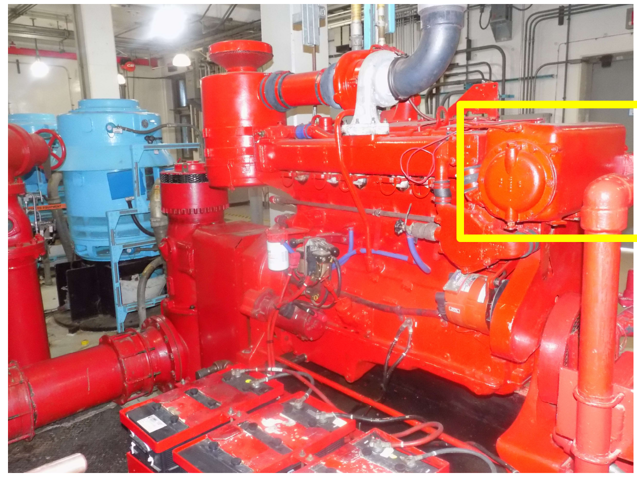
Fire Pump Engine Photos

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New Commitment

Table A4.0-1 Subsequent License Renewal Commitments

#	Program	Commitment	AMP	Implementation
49	N/A	Procedures will be developed to replace the diesel-driven fire pump engine heat exchanger tube bundle on a 20-year frequency and require the heat exchanger tube bundle for the spare engine to be replaced prior to being placed in-service with the diesel-driven fire pump. (Added – RAI Set 1)	N/A	Procedures to replace the diesel-driven fire pump heat exchanger tube bundle will be in place 5 years prior to the heat exchanger tube bundle achieving 20 years of active service.

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Engine History

1976: Serial #10277066 in-service (original acceptance testing of engine)
1978: Serial #10386949 installed
2003: Serial #10277066 installed (based on asset transfer history)
2013: Serial #10386949 installed
2019: Serial #10277066 installed

Run time on Serial #10277066: 14 yrs (now)
Run time on Serial #10386949: 29 yrs at time of tube leak

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Summary and Conclusion

- NUREG-2192 and Peach Bottom precedent support active status
- Heat exchanger tube leak was identified in 2017 while the engine was out-of-service for scheduled maintenance – no loss of function
- Two fire pump engines in service (with a spare engine available) with over 40 years of operating experience
  - North Anna also has a similar in-service engine installed in the Warehouse fire protection subsystem (which is not within SLRA scope)
  - One heat exchanger tube leak event identified in plant history
- Replacement interval of 20 years is conservative because two engines have been in service for over 40 years with only one leak

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RAI B2.1.27-1: Cyclic Fatigue of Buried Gray Cast Iron Using Jockey Pump Monitoring

RAI B2.1.21-1 Basis for Extent of Inspections For Selective Leaching

RAI B2.1.21-2 Basis of Single 10-foot Sample For Selective Leaching

1 May 13, 2021

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Discussion Topics

- Aging Management Effectiveness
- SLRA Table 3.3.2-42 Fire Protection: Cracking of Lined Gray Iron Pipe
- Enhanced Jockey Pump Monitoring
- Fire Protection Piping Fracture Mechanics “Calculations”
- Selective Leaching Extent of Inspections: NUREG-2222
- Selective Leaching Extent of Inspections: Considerations
- Selective Leaching Leading Sample Location
- Selective Leaching Sample Size Selection
- Conclusions

2 May 13, 2021

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Aging Management Effectiveness

- Six pipe ruptures due to cracking of cementitious lined buried gray cast iron fire protection piping occurred between 1984 and 2003 during the first half of installed pipe service life.
- Corrective actions as a result of the 2003 event prevented future occurrence by minimizing or eliminating overpressure events in the fire water system.
- A design change resulted in replacement of over 500 feet of cementitious lined buried gray cast iron piping with a higher pressure rated cementitious lined ductile iron piping.
- Of the 30 buried pipe inspections performed by the UPTI program since its initial excavations in 2011, there were seven inspections of cementitious lined buried gray cast iron fire protection piping.
- In 2015, the piping inspection guidance of the UPTI program that included selective leaching inspection considerations was enhanced to consider susceptible materials and look for the presence of selective leaching by visual, mechanical, or other appropriate means.
- None of the UPTI inspections of cementitious lined buried gray cast iron fire protection piping identified through wall leakage or minimum wall violations.

SLRA Table 3.3.2-42 Fire Protection: Cracking of Lined Gray Iron Pipe

- Cracking of buried gray cast iron piping <u>due to cyclic loading</u> is managed by the Buried and Underground Piping and Tanks (B2.1.27) program.
- Loss of material of buried gray cast iron piping is managed by the Buried and Underground Piping and Tanks (B2.1.27) program and the Selective Leaching Program (B2.1.21).
- Cyclic loading: Cyclic loading can cause cracking by periodic application of mechanical and thermal loads on a component. Examples of cyclic loading are pressure and thermally-induced loads due to thermal-hydraulic transients of piping components. Fatigue cracking is a typical result of cyclic loadings on metal components.
- Crack life cycle: initial crack due to manufacturing or construction, crack growth due overpressure event, crack leakage causes external surface loss of material, additional overpressure event(s) grows crack to failure/rupture (fracture chevrons).
- Cracking of steel piping (in a carbonate-bicarbonate environment) due to SCC is managed by NUREG-2191 XI.M41 Buried and Underground Piping and Tanks.

Enhanced Jockey Pump Monitoring

Enhanced jockey pump monitoring will be implemented to monitor and trend jockey fire pump starts or run time.

- Monitoring the activity of the jockey pump is allowed as an alternative to visual inspections by NUREG-2191 XI.M41 Buried and Underground Piping and Tanks.
- Jockey pump performance information will be monitored monthly and used to project and prevent unexpected fire pump starts, that with timely corrective actions, will reduce exposure of buried gray cast iron fire protection piping to an aggressive wet soil environment and the potential for overpressure events.
- If jockey pump run time projections can not be projected to the next monthly monitoring or an unexpected fire pump start occurs, then further investigation will be conducted to isolate and identify the potential leak location.
- When excavations are required, inspections will be conducted at the affected location to determine the cause of the failure and the findings included in CAP.
- SLRA Section B2.1.16 includes an enhancement to the “detection of aging effects” program element for enhanced jockey pump activity monitoring.

Fire Protection Piping Fracture Mechanics “Calculations”

The fire protection piping fracture mechanics calculations referenced in material analysis report NESML-Q-473 (October 15, 2001) were performed to support the findings of material analysis report MESL-N-00233 (1989) and material analysis report dated January 3, 1985. Appendix I of MESL-N-00233 is two pages in length and notes the following:

- The calculations are based on ideal theoretical values, and that the determined critical flaw size could vary as much as vary as much as 20% to 40%.
- Catastrophic failure will most likely occur due to a four to six inch flaw rather than a two-foot flaw or to a pinhole defect.
- While the calculated critical flaw size may be regarded, at best as a mere approximation, they provide support of the material analysis report findings.

The January 3,1985 material analysis report was similar with additional details.

Selective Leaching Extent of Inspections: NUREG-2222

The reduced extent of inspection is appropriate for NAPS buried gray cast iron piping with lining based on the following considerations

- 1 & 2 - Opportunistic (informed by enhanced jockey pump monitoring) and destructive examinations will be performed. In addition, SLR will perform periodic exams for aggressive environments rather than one-time inspections
- 3 - Initial License Renewal Selective Leaching program considerations:
  - Use of selective leaching destructive exams (M33 OE#1 2015) and (M33 OE#2 1st bullet 2001)
  - In 2015 UPTI program enhanced to look for selective leaching by visual, mechanical, or other appropriate means
- 4, 5, 6 – Operating experience:
  - 7 UPTI inspections performed since 2011 demonstrated good internal/external coatings and no wall leakage or no minimum wall violations
  - No fire protection pipe ruptures since 2003

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Selective Leaching Extent of Inspection: Considerations

Extent of inspections for cementitiously lined buried gray cast iron fire protection piping is based on periodic and opportunistic inspections that considers:

- Loss of material and cracking inspection samples focused on the bounding or lead components most susceptible to aging
- Use of enhanced jockey pump monitoring to identify, excavate, and mitigate elevated fire protection buried piping leakage as well as minimize aggressive wet soil environments and piping overpressure events
- Opportunistic inspections based on enhanced jockey pump monitoring to target specific piping leakage issues will augment periodic sampling – informed opportunistic inspections as a result of enhanced jockey pump monitoring are a more efficient use of resources
- Demonstration of the effectiveness of aging management for cementitious lined fire protection buried gray cast iron fire protection piping

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Selective Leaching Leading Sample Location

Based on operating experience, the following considerations would apply for selection of buried gray cast iron fire protection piping that is lined with a cementitious coating:

- Older piping segments (i.e. not previously replaced)
- Piping found to be continuously wetted due to leaking piping/valves or in soil with high corrosivity ratings as determined by EPRI Report 3002005294
- Piping that is not cathodically protected
- Piping with significant coating degradation or unexpected backfill
- Consequence of failure (i.e. proximity to safety-related piping)
- Pipe locations with potentially high stress and/or cyclic loading conditions such as piping adjacent to locations that were replaced due to cracking/rupture, locations subject to settlement, or locations subject to heavy load traffic

Selective Leaching Sample Size Selection

Periodically excavating one 10-foot piping segment per unit will satisfy the visual inspections (8 samples) and the mandatory destructive examination (2 samples).

- Selection of piping excavation location consistent with leading sample criteria
- NUREG-2191 considers each 1-foot piping segment (or equivalent 1 foot segment) as 1 component: M33, M36, M38 (any combination of 1-foot lengths), M41 (inspections based on 10 foot lengths), and M42
- Opportunistic inspections based on enhanced jockey pump monitoring to target specific piping leakage issues will augment periodic sampling – informed opportunistic inspections as a result of enhanced jockey pump monitoring are a more efficient use of resources

Conclusions

The previous information demonstrates with reasonable assurance that the intended function of the buried lined gray cast iron fire protection piping will be maintained throughout the subsequent period of extended operation.

- Enhanced jockey pump monitoring and trending using pump run time projections and unexpected fire pump starts will be implemented to identify and inform opportunistic inspections,
- Opportunistic inspections based on enhanced jockey pump monitoring target specific piping leakage issues and will efficiently augment periodic sampling.
- Selective Leaching program extent of inspections are appropriate based upon opportunistic inspections, continued use of in-house metallurgical lab for destructive examinations, first License Renewal program considerations, and AMP effectiveness/OE.
- Selection of periodic Selective Leaching program piping excavation locations are consistent with NUREG-2191 guidance for other piping segment inspections and will be consistent with leading sample criteria.

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