External Surfaces & Selective Leaching

RAI B.2.3.23-1

Regulatory Basis:

Section 54.21(a)(3) of Title 10 of the *Code of Federal Regulations* (10 CFR) requires an applicant to demonstrate that the effects of aging for structures and components will be adequately managed so that the intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation. One of the findings that the U.S. Nuclear Regulatory Commission (NRC) staff must make to issue a renewed license (10 CFR 54.29(a)) is that actions have been identified and have been or will be taken with respect to managing the effects of aging during the period of extended operation on the functionality of structures and components that have been identified to require review under 10 CFR 54.21, such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the current licensing basis. In order to complete its review and enable making a finding under 10 CFR 54.29(a), the staff requires additional information in regard to the matters described below.

Background:

SLRA Table 3.3.2-4, "Diesel Generators and Support Systems – Summary of Aging Management Evaluation," states the external surfaces of copper alloy with greater than 15 percent zinc heat exchanger radiator tubes exposed to air-indoor uncontrolled will be managed for reduction of heat transfer and cracking using the external surfaces monitoring of mechanical components program.

The staff recently became aware of operating experience at St. Lucie for an emergency diesel generator (EDG) radiator leak that occurred in June 2022. The cause of the leak was dezincification on the external surfaces of yellow brass EDG radiator tubes, which are exposed to an air – indoor uncontrolled environment. According to the NRC Resident Inspector, site personnel considered the leak to be a functional failure.

A subsequent review of historical operating experience by the NRC staff identified EDG radiator tube leaks in May and June of 2001 (Ref Licensee Event Report 335/2001-006 (ML012050195)). Although the radiator tube designs have been modified to eliminate the original soldered mechanical tube joints that had failed, the event report noted that corrosion of the radiator cooling fins was due to "humid salt-laden" air. The staff notes that the environment descriptions in SLRA Table 3.0-1 only includes salt-laden air for "Air – outdoor" and not for "Air indoor uncontrolled."

Issue:

The air environment in the EDG rooms appears to be a more aggressive environment based on the presence of salt-laden air. Based on the air environment classification as "air-indoor uncontrolled," the staff seeks clarification for whether different aging management activities are warranted for this potentially more aggressive air environment and, if so, whether other locations in the plant are similarly exposed to a comparable environment.

Request:

Provide information regarding the need to adjust any aging management activities as a result of the potentially more aggressive air environment within the EDG rooms and whether other rooms would be similarly exposed to a comparable environment.

PSL Response:

The response to RAI B.2.3.21-3 (Attachment 3 to this letter) provides a detailed evaluation of the May 2001 (Reference 1) and July 2022 1B2 EDG radiator tube failures. The evaluation concludes that the July 22 1B2 EDG tube failure was the first documented failure of a Unit 1 or 2 component due to selective leaching when exposed to an air-indoor uncontrolled or air-outdoor environment. Further evaluation concludes that the failure of the external surface of the 1B2 copper alloy with greater than 15 percent zinc radiator tubes exposed to air-indoor uncontrolled is a plant-specific aging effect unique to the Unit 1 EDG radiators based on the following:

- No other recent plant-specific OE regarding component failures due to selective leaching,
- No failures of the Unit 2 EDG Admiralty brass radiator tubes after approximately 39 years of service,
- The unique design of the Unit 1 EDG radiators,
- The periodic rinsing of the Unit 1 EDG radiators, and
- The severe environmental conditions the Unit 1 EDG radiators are exposed to during EDG runs with radiator fans in operation.

Therefore, there is no need to adjust any aging management activities for other structures and components within the EDG buildings as the more aggressive air-indoor uncontrolled environment is unique to only the Unit 1 EDG radiators. In addition, no other rooms or buildings containing structures and components within the scope of license renewal are similarly exposed to an environment comparable to the Unit 1 EDG radiators.

Note that the response to RAI B.2.3.23-2 (Attachment 2 to this letter) states that since the Unit 1 EDG radiators are subject to replacement based on a specified time, they are not considered long-lived and are not subject to an aging management review in accordance with 10 CFR 54.21(a)(1)(ii). As such, the Unit 1 EDG radiators have been deleted from SLRA Table 3.3.2-4.

References:

1. FPL letter L-2001-169, St. Lucie Unit 1 Reportable Event 2001-006-00, Degraded EDG Radiator Lead to Operation of Facility Prohibited by Technical Specifications, dated July 19, 2001 (ADAMS Accession No. ML012050195)

Associated SLRA Revisions:

None.

Associated Enclosures:

None.

External Surfaces & Selective Leaching

RAI B.2.3.23-2

Regulatory Basis:

Section 54.21(a)(3) of Title 10 of the *Code of Federal Regulations* (10 CFR) requires an applicant to demonstrate that the effects of aging for structures and components will be adequately managed so that the intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation. One of the findings that the U.S. Nuclear Regulatory Commission (NRC) staff must make to issue a renewed license (10 CFR 54.29(a)) is that actions have been identified and have been or will be taken with respect to managing the effects of aging during the period of extended operation on the functionality of structures and components that have been identified to require review under 10 CFR 54.21, such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the current licensing basis. In order to complete its review and enable making a finding under 10 CFR 54.29(a), the staff requires additional information in regard to the matters described below.

Background:

SLRA Section B.2.3.23 includes enhancements to the external surfaces monitoring of mechanical components program to conduct periodic visual inspections or surface examinations on components made from various materials, including copper alloy with greater than 15 percent zinc. SLRA Table 3.3.2-4, "Diesel Generators and Support Systems – Summary of Aging Management Evaluation," credits the above program for managing cracking due to the external air environment of the emergency diesel generator (EDG) radiator tubes.

As part of the operating experience information associated with the recent EDG radiator leak at St. Lucie, NRC regional inspectors provided an Imperia Engineering Partners report, "Failure Analysis of 1B2 EDG Radiator," Revision 0, July 2022. Section 4.4 of the report notes that neither visual nor mechanical detection methods are useful in detecting the selective leaching observed in the radiator tubes due to inaccessibility. The report also notes that there was no report of seepage or slow leakage prior to the rapid leak of the radiator tube and that the tube ultimately failed by cracking due to overload.

Issue:

Although the Imperia report's statement about inaccessibility only addressed the detection of selective leaching, the NRC staff believes it is comparably applicable to the detection of cracking of the EDG radiator tubes that are addressed in SLRA Table 3.3.2-4. Based on the apparent inaccessibility to the tube surface, it is also not clear how 20 percent of the radiator tube surface area can be either visually inspected or surface examined for cracking, as provided in an enhancement to the associated aging management program.

Request:

Provide information regarding the ability to detect cracking of the EDG radiator tubes given the inaccessibility of the tube surfaces, using currently proposed enhancements to the external surfaces monitoring of mechanical components for surface examinations or ASME Code Section XI VT-1 inspections. In addition, for the EDG radiator tubes, provide the bases for conducting aging management activities to detect cracking on a 10-year frequency, given that the recent tube leaks occurred with less than 10 years of operation.

PSL Response:

As described in St. Lucie Unit 1 Licensee Event Report (LER) 2001-006 (Reference 1), on May 22, 2001 during the performance of the monthly Technical Specification (TS) surveillance run for the 1B EDG, FPL discovered that the 1B2 EDG had a radiator leak. Corrosion of the EDG radiator cooling fins resulted in a loss of structural support of the radiator flat tubes that ultimately caused the failure of the soldered mechanical tube joints. Corrective actions included replacement of the 1B2 EDG radiator and revision to the preventative maintenance program and procedures to provide cleaning and replacement of the Unit 1 EDG radiators based on a specified time period.

10 CFR 54.21 states, in part, that each license renewal application must contain the following information:

(a) An integrated plant assessment (IPA). The IPA must--

1. For those systems, structures, and components within the scope of this part, as delineated in § 54.4, identify and list those structures and components subject to an aging management review. Structures and components subject to an aging management review shall encompass those structures and components--

(i) That perform an intended function, as described in § 54.4, without moving parts or without a change in configuration or properties; and

(ii) That are not subject to replacement based on a qualified life or specified time period.

Therefore, based on the FPL evaluation included in LER 2001-006, the Unit 1 EDG radiators are subject to replacement based on a specified time and are not considered long-lived and are not subject to an aging management review in accordance with 10 CFR 54.21(a)(1)(ii). Accordingly, the Unit 1 EDG radiators are deleted from SLRA Table 3.3.2-4 and the External Surfaces Monitoring of Mechanical Components AMP is no longer credited for managing the aging effects of the Unit 1 EDG radiators.

Note that the Unit 2 EDG radiator design is significantly different than Unit 1. The Unit 1 EDG radiators are a “truck-style”, copper fin and brass tube radiator (Unit 1 UFSAR Table 9.5-3) while the Unit 2 EDG design incorporates an air-cooled heat exchanger constructed of heavy-wall round Admiralty brass tubes with aluminum fins that are designed in accordance with the ASME Section VIII Code (Unit 2 UFSAR Table 9.5-3). The Unit 2 EDG radiators are designed for the life of the plant and have not been replaced. Therefore, the Unit 2 EDG radiators are considered long-lived and are subject to an aging management review in accordance with 10

CFR 54.21(a)(1)(ii). SLRA Table 3.3.2-4 credits the External Surfaces Monitoring of Mechanical Components AMP for managing cracking of the Unit 2 EDG radiator Admiralty brass tubes exposed to an air-indoor uncontrolled environment. Each of the four (2A1, 2A2, 2B1, and 2B2) Unit 2 EDG radiator enclosures have two (2) 30-inch wide by 45-inch tall access panels on opposite sides of the enclosures. Removal of these 2 access panels facilitates ASME Code Section XI VT-1 inspections of fan side of each radiator. Performance of these VT-1 inspections on a 10-year frequency in accordance SLRA Section B.2.3.23 is justified based on plant-specific OE and the fact that the Unit 2 EDG radiators have not required replacement after approximately 39-years of operation.

SLRA Tables 2.3.3-4 and 3.3.2-4 have been revised below to incorporate these changes and to delete reference to Plant Specific Note 1.

References:

1. FPL letter L-2001-169, St. Lucie Unit 1 Reportable Event 2001-006-00, Degraded EDG Radiator Lead to Operation of Facility Prohibited by Technical Specifications, dated July 19, 2001 (ADAMS Accession No. ML012050195)

Associated SLRA Revisions:

SLRA Table 2.3.3-4, page 2.3-37 is revised as follows:

Table 2.3.3-4
Diesel Generators and Support System Components Subject to Aging Management Review

Component Type	Component Intended Function(s)
Air motor	Pressure boundary
Air motor lubricator	Pressure boundary
Bolting	Mechanical closure
Expansion joint	Pressure boundary
Flame arrestor	Flame suppression
Filter (Unit 2 only)	**Filter**
Flexible hose	Pressure boundary
Heat exchanger (lube oil)	Heat transfer Pressure boundary
Heat exchanger (**Unit 2** radiator)~~1~~	Heat transfer Pressure boundary
Orifice	Pressure boundary Throttle
Piping	Pressure boundary
Piping and piping components	Pressure boundary Structural integrity (attached)
Pump casing (cooling water)	Pressure boundary
Pump casing (engine-driven fuel)	Pressure boundary
Pump casing (fuel oil transfer)	Pressure boundary

Component Type	Component Intended Function(s)
Pump casing (lube oil)	Pressure boundary
Pump casing (priming)	Pressure boundary
Sight glass	Pressure boundary
Silencer	Pressure boundary
Strainer	Filter Pressure boundary
Tank (air start)	Pressure boundary
Tank (day)	Pressure boundary
Tank (diesel oil storage)	Pressure boundary
Tank (expansion)	Pressure boundary
Thermowell	Pressure boundary
Valve body	Pressure boundary

Note:

1. **The Unit 1 EDG heat exchangers (radiators) are subject to replacement based on a specified time period. As described in SLRA Section 2.1.5, 10 CFR 54.21(a)(1)(ii) states that structures and components subject to an aging management review shall encompass those structures and components that are not subject to periodic replacement based on a qualified life or specified time period. Therefore, the Unit 1 EDG heat exchangers (radiators) are not considered long-lived and are not subject to an aging management review.**

SLRA Table 3.3.2-4, pages 3.3-114 and 3.3-115 are revised as follows:

Table 3.3.2-4: Diesel Generators and Support Systems – Summary of Aging Management Evaluation

Component Type	Intended Function	Material	Environment	Aging Effect Requiring Management	Aging Management Program	NUREG-2191 Item	Table 1 Item	Notes
Heat exchanger (lube oil tubes)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Loss of material	Closed Treated Water Systems (B.2.3.12)	VII.H2.AP-199	3.3-1, 046	C
Heat exchanger (lube oil tubes)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Loss of material	Selective Leaching (B.2.3.21)	VII.H2.AP-43	3.3-1, 072	C
Heat exchanger (lube oil tubesheet)	Pressure boundary	Copper alloy > 15% Zn	Lubricating oil (int)	Loss of material	Lubricating Oil Analysis (B.2.3.25) One-Time Inspection (B.2.3.20)	VII.H2.AP-133	3.3-1, 099	C
Heat exchanger (lube oil tubesheet)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Cracking	Closed Treated Water Systems (B.2.3.12)	VII.C2.A-473a	3.3-1, 160	C
Heat exchanger (lube oil tubesheet)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Loss of material	Closed Treated Water Systems (B.2.3.12)	VII.H2.AP-199	3.3-1, 046	C
Heat exchanger (lube oil tubesheet)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Loss of material	Selective Leaching (B.2.3.21)	VII.H2.AP-43	3.3-1, 072	C
Heat exchanger (Unit 2 radiator headers)	Pressure boundary	Carbon steel	Air – indoor uncontrolled (ext)	Loss of material	External Surfaces Monitoring of Mechanical Components (B.2.3.23)	VII.I.AP-41	3.3-1, 080	A
Heat exchanger (Unit 2 radiator headers)	Pressure boundary	Carbon steel	Treated water (int)	Loss of material	Closed Treated Water Systems (B.2.3.12)	VII.H2.AP-202	3.3-1, 045	C
Heat exchanger (Unit 2 radiator tubes)	Heat transfer	Copper alloy > 15% Zn	Air – indoor uncontrolled (ext)	Reduction of heat transfer	External Surfaces Monitoring of Mechanical Components (B.2.3.23)	VII.I.A-716	3.3-1, 151	A

Table 3.3.2-4: Diesel Generators and Support Systems – Summary of Aging Management Evaluation								
Component Type	**Intended Function**	**Material**	**Environment**	**Aging Effect Requiring Management**	**Aging Management Program**	**NUREG-2191 Item**	**Table 1 Item**	**Notes**
Heat exchanger (Unit 2 radiator tubes)	Heat transfer	Copper alloy > 15% Zn	Treated water (int)	Reduction of heat transfer	Closed Treated Water Systems (B.2.3.12)	VII.C2.AP-205	3.3-1, 050	A
Heat exchanger (Unit 2 radiator tubes)	Pressure boundary	Copper alloy > 15% Zn	Air – indoor uncontrolled (ext)	Cracking	External Surfaces Monitoring of Mechanical Components (B.2.3.23)	VIII.H.S-454	3.4-1, 106	C
Heat exchanger (Unit 2 radiator tubes)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Cracking	Closed Treated Water Systems (B.2.3.12)	VII.C2.A-473a	3.3-1, 160	C
Heat exchanger (Unit 2 radiator tubes)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Loss of material	Closed Treated Water Systems (B.2.3.12)	VII.H2.AP-199	3.3-1, 046	C
Heat exchanger (Unit 2 radiator tubes)	Pressure boundary	Copper alloy > 15% Zn	Treated water (int)	Loss of material	Selective Leaching (B.2.3.21)	VII.H2.AP-43	3.3-1, 072	C
Heat exchanger (Unit 1 lube oil channel header)	Pressure boundary	Gray cast iron	Air – indoor uncontrolled (ext)	Loss of material	External Surfaces Monitoring of Mechanical Components (B.2.3.23)	VII.I.AP-41	3.3-1, 080	A
Heat exchanger (Unit 1 lube oil channel header)	Pressure boundary	Gray cast iron	Treated water (int)	Loss of material	Closed Treated Water Systems (B.2.3.12)	VII.H2.AP-202	3.3-1, 045	C
Heat exchanger (Unit 1 lube oil channel header)	Pressure boundary	Gray cast iron	Treated water (int)	Loss of material	Selective Leaching (B.2.3.21)	VII.F4.AP-31	3.3-1, 072	C
~~Heat exchanger (Unit 1 radiator fins)~~	~~Heat transfer~~	~~Copper alloy~~	~~Air – indoor uncontrolled (ext)~~	~~Loss of material~~	~~External Surfaces Monitoring of Mechanical Components (B.2.3.23)~~	~~VIII.H.S-426~~	~~3.4-1, 075~~	~~C, 1~~

Table 3.3.2-4: Diesel Generators and Support Systems – Summary of Aging Management Evaluation								
Component Type	**Intended Function**	**Material**	**Environment**	**Aging Effect Requiring Management**	**Aging Management Program**	**NUREG-2191 Item**	**Table 1 Item**	**Notes**
~~Heat exchanger (Unit 1 radiator fins)~~	~~Heat transfer~~	~~Copper alloy~~	~~Air – indoor uncontrolled (ext)~~	~~Reduction of heat transfer~~	~~External Surfaces Monitoring of Mechanical Components (B.2.3.23)~~	~~V.E.E-424~~	~~3.2-1, 081~~	~~C~~

SLRA Table 3.3.2-4, page 3.3-116 is revised as follows:

Table 3.3.2-4: Diesel Generators and Support Systems – Summary of Aging Management Evaluation								
Component Type	**Intended Function**	**Material**	**Environment**	**Aging Effect Requiring Management**	**Aging Management Program**	**NUREG-2191 Item**	**Table 1 Item**	**Notes**
Heat exchanger (Unit 2 radiator fins)	Heat transfer	Aluminum	Air – indoor uncontrolled (ext)	Loss of material	External Surfaces Monitoring of Mechanical Components (B.2.3.23)	VII.F4.A-771b	3.3-1, 242	A~~, 1~~

SLRA Table 3.3.2-4, page 3.3-134 is revised as follows:

Table 3.3.2-4: Diesel Generators and Support Systems – Summary of Aging Management Evaluation

Component Type	Intended Function	Material	Environment	Aging Effect Requiring Management	Aging Management Program	NUREG-2191 Item	Table 1 Item	Notes
Valve body	Pressure boundary	Stainless steel	Air – indoor uncontrolled (int)	Loss of material	Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components (B.2.3.24)	VII.H1.AP-221c	3.3-1, 006	A
Valve body	Pressure boundary	Stainless steel	Fuel oil (int)	Loss of material	Fuel Oil Chemistry (B.2.3.18) One-Time Inspection (B.2.3.20)	VII.H1.AP-136	3.3-1, 071	B A
Valve body	Pressure boundary	Stainless steel	Lubricating oil (int)	Loss of material	Lubricating Oil Analysis (B.2.3.25) One-Time Inspection (B.2.3.20)	VII.H2.AP-138	3.3-1, 100	A

General Notes

A. Consistent with component, material, environment, aging effect, and AMP listed for NUREG-2191 line item. AMP is consistent with NUREG-2191 AMP description.
B. Consistent with component, material, environment, aging effect, and AMP listed for NUREG-2191 line item. AMP has exceptions to NUREG-2191 AMP description.
C. Component is different, but consistent with material, environment, aging effect, and AMP listed for NUREG-2191 line item. AMP is consistent with NUREG-2191 AMP description.

Plant Specific Notes

~~1. Plant experience shows a history of loss of material and fouling due to corrosion on fins~~**None.**

Associated Enclosures:

None.

External Surfaces & Selective Leaching

RAI B.2.3.21-3

Regulatory Basis:

Section 54.21(a)(3) of Title 10 of the *Code of Federal Regulations* (10 CFR) requires an applicant to demonstrate that the effects of aging for structures and components will be adequately managed so that the intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation. One of the findings that the U.S. Nuclear Regulatory Commission (NRC) staff must make to issue a renewed license (10 CFR 54.29(a)) is that actions have been identified and have been or will be taken with respect to managing the effects of aging during the period of extended operation on the functionality of structures and components that have been identified to require review under 10 CFR 54.21, such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the current licensing basis. In order to complete its review and enable making a finding under 10 CFR 54.29(a), the staff requires additional information in regard to the matters described below.

Background:

SLRA Table 3.3.2-4, "Diesel Generators and Support Systems – Summary of Aging Management Evaluation," states the external surfaces of copper alloy with greater than 15 percent zinc heat exchanger radiator tubes exposed to air-indoor uncontrolled will be managed for reduction of heat transfer and cracking using the external surfaces monitoring of mechanical components program. The staff notes that the external surfaces of the subject components are not being managed for loss of material due to selective leaching.

SLRA Section B.2.3.21, "Selective Leaching," states the following (in part):

> "[t]he PSL Selective Leaching AMP [aging management program] includes inspections of components made of gray cast iron, ductile iron, and copper alloys (except for inhibited brass) that contain greater than 15% Zn or greater than 8% Aluminum exposed to a raw water, closed-cycle cooling water, treated water, waste water, soil, or groundwater environment."

The staff recently became aware of operating experience at St. Lucie for an emergency diesel generator (EDG) radiator leak that occurred in June 2022. The cause of the leak was dezincification on the external surfaces of yellow brass EDG radiator tubes, which are exposed to an air-indoor uncontrolled environment.

Issue:

Based on its review of the SLRA, the staff noted loss of material due to selective leaching is being managed for components exposed to water or soil environments. However, based on the operating experience noted above, the staff seeks clarification with respect to why loss of material due to selective leaching is not being managed for copper alloy with greater than 15 percent zinc components exposed to air-indoor uncontrolled or more aggressive air environments (i.e., air-outdoor and condensation). The staff's issue is not applicable to less aggressive air environments (i.e., air-indoor controlled and air-dry).

Request:

1. Provide any additional clarifying information with respect to the operating experience noted above and revise the SLRA (as appropriate).

2. State the basis for why loss of material due to selective leaching is not an aging effect requiring management for copper alloy with greater than 15 percent zinc components exposed to air-indoor uncontrolled, air-outdoor, or condensation environments. Alternatively, revise the SLRA (as appropriate) to reflect that the subject components will be managed for loss of material due to selective leaching.

PSL Response:

The numbered responses below correspond to numbered requests in the RAI.

1. Additional information regarding the July 2022 failure of the 1B2 EDG radiator is provided below in the revision to the Plant Specific Operating Experience portion of SLRA Section B.2.3.21.

2. Based on a detailed review of the May 2001 (Reference 1) and July 2022 failures of the 1B2 EDG radiator tubes, it is reasonable to conclude that the loss of material due to selective leaching is an aging effect unique to the external surfaces of the Unit 1 1A1, 1A2, 1B1, and 1B2 EDG radiators exposed to an air-indoor uncontrolled environment. The bases for this conclusion are as follows:

   a) PSL Site-specific Operating Experience for Selective Leaching

      SLRA Section B.2.3.21 discusses plant-specific OE associated with the new Selective Leaching AMP and states an OE search from October 1, 2010 through October 1, 2020 did not identify any instances of component failure on either Unit 1 or 2 as a result of selective leaching. The recent July 2022 1B2 EDG radiator tube failure appears to be the first documented instance of a PSL component failure resulting from selective leaching.

   b) Unit 1 and 2 EDG Radiator Design Differences

      There are significant differences between the Unit 1 and 2 EDG radiator designs. The Unit 1 EDG radiators are a "truck-style", copper fin and brass tube radiator consisting of 4 cores bolted together which are bolted to upper and lower headers. Each core contains 5 rows of tubes; the outer row tubes are 0.012" thick, the inner row tubes are 0.008" thick, and the copper fins are 0.0035" thick. The radiators are approximately 8 inches thick. The Unit 1 EDG radiator core surface area is more compact than the Unit 2 EDG radiators. This radiator design has very efficient thermal performance but plant-specific OE has shown these radiators to be susceptible to external corrosion.

The Unit 2 EDG radiators are an air-cooled heat exchanger using an extended fin surface to remove heat. The heat exchanger is constructed of 1 inch heavy-wall round Admiralty tubes with aluminum fins and each tube is pluggable. The heat exchangers are much larger than the Unit 1 EDG radiators The heat exchangers are designed in accordance with the ASME Section VIII Code (Unit 2 UFSAR Table 9.5-3). These heat exchangers are designed for the life of the plant and they have not experienced a tube failure in 39 years of operation.

c) Unit 1 EDG Radiator Periodic Rinsing

Corrective actions implemented after the 2001 failure of the 1B2 EDG radiator tube included revisions to the preventive maintenance program and procedures to provide cleaning and time-based replacement of the Unit 1 EDG radiators. Inspection ports were cut into the Unit 1 EDG radiator shrouds to facilitate visual inspection and PMs were developed to inspect and document radiator fin corrosion using detailed functional criteria. This PM was originally performed every 24 months and is now performed every 36 months during EDG critical maintenance activities. Radiator cleaning and inspection PMs with a 6-month frequency were also implemented. Note that the PMs recommend washing the Unit 1 EDG radiators from the inside, or fan side of the radiator, to the outside of the EDG room if particulate fouling buildup was identified. A review of the Unit 2 EDG radiator PMs indicate that periodic rinsing of the Unit 2 EDG radiator tubes is not performed, so the radiator rinsing activity is unique to Unit 1.

Subsequent to the recent 2022 1B2 EDG radiator tube failure, the core section of the radiator containing the failed brass tube was sent off site for independent failure analysis. Results of the radiator tube failure analysis identified the failure mechanism to be a crack in the seamless tube material at a location weakened by low zinc content. The failure analysis report identified several key facts about the specific mechanism that caused the seamless tube to fail. The report states the following:

“During operation of the diesel generator, the 1B2 EDG radiator was subjected saltwater vapor rich air passing through the radiator from the fan side to the exhaust side. The air flow resulted in corrosive deposit accumulation on the fan side fins and tubes. PSL reported that regular maintenance included rinsing the radiator every 6-12 months using potable water. The rinsing action is suspected to have contributed to increased accumulation of corrosive deposits on the fan side of the radiator, particularly toward the bottom of the radiator as the water ran down the fan side of the radiator.”

"Laboratory analysis of the failed tube crack tips revealed the zinc was leached from the brass material, leaving behind a porous, copper-rich structure with zinc content ranging from 6.55% to 15.75% as compared with the zinc content of 32.53% in the smooth (non-corroded) tube area. Zinc leaching was assisted by the corrosive deposit accumulations at the bottom half of the radiator. The leaching process removed zinc from the alloy and allowed the zinc to form a porous white zinc oxide deposit layer on the tube OD surfaces. The remaining porous copper-rich structure of the tube wall possessed reduced mechanical strength. As the corrosion process continued, with resulting reduction of mechanical strength, the tube wall eventually became unable to withstand the water pressure in the coolant system and cracked.”

The report concluded:

"The combination of damp conditions, elevated temperature during operation, and accumulation of corrosive deposits on the tube OD surface accelerated corrosion of the fan side fin and tubes. The copper fins were degraded by general corrosion. The yellow brass tubes contained more than 15% zinc and were susceptible to selective leaching of the zinc, or dezincification. This process reduced the mechanical strength of the tube to the point where the remaining tube wall was unable to withstand the water pressure in the coolant system, resulting in the through wall crack.”

Unlike the Unit 1 EDG radiators, PSL copper alloy with greater than 15 percent zinc components within the scope of license renewal that are located indoors in Class 1 structures, including the Unit 2 EDG radiators, are not exposed to periodic wetting.

d) Unit 1 and 2 EDG Radiator Environmental Conditions

Unit 1 and 2 Technical Specification surveillance testing requires each EDG to be started monthly on a staggered test basis and also started, loaded, and run for 24-hours every 18 months during refueling outages. Conservatively assuming a full day of EDG operation for each bi-monthly EDG test and 7 days of operation for each 24-hour outage test every 18 months equates to a total of 16 days of EDG operation during a typical 18-month (548 day) fuel cycle. Therefore, the EDG buildings are exposed to normal operating ventilation conditions for (548-16)/548, or greater than 97% of the time.

During this period of EDG standby operation, normal ventilation for the Unit 1 and 2 EDG buildings is provided by a single roof ventilator fan with capacity of 5000 cfm for Unit 1 (UFSAR Table 9.4-7) and 6600 cfm for Unit 2 (UFSAR Table 9.4-12). The roof ventilators pull outside air into the EDG buildings through the building outside air intakes and radiator exhaust openings.

During the approximate 3% EDG test condition, both the 16-cylinder and 12-cylinder engine radiator fans are in operation and ventilation flow rates through each EDG room increases significantly due to EDG engine radiator fan operation. EDG radiator fan flow rates for the 16-cylinder and 12-cylinder engines are provided in Table 9.5-3 of each of the Unit 1 and 2 UFSARs and are included in the table below. This EDG test radiator fan total ventilation flow rate (255,000 cfm for Unit 1 and 157,491 cfm for Unit 2) is significantly higher than the 5000 cfm and 6600 cfm normal ventilation flow rate through the Unit 1 and 2 EDG buildings, respectively. During these test conditions, the fan side of the Unit 1 EDG 16-cylinder and 12-cylinder engine radiators are exposed to significantly higher air velocity than Unit 2 due to higher radiator fan flow rates and smaller radiator face surface area (between 24.2 and 28.2 feet per second for Unit 1 and between 6.3 and 6.4 feet per second for Unit 2). The combination of a more torturous flow path for radiator fan ventilation flow thorough the EDG radiators, significantly higher air velocity on the

EDG fan side radiator faces, and periodic wetting of the EDG radiators during PMs, provides a much greater potential for contaminants (salt) to accumulate on the fan side face of the Unit 1 EDG radiators. This is confirmed by photographs in the July 2022 failure analysis report that show significant accumulation of contaminants and corrosion located on the bottom of the fan side of 1B2 radiator where the EDG radiator tube failure occurred.

EDG	Engine	Radiator Core Size (Width x Height)	Radiator Core Area	Radiator Fan Air Flow	Radiator Face Air Velocity
Unit 1					
1A1 and 1B1	16 cylinder	10 ft x 10 ft	100 ft^2	145,000 cfm	24.2 ft/sec
1A2 and 1B2	12 cylinder	10 ft x 6.5 ft	65 ft^2	110,000 cfm	28.2 ft/sec
Total radiator fan flow				255,000 cfm	
Unit 2					
2A1 and 2B1	16 cylinder	19 ft x 12.5 ft	237.5 ft^2	90,000 cfm	6.3 ft/sec
2A2 and 2B2	12 cylinder	16 ft x 11 ft	176 ft^2	67,491 cfm	6.4 ft/sec
Total radiator fan flow				157,491 cfm	

Based on the information presented above, the PSL plant specific OE regarding selective leaching and the significant differences between the Unit 1 and 2 EDG radiator design, preventive maintenance procedures requiring periodic rinsing, and radiator environmental conditions, it is reasonable to conclude that the July 2022 failure of the 1B2 EDG radiator tube due to loss of material due to selective leaching is an aging effect unique to the external surfaces of the Unit 1 EDG radiators that are exposed to an air-indoor uncontrolled environment.

References:

1. FPL letter L-2001-169, St. Lucie Unit 1 Reportable Event 2001-006-00, Degraded EDG Radiator Lead to Operation of Facility Prohibited by Technical Specifications, dated July 19, 2001 (ADAMS Accession No. ML012050195)

Associated SLRA Revisions:

SLRA Section B.2.3.21, page B-181 is revised as follows:

the pipe was representative of the fire water distribution system for the plant.

- **On June 13, 2022, the 1B EDG was started for its monthly surveillance test. At approximately 1 hour and 21 minutes into the unloaded portion of the surveillance run, Operations reported a significant coolant leak coming from the radiator on the 1B2 engine and requested the EDG be shut down. The 1B EDG remained out of service for approximately 3 days while the 1B2 EDG radiator was replaced. On June 16, 2022, the 1B EDG was satisfactorily tested and restored to Operable status.**

  The 1B2 radiator core section containing the failed brass tube was sent off site for independent forensic analysis. Results of the radiator tube failure analysis identified the failure mechanism to be a crack in the seamless tube material at a location weakened by low zinc content. The failure analysis report identified several key facts about the specific mechanism that caused the seamless tube to fail. The report stated:

  > ***"Laboratory analysis of the failed tube crack tips revealed the zinc was leached from the brass material, leaving behind a porous, copper-rich structure with zinc content ranging from 6.55% to 15.75% as compared with the zinc content of 32.53% in the smooth (non-corroded) tube area. Zinc leaching was assisted by the corrosive deposit accumulations at the bottom half of the radiator. The leaching process removed zinc from the alloy and allowed the zinc to form a porous white zinc oxide deposit layer on the tube OD surfaces. The remaining porous copper-rich structure of the tube wall possessed reduced mechanical strength. As the corrosion process continued, with resulting reduction of mechanical strength, the tube wall eventually became unable to withstand the water pressure in the coolant system and cracked."***

  The report concluded:

  > ***"The combination of damp conditions, elevated temperature during operation, and accumulation of corrosive deposits on the tube OD surface accelerated corrosion of the fan side fin and tubes. The copper fins were degraded by general corrosion. The yellow brass tubes contained more than 15% zinc and were susceptible***

to selective leaching of the zinc, or dezincification. This process-reduced the mechanical strength of the tube to the point where the remaining tube wall was unable to withstand the water pressure in the coolant system, resulting in the through wall crack."

Other key take-aways from the report and discussions with in-house and metallurgists include:

- **The crack developed and propagated rapidly based on the following:**
  - **The crack was uniform in width.**
  - **The tube wall thickness was relatively uniform (i.e., no wall thinning due to the identified corrosion mechanism).**
  - **There was no evidence of tube swelling in the seamless tubes.**
  - **There was no evidence of a pre-existing flaw or crack at the initiation site. (i.e., no prior leakage)**
  - **There was no evidence of a small flaw or crack that propagated over time due to vibration, fatigue, or wall thinning.**
- **De-alloying and selective leaching were OD-initiated and led to the failure.**
- **Dezincification of yellow brass tubes is a time-dependent corrosion mechanism with the corrosion rate based on several variables including humidity, salt concentration, effectiveness of coating material, effectiveness of rinsing, moisture in the core, etc. (but there are too many variables to predict the zinc oxide corrosion rates).**
- **Dezincification is localized with selective de-alloying in one area, and little or no de-alloying in nearby locations.**
- **Dezincification of yellow brass tubes is a different corrosion mechanism than the general corrosion mechanism of the copper fins.**
- **Tube corrosion is not dependent on fin corrosion.**

- **The selective leaching/dezincification rate is non-linear, non-uniform, and the rate is unpredictable. (i.e., it is not possible to estimate a threshold for tube failures.)**

- **The failure mechanism of the yellow brass tube required Scanning Electron Microscopy (SEM) to detect selective leaching, weakening and embrittlement of the base material.**

Historically, a previous 1B2 EDG radiator tube leak failure occurred in 2001. At that time, the yellow brass tubes were rolled and soldered; not seamless as is the current design. Similar to the 2022 1B2 EDG radiator failure, tube, the tube failure occurred on the fan side of the radiator. A root cause evaluation of the 2001 failure, including forensic analysis, was performed and concluded:

> ***"The root cause of the radiator tube failure was the result of the loss of the cooling fins due to corrosion that provided structural support for the radiator flat tubes. The loss of the fins allowed the flat tubes to swell and vibrate combined with the thermal and pressure cycles experienced by the radiator contributed to the failure of the soldered mechanical tube joint. The loss of the cooling fin was due to corrosion from humid, salt laden environment."***

Therefore, this first-time failure of the 1B2 copper alloy radiator tube exposed to an air-indoor uncontrolled environment due to selective leaching is a PSL plant-specific aging effect. Further evaluation concludes that this plant-specific aging effect unique to the Unit 1 EDG radiators based on the following:

- **No other recent plant-specific OE regarding component failures due to selective leaching,**

- **No failures of the Unit 2 EDG radiators after approximately 39 years of service,**

- **Unique design of the Unit 1 EDG radiators,**

- **Periodic rinsing of the Unit 1 EDG radiators**

- **Severe environmental conditions the Unit 1 EDG radiators are exposed to during EDG runs with radiator fans in operation.**

- NRC Reviews and Inspections

On November 20, 2015 and October 20, 2017, the NRC completed a Post-Approval Site Inspection for License Renewal at PSL Unit 1 and Unit 2, respectively, in accordance with NRC IP71003. The NRC inspectors did not identify any findings or violations of more than minor significance and determined that the overall implementation of aging management programs and time-limited aging analyses was consistent with the licensing basis of the facility. The inspectors also determined that the regulatory requirements of 10 CFR 54.37(b) were met, and commitment changes were evaluated and reported in accordance with the applicable requirements.

OE will be reviewed such that if there is an indication that the effects of aging are not being adequately managed, a corrective action will be initiated to either enhance the AMP or implement new AMPs, as appropriate. In addition, AMP effectiveness will be assessed at least every five years per NEI 14-12.

The PSL Selective Leaching AMP will be informed and enhanced when necessary through the systematic and ongoing review of both plant-specific and industry OE, including research and development, such that the effectiveness of the AMP is evaluated consistent with the discussion in NUREG-2191, Appendix B.

Conclusion

The PSL Selective Leaching AMP will provide reasonable assurance that the effects of aging will be managed so that the intended function(s) of components within the scope of the AMP will be maintained consistent with the CLB during the SPEO.

Associated Enclosures:

None.