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STEVE CRISAFULLI
Speaker of the House of Representatives

September 23, 2015

Ms. Carlotta Stauffer, Commission Clerk
Florida Public Service Commission
2540 Shumard Oak Boulevard
Tallahassee, Florida 32399-0850

Re: Docket No. 150001-EI

Dear Ms. Stauffer:

Please find enclosed for filing in the above referenced docket the Direct Testimony of **William R. Jacobs, Jr. Ph.D.** This filing is being made via the Florida Public Service Commission's Web Based Electronic Filing portal.

If you have any questions or concerns; please do not hesitate to contact me. Thank you for your assistance in this matter.

Sincerely,

Patricia A. Christensen
Associate Public Counsel

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that a true and correct copy of the foregoing Direct Testimony of William R. Jacobs, Jr., Ph.D. to Florida Power & Light Company has been furnished by electronic mail on this 23rd day of September, 2015, to the following:

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BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

In Re: Fuel and Purchased Power Cost Recover Clause with Generating Performance Incentive Factor)
_____/

Docket No. 150001-EI

FILED: September 23, 2015

DIRECT TESTIMONY
OF
WILLIAM R. JACOBS, JR., Ph.D.
ON BEHALF OF THE CITIZENS OF
THE STATE OF FLORIDA

J. R. Kelly
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Patricia A. Christensen
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DIRECT TESTIMONY

OF

WILLIAM R. JACOBS, JR., Ph.D.

On Behalf of the Office of Public Counsel

Before the

Florida Public Service Commission

Docket No. 150001-EI

Q. PLEASE STATE YOUR NAME, TITLE AND BUSINESS ADDRESS.

A. My name is William R. Jacobs, Jr., Ph.D. I am an Executive Consultant with GDS Associates, Inc. ("GDS"). My business address is 1850 Parkway Place, Suite 800, Marietta, Georgia 30067.

Q. DR. JACOBS, PLEASE SUMMARIZE YOUR EDUCATIONAL BACKGROUND AND EXPERIENCE.

A. I received a Bachelor of Mechanical Engineering in 1968, a Master of Science in Nuclear Engineering in 1969 and a Ph.D. in Nuclear Engineering in 1971, all from the Georgia Institute of Technology. I am a registered professional engineer and a member of the American Nuclear Society. I have more than 35 years of experience in the electric power industry including more than 12 years of power plant construction and start-up experience. I have participated in the construction and start-up of seven power plants in this country and overseas in management positions including start-up manager and site manager. As a loaned employee at the Institute of Nuclear Power Operations ("INPO"), I participated in

the Construction Project Evaluation Program, performed operating plant evaluations and assisted in the development of the Outage Management Evaluation Program. Since joining GDS in 1986, I have participated in rate case and litigation support activities related to power plant construction, operation and decommissioning. I have evaluated nuclear power plant outages at numerous nuclear plants throughout the United States. I served on the management committee of Plum Point Unit 1, a 650 MWe coal fired power plant located near Osceola, Arkansas. As a member of the management committee, I assisted in providing oversight of the engineering, procurement and construction (EPC) contractor for this project. I am currently the Georgia Public Service Commission's ("GPSC") Independent Construction Monitor for Georgia Power Vogtle Units 3 and 4 nuclear project (Vogtle). As the Independent Construction Monitor, I assist the GPSC Commissioners and Staff in providing regulatory oversight of the project. My monitoring activities include regular meetings with project management personnel and regular visits to the Vogtle plant site to monitor construction activities and assess the project schedule and budget. My résumé is included as Exhibit WRJ-1.

Q. WHAT IS THE NATURE OF YOUR BUSINESS?

A. GDS is an engineering and consulting firm with offices in Marietta, Georgia; Austin, Texas; Manchester, New Hampshire; Madison, Wisconsin; and Auburn, Alabama. GDS provides a variety of services to the electric utility industry, including power supply planning, generation support services, rates and regulatory consulting, financial analysis, load forecasting and statistical services. Generation support services provided by GDS include fossil and nuclear plant monitoring, plant ownership feasibility studies, plant

management audits, production cost modeling and expert testimony on matters relating to plant management, construction, licensing and performance issues in technical litigation and regulatory proceedings.

Q. ON WHOSE BEHALF ARE YOU TESTIFYING IN THIS PROCEEDING?

A. I am appearing on behalf of the Florida Office of Public Counsel ("OPC"), who represents the ratepayers of Florida Power & Light Company ("FPL").

Q. WHAT WAS YOUR ASSIGNMENT IN THIS PROCEEDING?

A. My assignment was to review the St. Lucie Unit 2 outage extension that began on April 8, 2014 as a result of foreign material in the "B" Steam Generator. I was asked to determine if this outage extension was reasonable or was it preventable.

Q. HAVE YOU PREVIOUSLY TESTIFIED BEFORE THIS COMMISSION?

A. Yes. I testified on behalf of OPC in Docket No. 970261-EI related to an outage at Crystal River Unit 3 and in nuclear cost recovery clause ("NCRC") proceedings in Docket Nos. 080009-EI, 090009-EI, 100009-EI, 110009-EI, 120009-EI, 130009-EI and 150009-EI.

Q. **PLEASE DESCRIBE THE FOREIGN MATERIAL EVENT THAT EXTENDED THE RESTART FROM THE ST. LUCIE 2 OUTAGE IN APRIL 2014.**

A. On April 8, 2014, FPL had concluded a refueling outage at St. Lucie Unit 2 and was in the process of restarting the unit and restoring it to full power generation. During the starting of the reactor coolant pumps, the system designed to detect loose parts within the

reactor coolant system began to alarm. The alarming sensors indicated that there may be a loose part in the B steam generator. The pumps were shut down and the plant was depressurized. Upon inspection, a single loose part was found in the primary coolant side of Steam Generator "B" channel head. The retrieved loose part was egg-shaped, a little over an inch and a half long, and made of 304 stainless steel. Based on analysis by FPL and its consultants, the deformed piece appeared to be a nozzle used for high pressure water cleaning. There was some radioactive activation of the part indicating it had been in the Reactor Coolant System for a time (but not a lengthy period). The nozzle's activation did not indicate significant neutron activation, which indicates that the part did not spend much time near the reactor core during plant operation.

After a thorough inspection of the steam generator channel head and tube sheet, FPL determined that a plug, installed earlier to seal off a leaky tube, needed to be replaced, but no other significant damage occurred. FPL determined that it was safe to resume plant operations for at least another refueling cycle. The total length of outage extension caused by the event was 12.40 days or 298 hours (FPL's response to OPC's Interrogatory (Int.) No. 2 in Docket No. 140001-EI). The total cost of replacement energy to all rate classes during that time period was $8,001,909 (FPL's response to Int. No. 7 in Docket 150001-EI).

Q. DID FPL CONDUCT A ROOT CAUSE ANALYSIS FOR THIS EVENT?

A. Yes. In fact, FPL conducted two root cause analyses (RCA's). The first was done immediately after the event occurred and the second was conducted more than a year after the event on July 14, 2015. The first RCA was provided in response to OPC Production of

Document (POD) No. 12 and entitled St. Lucie Generating Station, Unit 2 2B S/G Hotleg Foreign Object, Event Date: April 8, 2014 (first RCA). The second RCA was provided in response to OPC POD No. 5 Supplemental and is entitled St Lucie Generating Station, Unit 2 2B S/G Hot-leg Foreign Object, Event Date: July 14, 2014 [sic] (second RCA). In response to OPC Interrogatory No. 126, FPL advised that the revised (second) RCA replaces the original (first) RCA. However, the replacement of the first RCA with the revised, second RCA did not impact my analysis and conclusion regarding the St. Lucie Unit 2 2B S/G Hot-leg Foreign Object Event (Event). Furthermore, the first RCA provides additional, relevant context for discussion of this Event, as I discuss below.

Q. **WHAT IS A ROOT CAUSE ANALYSIS (RCA)?**

A. A RCA is a process used in all U.S. nuclear power plants to evaluate unexpected occurrences, to determine the cause of the event and to recommend actions to prevent its recurrence. The regulatory requirement for conducting a RCA is described in Title 10, CFR, Part 50, Appendix B, XVI. Corrective Action:

> Measures shall be established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and equipment, and nonconformances are promptly identified and corrected. In the case of significant conditions adverse to quality, the measures shall assure that the cause of the condition is determined and corrective action taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken shall be documented and reported to appropriate levels of management.

Q. **WHAT CONCLUSIONS DID FPL REACH IN THE FIRST RCA?**

A. In its first RCA, FPL identified the loose part as made of stainless steel and weighing 223 grams. FPL was unable to determine the origin of the foreign material nor how it made its

way to the Steam Generator "B" channel head. The first RCA identified one root cause and one contributing cause for the Event. On page 2 of the first RCA, the root cause was determined to be:

> ROOT CAUSE: Current FME [Foreign Material Exclusion] practices, as stated in MA AA 101 1000, Foreign Material Exclusion Procedure, define requirements for establishment and maintenance of FMEAs [Foreign Material Exclusion Areas]. The interpretation of the requirements, although within procedural compliance, allows for a less conservative approach to foreign material exclusion than the intent of the procedure. This resulted in foreign material entering the reactor hot leg during refueling activities.

Q. PLEASE EXPLAIN THE FOREIGN MATERIAL EXCLUSION PRACTICES EMPLOYED BY FPL.

A. FPL's Foreign Material Exclusion Procedure MA-AA-101-1000 defines a Foreign Material Exclusion Area (FMEA), and the various levels of FMEA, such as FMEA 1 and FMEA 2. A Foreign Material Exclusion Area is a work area established around an open system or component that requires specific controls to prevent the introduction of foreign material into the system or components during work activities that could impact plant safety or power generation in a nuclear plant. An FMEA may be classified as FMEA 1 or FMEA 2. FMEA 1 is the highest level of FME control imposed on a system or component. FMEA 1 is established when a loss of FME integrity could result in personnel injury, nuclear fuel failure, reduced nuclear safety system or station availability, or, as in the April 8, 2014 outage extension discussed in this testimony, an outage extension or significant cost for recovery. FMEA 1 is also established when a final visual inspection of internal cleanliness prior to system closure is not possible. FMEA 2 is established in situations where final visual inspection of internal cleanliness prior to system closure is possible.

Q. IS A FINAL INSPECTION OF COMPONENTS PRIOR TO REMOVING THE FEMA REQUIRED IN BOTH FMEA 1 AND FMEA 2?

A. Yes it is. Prior to closing a system and removing the FMEA, both FMEA 1 and FMEA 2 require a final inspection to ensure that no foreign materials have entered the system.

Q. WHAT DID THE FIRST RCA DETERMINE REGARDING THE FMEA STATUS EMPLOYED BY FPL DURING THE ST. LUCIE 2-21 REFUELING?

A. FPL's first root cause determined that during the SL2-21 refueling outage which occurred from March 3, 2014 to April 23, 2014, the level of FME control was reduced to FMEA 2 once a temporary head was placed on the reactor vessel. FPL found that this less conservative approach to foreign material exclusion resulted in foreign material entering the reactor hot leg during refueling activities.

Q. IN THE FIRST RCA, WERE ANY CONTRIBUTING CAUSES IDENTIFIED?

A. Yes. In addition to the root cause described above, on page 2 of the first RCA FPL identified the following contributing cause:

> CONTRIBUTING CAUSES---Lack of performing FME inspections on the upper guide structure prior to installation into the reactor vessel could have allowed foreign material to enter the reactor coolant system.

In addition to not maintaining the highest level of foreign material exclusion, FPL failed to perform inspections on the upper guide structure which could have allowed foreign material to enter the reactor coolant system. As noted above, a visual inspection is required to be conducted for a FMEA 2 designation. FPL's first RCA of this Event is attached as Exhibit WRJ-2.

Q. DO OTHER UTILITIES ALLOW RELAXATION OF FMEA ZONES DURING REFUELING OUTAGES?

A. As part of the first RCA, FPL conducted a survey of 7 U.S. Pressurized Water Reactor facilities. None allowed relaxing of FMEA class 1 requirement as was done at St Lucie Unit 2.

Q. **WHAT CONCLUSIONS DID FPL REACH IN THE SECOND RCA?**

A. The second RCA identified one root cause and one contributing cause for the Event. On page 2 of the second RCA, the root cause was determined to be:

> ROOT CAUSE: The root cause investigation identified the station's prior practice of using stainless steel nozzles within the reactor coolant system envelope as the root cause of this event. This practice had already been discontinued prior to this event, and all water lancing nozzles used in safety systems have been required to be constructed of brass or other soft metals since approximately 2011 (after the completion of SL2-19).

The contributing cause as shown on page 3 of the second RCA was determined to be:

> CC-1: Missed opportunity to use camera inspection tools to assist in performing more comprehensive FME inspections on the UGS during final reactor reassembly which could allow foreign material within the UGS to go undetected. Although procedural requirements and industry practice only require visual inspections of accessible areas of reactor components prior to reassembly, more robust inspections utilizing cameras may provide better opportunities to detect FME prior to entry into the RCS during future refueling activities. It should be noted that the labyrinth design of the UGS means that even extensive use of camera inspection tools would not permit direct observation of all surfaces where foreign material could become lodged within the UGS.

Q. DO YOU AGREE WITH THE ROOT CAUSE PRESENTED IN FPL'S SECOND RCA?

A. No I do not. In my opinion, the cause of the Event was FPL's failure to prevent foreign material from entering the St. Lucie 2 reactor coolant system. The significance of this failure might have been less if the foreign material had been made of a softer metal but the Event would not have occurred if FPL had prevented the nozzle from entering the system.

Q. WHAT ADDITIONAL INFORMATION DID FPL PROVIDE IN ITS SECOND RCA OF THIS EVENT?

A. FPL's second RCA included additional information not contained in the first RCA. FPL determined that the foreign material was a "Hurricane Ball" type nozzle used for hydro lancing and cleaning. FPL concluded that the nozzle was lodged within the Upper Guide Structure and became dislodged following the lifting of the internals for inspections during the SL2-21 outage. FPL determined that the foreign material was most likely introduced into the reactor coolant system during the January 3, 2011 to May 3, 2011, SL2-19 refueling outage during Upper Guide Structure thimble replacement work that was done during that outage. During the SL-19 refueling outage, a similar stainless steel type nozzle was dropped and subsequently retrieved from the lower cavity floor. Shortly after completion of the SL2-19 refueling outage, FPL prohibited the use of stainless steel tools during refueling outages in 2011. FPL's second RCA of this Event is attached as Exhibit WRJ-3.

Q. PLEASE DESCRIBE THE OTHER INCIDENT IN WHICH A SIMILAR HURICANE BALL NOZZLE WAS DROPPED INTO THE FMEA 1 AREA.

A. FPL reports that on at least one documented occasion during the thimble replacement project during SL2-19, a spray wand nozzle similar to the FME causing the SL2-21 outage extension separated and descended to the lower cavity floor. While this nozzle was retrieved, this event further supports the conclusion that SL2-19 is the most probable time and method of FME entry into the Upper Guide Structure. This incident should have emphasized the need for FPL to ensure that all similar nozzles were accounted for prior to concluding the outage.

Q. HOW ARE THE TWO RCAS SIMILAR?

A. The two RCAs are similar in one important aspect. They both identify the failure to fully inspect the Upper Guide Structure as a contributing cause to the Event.

Q. **HOW DO THE TWO RCAS DIFFER?**

A. The root causes identified in each RCA are quite different. The first RCA identifies failure to maintain Level 1 FME requirements while the reactor head is off as the root cause while the second RCA identifies use of stainless steel nozzles during earlier refueling outages as the root cause. Interestingly, the second RCA rejects the root cause found in the first RCA, stating that the introduction of foreign material lodged in the Upper Guide Structure is "completely unrelated to the procedural administrative differences between FMEA1 and FMEA2." (St. Lucie Generating Station, Unit 2 2B S/G Hot-leg Foreign Object Root Cause Analysis dated July 14, 2015, page 11, Bates No. FCR-15-05184)

Q. WAS THIS EVENT REASONABLY PREVENTABLE BASED ON INFORMATION KNOWN BY FPL AT THE TIME?

A. Yes, this Event was reasonably preventable based on the information known at the time. FPL missed several opportunities to prevent this Event if they had applied good utility practice.

Q. PLEASE EXPLAIN THE TERM "GOOD UTILITY PRACTICE."

A. Good utility practice simply means practices that are utilized by a significant portion of the electric utility industry in performing similar activities, in this case ensuring that foreign materials do not enter the reactor coolant system. Good utility practice is defined in more detail in Federal Energy Regulatory Commission Order 888, issued April 24, 1996, Appendix D, Open Access Transmission Tariff, Original Sheet No. 11, 1.14 Good Utility Practices, as follows:

> Any of the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. Good Utility Practice is not intended to be limited to the optimum practice, method, or act to the exclusion of all others, but rather to be acceptable practices, methods, or acts generally accepted in the region.

Q. PLEASE DESCRIBE THE OPPORTUNITIES FPL HAD TO PREVENT THIS EVENT.

A. First, a similar nozzle was dropped into the refueling cavity during SL2-19. This prior event should have alerted FPL to the possibility of a dropped nozzle and FPL should have increased the inspections of reactor components prior to reassembly. It is good utility practice for an inventory to be kept of all tools and attachments used in and around the refueling area during a refueling outage. A complete and detailed tool inventory would have identified the missing nozzle prior to restart following the SL2-19 outage and provided the opportunity for FPL to locate the missing nozzle. FPL's failure to account for all spray nozzles at the conclusion of SL2-19 represents a clear missed opportunity to have prevented the SL2-21 outage extension. Next, FPL had three separate opportunities to fully inspect the Upper Guide Structure and identify and retrieve the foreign material prior to the Event following SL2-21. The opportunities for inspections are following refueling outages SL2-19, SL2-20 (which occurred from August 6, 2012 to November 19, 2012) and SL2-21. A complete and thorough inspection of the Upper Guide Structure following any one of these refueling outages could have identified the foreign material and prevented the outage. Thus, FPL had numerous opportunities to follow good utility practice and prevent the outage extension following SL2-21.

Q. WHAT DO YOU RECOMMEND REGARDING THIS OUTAGE EXTENSION?

A. As shown above, the outage extension following SL2-21 was reasonably preventable. Therefore, FPL, and not its ratepayers, should be responsible for the additional fuel cost incurred during this outage. I recommend that this Commission disallow the $8,001,909

incurred during the outage extension following SL2-21 from recovery from FPL ratepayers.

Q. DOES THIS CONCLUDE YOUR TESTIMONY?

A. Yes, it does.

EDUCATION: Ph.D., Nuclear Engineering, Georgia Tech 1971
MS, Nuclear Engineering, Georgia Tech 1969
BS, Mechanical Engineering, Georgia Tech 1968

ENGINEERING REGISTRATION: Registered Professional Engineer

PROFESSIONAL MEMBERSHIP: American Nuclear Society

EXPERIENCE:

Dr. Jacobs has over thirty-five years of experience in a wide range of activities in the electric power generation industry. He has extensive experience in the construction, startup and operation of nuclear power plants. While at the Institute of Nuclear Power Operation (INPO), Dr. Jacobs assisted in development of INPO's outage management evaluation group. He has provided expert testimony related to nuclear plant operation and outages in Texas, Louisiana, South Carolina, Florida, Wisconsin, Indiana, Georgia and Arizona. He currently provides nuclear plant operational monitoring services for GDS clients. Dr. Jacobs was a witness in nuclear plant certification hearings in Georgia for the Plant Vogtle 3 and 4 project on behalf of the Georgia Public Service Commission and in South Carolina for the V.C. Summer 2 and 3 projects on behalf of the South Carolina Office of Regulatory Staff. His areas of expertise include evaluation of reactor technology, EPC contracting, risk management and mitigation, project cost and schedule. He is assisting the Florida Office of Public Counsel in monitoring the development of four new nuclear units in the State of Florida, Levy County Units 1 and 2 and Turkey Point Units 6 and 7. He also evaluated extended power uprates on five nuclear units for the Florida Office of Public Counsel. He has been selected by the Georgia Public Service Commission as the Independent Construction Monitor for Georgia Power Company's new AP1000 nuclear power plants, Plant Vogtle Units 3 and 4. He has assisted the Georgia Public Service Commission staff in development of energy policy issues related to supply-side resources and in evaluation of applications for certification of power generation projects and assists the staff in monitoring the construction of these projects. He has also assisted in providing regulatory oversight related to an electric utility's evaluation of responses to an RFP for a supply-side resource and subsequent negotiations with short-listed bidders. He has provided technical litigation support and expert testimony support in several complex law suits involving power generation facilities. He monitors power plant operations for GDS clients and has provided testimony on power plant operations and decommissioning in several jurisdictions. Dr. Jacobs represents a GDS client on the management committee of a large coal-fired power plant currently under construction. Dr. Jacobs has provided testimony before the Georgia Public Service Commission, the Public Utility Commission of Texas, the North Carolina Utilities Commission, the South Carolina Public Service Commission, the Iowa State Utilities Board, the Louisiana Public Service Commission, the Florida Public Service Commission, the Indiana

Regulatory Commission, the Wisconsin Public Service Commission, the Arizona Corporation Commission and the FERC.

A list of Dr. Jacobs' testimony is available upon request.

1986-Present GDS Associates, Inc.

As Executive Consultant, Dr. Jacobs assists clients in evaluation of management and technical issues related to power plant construction, operation and design. He has evaluated and testified on combustion turbine projects in certification hearings and has assisted the Georgia PSC in monitoring the construction of the combustion turbine projects. Dr. Jacobs has evaluated nuclear plant operations and provided testimony in the areas of nuclear plant operation, construction prudence and decommissioning in nine states. He has provided litigation support in complex law suits concerning the construction of nuclear power facilities. Dr. Jacobs is the Georgia PSC's Independent Construction Monitor for the Plant Vogtle 3 and 4 nuclear project.

1985-1986 Institute of Nuclear Power Operations (INPO)

Dr. Jacobs performed evaluations of operating nuclear power plants and nuclear power plant construction projects. He developed INPO Performance Objectives and Criteria for the INPO Outage Management Department. Dr. Jacobs performed Outage Management Evaluations at the following nuclear power plants:

- Connecticut Yankee - Connecticut Yankee Atomic Power Co.
- Callaway Unit I - Union Electric Co.
- Surry Unit I - Virginia Power Co.
- Ft. Calhoun - Omaha Public Power District
- Beaver Valley Unit 1 - Duquesne Light Co.

During these outage evaluations, he provided recommendations to senior utility management on techniques to improve outage performance and outage management effectiveness.

1979-1985 Westinghouse Electric Corporation

As site manager at Philippine Nuclear Power Plant Unit No. 1, a 655 MWe PWR located in Bataan, Philippines, Dr. Jacobs was responsible for all site activities during completion phase of the project. He had overall management responsibility for startup, site engineering, and plant completion departments. He managed workforce of approximately 50 expatriates and 1700 subcontractor

personnel. Dr. Jacobs provided day-to-day direction of all site activities to ensure establishment of correct work priorities, prompt resolution of technical problems and on schedule plant completion.

Prior to being site manager, Dr. Jacobs was startup manager responsible for all startup activities including test procedure preparation, test performance and review and acceptance of test results. He established the system turnover program, resulting in a timely turnover of systems for startup testing.

As startup manager at the KRSKO Nuclear Power Plant, a 632 MWe PWR near Krsko, Yugoslavia, Dr. Jacobs' duties included development and review of startup test procedures, planning and coordination of all startup test activities, evaluation of test results and customer assistance with regulatory questions. He had overall responsibility for all startup testing from Hot Functional Testing through full power operation.

1973 - 1979 NUS Corporation

As Startup and Operations and Maintenance Advisor to Korea Electric Company during startup and commercial operation of Ko-Ri Unit 1, a 595 MWe PWR near Pusan, South Korea, Dr. Jacobs advised KECO on all phases of startup testing and plant operations and maintenance through the first year of commercial operation. He assisted in establishment of administrative procedures for plant operation.

As Shift Test Director at Crystal River Unit 3, an 825 MWe PWR, Dr. Jacobs directed and performed many systems and integrated plant tests during startup of Crystal River Unit 3. He acted as data analysis engineer and shift test director during core loading, low power physics testing and power escalation program.

As Startup engineer at Kewaunee Nuclear Power Plant and Beaver Valley, Unit 1, Dr. Jacobs developed and performed preoperational tests and surveillance test procedures.

1971 - 1973 Southern Nuclear Engineering, Inc.

Dr. Jacobs performed engineering studies including analysis of the emergency core cooling system for an early PWR, analysis of pressure drop through a redesigned reactor core support structure and developed a computer model to determine tritium build up throughout the operating life of a large PWR.

SIGNIFICANT CONSULTING ASSIGNMENTS:

Georgia Public Service Commission – Selected as the Independent Construction Monitor to assist the GPSC staff in monitoring all aspects of the design, licensing and construction of Plant Vogtle Units 3 and 4, two AP1000 nuclear power plants.

Georgia Public Service Commission – Assisted the Georgia Public Service Commission Staff and provided testimony related to the evaluation of Georgia Power Company's request for certification to construct two AP1000 nuclear power plants at the Plant Vogtle site.

South Carolina Office of Regulatory Staff – Assisted the South Carolina Office of Regulatory Staff in evaluation of South Carolina Electric and Gas' request for certification of two AP1000 nuclear power plants at the V.C. Summer site.

Florida Office of Public Counsel – Assists the Florida Office of Public Counsel in monitoring the development of four new nuclear power plants and extended power uprates on five nuclear units in Florida including providing testimony on the prudence of expenditures.

East Texas Electric Cooperative – Represented ETEC on the management committee of the Plum Point Unit 1 a 650 MW coal-fired plant under construction in Osceola, Arkansas and represents ETEC on the management committee of the Harrison County Power Project, a 525 MW combined cycle power plant located near Marshall, Texas.

Arizona Corporation Commission – Evaluated operation of the Palo Verde Nuclear Generating Station during the year 2005. Included evaluation of 11 outages and providing written and oral testimony before the Arizona Corporation Commission.

Citizens Utility Board of Wisconsin – Evaluated Spring 2005 outage at the Kewaunee Nuclear Power Plant and provided direct and surrebuttal testimony before the Wisconsin Public Service Commission.

Georgia Public Service Commission - Assisted the Georgia PSC staff in evaluation of Integrated Resource Plans presented by two investor owned utilities. Review included analysis of purchase power agreements, analysis of supply-side resource mix and review of a proposed green power program.

State of Hawaii, Department of Business, Economic Development and Tourism – Assisted the State of Hawaii in development and analysis of a Renewable Portfolio Standard to increase the amount of renewable energy resources developed to meet growing electricity demand. Presented the results of this work in testimony before the State of Hawaii, House of Representatives.

Georgia Public Service Commission - Assisted the Georgia PSC staff in providing oversight to the bid evaluation process concerning an electric utility's evaluation of responses to a Request for Proposals for supply-side resources. Projects evaluated include simple cycle combustion turbine projects, combined cycle combustion turbine projects and co-generation projects.

Millstone 3 Nuclear Plant Non-operating Owners – Evaluated the lengthy outage at Millstone 3 and provided analysis of outage schedule and cost on behalf of the non-operating owners of Millstone 3. Direct testimony provided an analysis of additional post-outage O&M costs that would result due to the outage. Rebuttal testimony dealt with analysis of the outage schedule.

H.C. Price Company – Evaluated project management of the Healy Clean Coal Project on behalf of the General Contractor, H.C. Price Company. The Healy Clean Coal Project is a 50 megawatt coal burning power plant funded in part by the DOE to demonstrate advanced clean coal technologies. This project involved analysis of the project schedule and evaluation of the impact of the owner's project management performance on costs incurred by our client.

Steel Dynamics, Inc. – Evaluated a lengthy outage at the D.C. Cook nuclear plant and presented testimony to the Indiana Utility Regulatory Commission in a fuel factor adjustment case Docket No. 38702-FAC40-S1.

Florida Office of Public Counsel - Evaluated lengthy outage at Crystal River Unit 3 Nuclear Plant. Submitted expert testimony to the Florida Public Service Commission in Docket No. 970261-EI.

United States Trade and Development Agency - Assisted the government of the Republic of Mauritius in development of a Request for Proposal for a 30 MW power plant to be built on a Build, Own, Operate (BOO) basis and assisted in evaluation of Bids.

Louisiana Public Service Commission Staff - Evaluated management and operation of the River Bend Nuclear Plant. Submitted expert testimony before the LPSC in Docket No. U-19904.

U.S. Department of Justice - Provided expert testimony concerning the in-service date of the Harris Nuclear Plant on behalf of the Department of Justice U.S. District Court.

City of Houston - Conducted evaluation of a lengthy NRC required shutdown of the South Texas Project Nuclear Generating Station.

Georgia Public Service Commission Staff - Evaluated and provided testimony on Georgia Power Company's application for certification of the Intercession City Combustion Turbine Project - Docket No. 4895-U.

Seminole Electric Cooperative, Inc. - Evaluated and provided testimony on nuclear decommissioning and fossil plant dismantlement costs - FERC Docket Nos. ER93-465-000, et al.

Georgia Public Service Commission Staff - Evaluated and prepared testimony on application for certification of the Robins Combustion Turbine Project by Georgia Power Company - Docket No. 4311-U.

North Carolina Electric Membership Corporation - Conducted a detailed evaluation of Duke Power Company's plans and cost estimate for replacement of the Catawba Unit 1 Steam Generators.

Georgia Public Service Commission Staff - Evaluated and prepared testimony on application for certification of the McIntosh Combustion Turbine Project by Georgia Power Company and Savannah Electric Power Company - Docket No. 4133-U and 4136-U.

New Jersey Rate Counsel - Review of Public Service Electric & Gas Company nuclear and fossil capital additions in PSE&G general rate case.

Corn Belt Electric Cooperative/Central Iowa Power Electric Cooperative - Directs an operational monitoring program of the Duane Arnold Energy Center (565 MWe BWR) on behalf of the non-operating owners.

Cities of Calvert and Kosse - Evaluated and submitted testimony of outages of the River Bend Nuclear Station - PUCT Docket No. 10894.

Iowa Office of Consumer Advocate - Evaluated and submitted testimony on the estimated decommissioning costs for the Cooper Nuclear Station - IUB Docket No. RPU-92-2.

Georgia Public Service Commission/Hicks, Maloof & Campbell - Prepared testimony related to Vogtle and Hatch plant decommissioning costs in 1991 Georgia Power rate case - Docket No. 4007-U.

City of El Paso - Testified before the Public Utility Commission of Texas regarding Palo Verde Unit 3 construction prudence - Docket No. 9945.

City of Houston - Testified before Texas Public Utility Commission regarding South Texas Project nuclear plant outages - Docket No. 9850.

NUCOR Steel Company - Evaluated and submitted testimony on outages of Carolina Power and Light nuclear power facilities - SCPSC Docket No. 90-4-E.

Georgia Public Service Commission/Hicks, Maloof & Campbell - Assisted Georgia Public Service Commission staff and attorneys in many aspects of Georgia Power Company's 1989 rate case including nuclear operation and maintenance costs, nuclear performance incentive plan for Georgia and provided expert testimony on construction prudence of Vogtle Unit 2 and decommissioning costs of Vogtle and Hatch nuclear units - Docket No. 3840-U.

Swidler & Berlin/Niagara Mohawk - Provided technical litigation support to Swidler & Berlin in law suit concerning construction mismanagement of the Nine Mile 2 Nuclear Plant.

Long Island Lighting Company/Shea & Gould - Assisted in preparation of expert testimony on nuclear plant construction.

North Carolina Electric Membership Corporation - Prepared testimony concerning prudence of construction of Carolina Power & Light Company's Shearon Harris Station - NCUC Docket No. E-2, Sub537.

City of Austin, Texas - Prepared estimates of the final cost and schedule of the South Texas Project in support of litigation.

Tex-La Electric Cooperative/Brazos Electric Cooperative - Participated in performance of a construction and operational monitoring program for minority owners of Comanche Peak Nuclear Station.

Tex-La Electric Cooperative/Brazos Electric Cooperative/Texas Municipal Power Authority (Attorneys - Burchette & Associates, Spiegel & McDiarmid, and Fulbright & Jaworski) - Assisted GDS personnel as consulting experts and litigation managers in all aspects of the lawsuit brought by Texas Utilities against the minority owners of Comanche Peak Nuclear Station.

Florida Power & Light Company
Docket No. 150001-EI
OPC's 1st Request for POD's
Request No. 12

St. Lucie Generating Station

Unit 2 2B S/G Hotleg Foreign Object

Event Date: April 8, 2014

CR Number: 1955927

Root Cause Team	Name	Dept/Group
Management Sponsor	Jim Connolly	Engineering
Team Leader	Randy Woodard	Maintenance
RC Evaluator	Krista Simpson	Security
Team Members	Darlene Benham	Work Control
	Ron Gardinski	Operations

Root Cause Evaluator: Krista Simpson _____ **Date:** 5/15/14
Print/Sign

Management Sponsor: Jim Connolly _____ **Date:** 5/15/14
Print/Sign

MRC Chair: _____ **Date:** _____
Print/Sign

The root cause process is designed to be self critical to drive improvement. As such, specific organizational and/or programmatic causes within the plant's span of control are identified. The root cause process determines a functional cause and not a legal or contractual cause.

1.0 Executive Summary

Event Description

Shortly after restart from a refueling outage in April of 2014, alarms on loose parts sensors #7 and #8 indicated a loose part inside St Lucie 2 steam generator B. Further evaluation of the signal confirmed that a loose part appeared to be contained inside of the hot leg channel head. The decision was made to depressurize the reactor and inspect for damages. Once the manway was removed, the inspection revealed a single loose part lying in the SG channel head. The retrieved part was metallic (304SS) with a weight of 223 grams. The part itself showed heavy deformation and is believed to have been in the primary head for approximately 123 hours as the plant began startup. The object, as of this report, remains as "unidentified", as its origin and delivery method to the B S/G channel head have not been established.

Root Cause(s)

Current FME practices, as stated in MA AA-101-1000, Foreign Material Exclusion Procedure, define requirements for establishment and maintenance of FMEAs. The interpretation of the requirements, although within procedural compliance, allows for a less conservative approach to foreign material exclusion than the intent of the procedure. This resulted in foreign material entering the reactor hot leg during refueling activities.

Corrective Actions to Prevent Recurrence

Maintain the reactor cavity as FMEA 1 continuously from prior to flooding the cavity to reinstallation of the reactor head. (CAPR)

Contributing Cause(s)

Lack of performing FME inspections on the upper guide structure prior to installation into the reactor vessel could have allowed foreign material to enter the reactor coolant system.

CA – Revise procedure 1/2 -GMM-01.02B, Reactor Vessel Maintenance-Sequence of Operation Component Installation, Att. 1, Upper Guide Structure (UGS) Installation, to add a supervisory hold point to perform visual inspection prior to installation.

2.0 Report

1. Event Description:

On April 8, 2014, during reactor coolant pump starts, the loose parts monitor alarmed indicating the presence of foreign materials in the steam generator. Investigations identified that foreign material was present in the hot leg side of the 2B steam generator. The operators returned the plant to mode 5 and secured all reactor coolant pumps in preparation for primary system drain down. The foreign material was removed from the 2B steam generator and the reactor coolant system was returned to operation. Inspections of the tube sheet were performed and the system was restored to service. The outage was extended to support the retrieval and return to service of the reactor coolant system.

2. Problem Statement:

During reactor coolant pump starts, channels 7 and 8 of Loose Parts Monitoring spiked high into alarm, indicating the presence of foreign material in the steam generator. The foreign material in the steam generator challenged SL2-21 return to service.

3. Analysis

A fault tree (Attachment 4) and associated Support/Refute Matrix (Attachment 5) was developed by station personnel, with assistance from the vendors being used during the outage, to determine the source of the loose part. Based on the fault tree and Support/Refute Matrix, the loose part is not associated with permanent plant equipment within the reactor coolant system. As a result, the loose part is considered to be foreign material which entered the reactor, hot leg or steam generator channel head during refueling activities.

Interviews with numerous personnel involved with the refueling outage, inspection of tooling used during the outage and review of work order documentation and FME logs could not define the source of the loose part or identify its original configuration. The Westinghouse Evaluation did not identify the part or its possible source (reviewed components and work performed around the reactor vessel), but concluded that the part was not associated with safety related systems within the RCS or associated work.

If it were to be presumed that the retrieved part were to have been resting in the upper internals either as an inadvertent consequence during vessel disassembly or reassembly process or while resting on the refueling pool, it is possible that once RCP's were started, flow rate conditions in the upper head region could conceivably have caused the part to move toward the postulated drop paths between the upper head region and the core outlet region (Attachment 2, pgs. 18-22). With the starting of the 2B1 and 2B2

RCPs on 4/4/14 and an optimum location of the loose part in the reactor upper internals, the velocity would be sufficient to draw this part into the 2B hot leg and SG 2B hot leg channel head.

A separate evaluation performed by Areva (Attachment 1) confirmed the foreign material was not associated with the work performed in the steam generator. Based on the composition of the material, series 300 stainless steel, the steam generator inspection and tube repair could not have been a factor in the introduction of the foreign material. Although an opening exists into the steam generator bowl during the inspection and repair process, the vendor and Radiation Protection focused independent cameras, which are continuously monitored, on the opening to ensure the integrity of the environment of the steam generator. The practice of steam generator FME control meets and /or exceeds expectations; therefore, introduction of the material via the steam generator manway is not considered the source of the foreign material.

Analysis Methodology:

The scope of the analysis is focused on the possible method of introduction of foreign material into the B S/G hot leg channel head. The team used previously performed interviews, timelines and analysis (provided by both in-house technical experts and contracted work groups), and Industry Benchmarking Data (Attachment 6), to evaluate gaps in the station processes that could allow a breach of the integrity of the foreign material exclusion process.

The methodologies the team used to perform the investigation include:

- Fault Tree – A fault tree was established during the failure investigation process that identified all outage work activities that have the ability to introduce foreign material into the steam generator.
- Support Refute Matrix – Each node of the Fault Tree was supported as a cause or refuted. This matrix was used to augment the detail of the Fault Tree.
- Barrier Analysis – The Support Refute Matrix served as the foundation for the development of a Barrier Analysis. The focus of the analysis was to determine the failures and/or deficiencies identified during the recent outage station performance.

4. **Causal Factor Categorization**

People:

In accordance with procedure MA-AA-101-1000, Foreign Material Exclusion Procedure, 4.14.3, "The Work Group Supervisor (WGS) or designee shall visually inspect affected areas prior to installation of components, which would impair later inspections. Verify that the system internal components and parts being installed are free of foreign materials prior to assembly". Inspections were performed in accordance with procedure; however, based on previous work practices, these inspections were only performed on the accessible areas of the upper guide structure and not the lower areas.

Lack of performing FME inspections on the upper guide structure prior to installation into the reactor vessel could have allowed foreign material to enter the reactor coolant system. (Contributing Cause)

Programmatic:

The Work Group Supervisor (WGS) has historically made a questionable judgment decision when down-posting the reactor cavity to an FMEA 2 when the temporary reactor head was installed and the upper guide structure was stored in the adjacent area.

In accordance with procedure MA-AA-101-1000, Foreign Material Exclusion Procedure, 4.9.1 states, " The spent Fuel Pool and the Reactor Vessel with the Reactor Head removed are always considered an FMEA 1. During outage SL2-21, after the Reactor Head was removed, a temporary reactor head was installed and the area was downposted from FMEA 1 to FMEA2. The interpretation of the procedure was to protect the Reactor Vessel as opposed to the reactor cavity.

Based upon industry benchmarking, the accepted practice is to maintain the reactor cavity as an FMEA 1 at any time the permanent reactor head is removed from the vessel. (Att. 6, Industry Benchmarking data)

The interpretation of the requirements, although within procedural compliance, allows for a less conservative approach to foreign material exclusion than the intent of the procedure. (Root Cause)

Organizational:

The FIP Team concluded there was no evidence which would indicate there was willful intent to intentionally introduce a foreign object into the Steam Generator.

There were no organizational issues identified during this evaluation.

Equipment:

There were no "Equipment" issues identified during this evaluation.

Based upon the above documentation, categorize the results using the Causal Factor Characterization Matrix below.

Causal Factor Characterization (Each causal factor identified is listed and classified in the appropriate People, Programmatic, Organizational and Equipment categories.)		
Cause Type	**Cause Statement**	**Category**
Root Cause (RC1)	The interpretation of the requirements, although within procedural compliance, allows for a less conservative approach to foreign material exclusion than the intent of the procedure.	Programmatic
Contributing Cause (CC1)	Lack of performing FME inspections on the upper guide structure prior to installation into the reactor vessel could have allowed foreign material to enter the reactor coolant system.	Programmatic

5. Evaluation Attributes

Previous Occurrences:

A search of NAMS, INPO and ICES reports for the previous 8 years was conducted. There have been no specific occurrences in the industry such as the object found in the primary side of the 2B Steam Generator. However, there are numerous documented events of foreign material introduced into the refueling cavity of PSL. This issue is resolved with the development of a retrieval plan and the recovery of the foreign material. This has prevented known objects from entering the SG, therefore, this is not a repeat event.

Extent of Condition:

This problem could only occur in 2 areas -- Unit1 or Unit 2.

The upper guide structure of both units is stored in the tower cavity with the temporary reactor head installed. Site practice has been to down post both areas to FMEA 2 during this time. Both units are handled the same way which has been identified in this root cause evaluation. Corrected by RCE 1 CAPR and CA for the Contributing Cause.

Extent of Cause:

The reactor cavity has presented a unique circumstance that, per site interviews, is not performed during the work process associated with any other systems. The WGS, using procedure guidance to protect the reactor vessel, routinely downposted the cavity due to the covering of the vessel "proper" and the dismissal of the work group from site. A review of the procedures used to perform reactor activities, 1/2- GMM-01.02 A and B has been performed and corrective actions associated with these procedures is recommended.

Revise procedure, Reactor Vessel Maintenance-Sequence of Operation Component Removal, 1-GMM-01.02A, Att. 12, Reactor Head Removal, Step 9 will require the establishment of an FMEA1 for the reactor cavity. This condition is to be maintained continuously until the completion of Reactor Vessel Maintenance-Sequence of Operation Component Installation,1-GMM-01.02B, Att. 3, Reactor Head Installation Step 3.4.5. The identical changes are to be completed for 2-GMM-01.02 A and B.

Safety Culture Evaluation:

During the evaluation it was identified that Resources, H.1 was a contributing attribute and are addressed in the evaluation and subsequent

corrective actions. The nuclear safety culture checklist is included as Attachment 7.

Risk/Consequence:

The risk/consequence of the introduction if foreign material into the RCS is the damage to SSCs and the loss of the generating capacity of the station.

Operating Experience:

Upon review of the ICES Reports and the Condition Reports for the previous 8 years, there have been no specific occurrences in the industry such as the object found in the primary side of the 2B Steam Generator. There have been similar events that have occurred in the Primary Systems, of which the method of introduction into the system was unknown and the foreign objects were unidentifiable or inconclusive. In all cases reviewed, it was determined that the issue was not a repeat problem indicating it was not a major problem with their FME process or monitoring. Some of the corrective actions that were considered were to enhance the training of personnel to include previous OE; consider the Polar Crane hook and anything attached to it an FME1 area when traversing over or near the reactor cavity, and to include more video inspections of components/areas not previously inspected.

NEXTera ENERGY

St. Lucie Generating Station

Unit 2 2B S/G Hot-leg Foreign Object

Event Date: July 14, 2014

CR Number: 1955927

Root Cause Team	Name	Dept/Group
Management Sponsor	Jim Connolly	Engineering
Team Leader	Randy Woodard	Maintenance
RC Evaluator	Krista Simpson	Security
Team Members	Darlene Benham	Work Control
	Ron Gardinski	Operations

Root Cause Evaluator: Harry Anderson Jr/ *Print/Sign* Date: 7/14/15

Management Sponsor: Rick Bashwiner/ *Print/Sign* Date: 7/14/15

MRC Chair: Robert Coffey/ *Print/Sign* Date: 7/14/15

The root cause process is designed to be self critical to drive improvement. As such, specific organizational and/or programmatic causes within the plant's span of control are identified. The root cause process determines a functional cause and not a legal or contractual cause.

1.1 Executive Summary

Event Description

Shortly after restart from a refueling outage in April of 2014, alarms on loose parts sensors #7 and #8 indicated the presence of a loose part inside St. Lucie 2 Steam Generator B ("SG 2B") hot leg channel head. The station made the decision to cool down and depressurize the reactor and inspect SG 2B for damage. The inspection revealed a single loose part lying in the SG 2B channel head. The retrieved part was a deformed, roughly egg-shaped, metallic (later determined to be 304SS) object. The object measured approximately 1.66" (length) x 1.55" (width) at its largest points, and weighed 223 grams (7.9 oz.).

Based on material forensics (destructive metallurgical) analyses performed by FPL and its consultants, the foreign object appears to be the remains of a "Hurricane Ball" type nozzle used for circumferential hydro lancing/cleaning. The nozzle showed slight radiological activation, primarily attributable to contact with the primary side corrosion layer (i.e., CRUD) and cladding activation products, which suggests that the nozzle had been within the Reactor Coolant System ("RCS") for some (but not extended) period of time during reactor operation but had not been directly exposed to significant neutron flux (as would be expected if the part were in the relatively shielded area of the upper vessel). Unfortunately, given the characteristics of the nozzle's activation, it is not possible to precisely relate the activity to a particular time in the reactor's cycle life.

The part is believed to have entered the RCS via the reactor head region (the upper surfaces of the Upper guide Structure ("UGS")), mostly likely during reactor reassembly. Because St. Lucie had stopped allowing stainless steel lancing/cleaning nozzles in and around the RCS several years prior to this (SL2-21) outage, it is surmised that the nozzle had been lodged within the UGS since its introduction into the system and became dislodged following the lifting of the internals for inspections during the recent refueling outage.

Root Cause(s)

The root cause investigation identified the station's prior practice of using stainless steel nozzles within the reactor coolant system envelope as the root cause of this event. This practice had already been discontinued prior to this event, and all water lancing nozzles used in safety systems have been required to be constructed of brass or other soft metals since approximately 2011 (after the completion of SL2-19). **Corrective Actions to Prevent Recurrence**

Industry experience with foreign material exclusion programs shows that despite the consistent and conscientious use of best practices there will be occasions when foreign material enters the systems on which work is performed. This is why the selection of materials used in and around the reactor coolant system is important. Some materials, like stainless steel, are hard enough to physically deform reactor structures and other primary-side components if they strike with sufficient velocity, while other materials, like copper and brass, are soft enough that the foreign material itself would be deformed, and eventually essentially disintegrate, under these same circumstance. This material selection is especially important on small, relatively easily detachable components such as hydrolasing nozzles.

Accordingly, St. Lucie has prohibited the use of stainless steel nozzles in and around the reactor coolant system or other safety system components since approximately 2011 (shortly after the completion of SL2-19). However, as noted above, this investigation concluded that the foreign material was likely introduced into the reactor vessel during the spring 2011 outage (SL2-19), when the use of stainless steel nozzles was still permitted, and later became dislodged when the reactor internals were lifted to support inspections.

The CAPR to discontinue the use of stainless steel nozzles in and around the reactor coolant system or other safety system components is complete. (CAPR)

Contributing Cause(s)

CC-1: Missed opportunity to use camera inspection tools to assist in performing more comprehensive FME inspections on the UGS during final reactor reassembly which could allow foreign material within the UGS to go undetected. Although procedural requirements and industry practice only require visual inspections of accessible areas of reactor components prior to reassembly, more robust inspections utilizing cameras may provide better opportunities to detect FME prior to entry into the RCS during future refueling activities. It should be noted that the labyrinth design of the UGS means that even extensive use of camera inspection tools would not permit direct observation of all surfaces where foreign material could become lodged within the UGS.

CA – Revise procedure 1/2-GMM-01.2, Upper Guide Structure Removal and Installation, to add a supervisory hold point to perform a camera inspection of accessible areas of the UGS, including the UGS lift rig, prior to UGS installation in an effort to identify any foreign material.

1.2 Report

1. Event Description:

On April 8, 2014, during reactor coolant pump starts, the loose parts monitor alarmed indicating the presence of foreign materials in the steam generator. Investigations identified that foreign material was present in the hot leg side of the 2B steam generator. The operators returned the plant to mode 5 and secured all reactor coolant pumps in preparation for primary system drain down. The foreign material was removed from the 2B steam generator and the reactor coolant system was returned to operation. Inspections of the tube sheet were performed and the system was restored to service. The outage was extended to support the retrieval and return to service of the reactor coolant system.

2. Problem Statement:

During reactor coolant pump starts, channels 7 and 8 of Loose Parts Monitoring spiked high into alarm, indicating the presence of foreign material in the steam generator. The foreign material in the steam generator challenged SL2-21 return to service.

3. Analysis

Based upon the data available to the Root Cause Team during this revision of the Root Cause Evaluation (RCE), it was determined that the foreign material was most probably introduced into the RCS during SL2-19 Upper Guide Structure (UGS) thimble replacement work, not withstanding that available data indicates all FME requirements were followed while doing that work. It is known that on at least one documented occasion during the thimble replacement project work (AR# 01610999), a spray wand nozzle similar to the FME discovered during SL2-21 separated and descended to the lower cavity floor. Although that particular nozzle was located and subsequently retrieved, it further supports the conclusion that this is the most probable method and time of FME entry into the UGS.

Based upon the Root Cause Team's review of available FME logs (SL2-21 only), interviews and observations of both FPL workers and contractors, documented supervisory oversight, and close out inspections it was determined that there was no evidence indicating that any FME program or implementation deficiency existed during SL2-20 or SL2-21 that would have allowed the introduction of a stainless steel nozzle into the RCS. The permitted use of stainless steel nozzles during the SL2-19 UGS and thimble tube work is the identified root cause of this event.

The FME (later demonstrated to be a Hurricane Ball nozzle) showed slight radiological activation, primarily attributable to contact with PWR crud and cladding activation products, which suggests that the nozzle had been within the Reactor Coolant System ("RCS") for some (but not extended) period of time during reactor operation but had not been directly exposed to significant neutron flux (as would be expected if the part were in the relatively shielded area of the upper vessel). This further supports the Team's conclusion that the most likely period of FME introduction was during the SL2-19 UGS thimble project work when nozzles made of that type of metal was allowed to be used on RCS components.

4. In conclusion, although the Root Cause Team identified opportunities for programmatic enhancements unrelated to this event, team determined that the station took appropriate actions with respect to foreign material exclusion practices during SL2-19, SL2-20, and SL2-21. These industry-standard practices included FME plan challenges, Nuclear Oversight reviews, and visual inspections of the reactor cavity prior to allowing the UGS to be inserted into the reactor vessel. The station's since discontinued prior practice of allowing the use of stainless steel tools was a latent program weakness that led to this event. The Root Cause Team has recommended additional corrective actions to further enhance the station's FME program, including more stringent procedural controls and the use of camera inspections of the UGS prior to UGS movement into the reactor vessel.Analysis Methodology:

   An evaluation performed by AREVA (Attachment 1) concluded the foreign material was not associated with any work performed in the steam generator. Based on the composition of the material (304SS), the steam generator inspection and tube repair could not have been a factor in the introduction of the foreign material. Although an opening exists into the steam generator bowl during the inspection and repair process, the vendor and Radiation Protection focused independent cameras, which are continuously monitored, on the opening to ensure the integrity of the environment of the steam generator is maintained. This practice of steam generator FME control meets or exceeds industry standards. Therefore, introduction of the material via the steam generator manway is not considered a credible source of the foreign material.

AREVA also performed material forensics on the object, which determined that the foreign material is a stainless steel Hurricane Ball hydro-lancing nozzle. A review of prior UGS work revealed that not only was this type of nozzle used on the UGS during SL2-19, there was at least one documented incident during that outage of a hydro lancing nozzle separating itself from the wand and landing in the cavity below (that part was retrieved). Additionally, the team's review of the SL2-21 FME logs (the only outage for which these logs, which are not permanent plant records and are not required to be retained, were available) demonstrated that all nozzles and nozzle-like equipment used during SL2-21 had been accounted for.

A separate evaluation performed by AREVA concluded that the nozzle showed slight radiological activation, primarily attributable to contact with the primary side corrosion layer (i.e., CRUD) and cladding activation products, which suggests that the nozzle had been within the Reactor Coolant System ("RCS") for some (but not an extended) period of time during reactor operation.

An evaluation performed by Westinghouse (Attachment 2) concluded that the part was not associated with safety related systems within the RCS or associated work. The Westinghouse analysis further describes how the unique flow conditions that exist during RCS initial gas sweeping (the initial starting of a single RCP causing non-symmetric flow) could cause the part to move toward the steam generator. This flowpath accurately describes how a part of this size, shape, and composition could transition from external to the reactor vessel to the steam generator without affecting the fuel or any other reactor component.

Extensive interviews with numerous personnel involved with the SL2-21 refueling outage, inspections of tooling used during the outage, and review of work order documentation and FME logs could not determine any other potential source of the loose part. As noted above, the use of stainless steel nozzles for water lancing in the reactor cavity had been discontinued at St. Lucie since SL2-19.

A Failure Investigation Process (FIP) team, working with numerous industry experts (see listing below) invested more than 1,400 person hours in an attempt to determine the origin of the foreign object retrieved from the 2B SG. The FIP team developed a fault tree and a support/refute matrix to guide their efforts. Investigative tools and methods included:

- Work order reviews
- Interviews with plant staff and contractor personnel

Forensic tools and other investigation methods utilized by the FIP team included:

- Visual
- Photography (including enhanced optical imaging)
- Video
- Electro etching with oxalic acid
- Gamma counting
- Cobalt 58/60 aging evaluation
- Micro hardness testing
- X-ray Fluorescence scanning
- Glow Discharge Optical Emissions Spectrometry
- Acoustic Emissions monitoring and evaluation

The FIP team's investigation focused on two primary paths (loose reactor coolant system components and plant maintenance activities tools or materials). The material is a single 1.665" x 1.6" stainless steel Type 304 object that weighed 7.9 oz. when discovered. The potential RCS components/sources reviewed included:

- Reactor internals
- Pressurizer
- Hot leg piping
- Steam Generator (including materials tools used during maintenance and inspection activities)
- Thermowells and nozzles
- Steam Generator tube plugs

Review of Potential Maintenance activities/sources included:

- Polar Crane, parts and lifting activities
- Reactor reassembly equipment and tools. For example, the Control Element Assembly latching tool, Upper Guide Structure lift rig, refueling machine parts, cavity seal ring, and containment spray nozzles.
- Work Adjacent to or in the refueling cavity, reactor coolant pump and motor work, fuel slipping tool, Tri-Nukes filters, Cavity Safety Clips, upper guide structure lift rig hole tapping tooling, Core Barrel lifting ring stud hold activities
- Steam Generator activities such as nozzle dams, tube plugging and components used for secondary steam generator side inspection and sludge lancing.

The Root Cause Team, with vendor support, utilized this information to develop a fault tree (Attachment 4) and an associated Support/Refute Matrix (Attachment 5). Based on the fault tree, the support/refute matrix, and the results of the material forensics, the team concluded that the nozzle most likely entered the upper head area of the UGS during SL2-19 and became dislodged following the lifting of the internals for inspections during the SL2-21 outage.

While the method and time of introduction of the foreign material is not absolutely determinative, all available information supports the team's conclusion that the nozzle was most likely introduced into the RCS during the SL2-19 work on the UGS and the replacement thimble plugs. Consistent with Westinghouse's analysis, the nozzle's most likely path from the UGS to SB 2B is from the incore instrumentation support plate, through the upper guide structure support plate and into the reactor coolant pump flow stream after the B reactor coolant pump was started. The nozzle then would have been carried through the RCS hot leg to the SG 2B channel head.

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4. Analysis of Causal Factors:

The scope of the causal factor analysis is limited to the possible method of introduction of foreign material into the SG 2B hot leg channel head. The team used previously performed interviews, timelines, and analysis (provided by both in-house technical experts and contracted work groups), and Industry Benchmarking Data (Attachment 6), to evaluate gaps in the station processes that could allow a breach of the integrity of the foreign material exclusion process.

The methodologies the team used to perform the investigation include:

- Fault Tree – A fault tree was established during the failure investigation process that identified all outage work activities that have the ability to introduce foreign material into the steam generator.
- Support Refute Matrix – Each node of the Fault Tree was supported as a cause or refuted. This matrix was used to augment the detail of the Fault Tree.
- Barrier Analysis – The Support Refute Matrix served as the foundation for the development of a Barrier Analysis. The focus of the analysis was to determine the failures and/or deficiencies identified during the recent outage station performance.

5. Causal Factor Categorization.

People:

There were no personnel performance issues identified that could have contributed to this event.

There is no evidence that would indicate there was willful intent by any person or organization to intentionally introduce a foreign object into the Steam Generator.

Programmatic:

The station's prior practice of using stainless steel nozzles within the reactor coolant system envelope, though already discontinued since approximately 2011 (after the completion of SL2-19), was identified as a previously-existing programmatic weakness and the root cause of this event (Root Cause 1).

Procedure MA-AA-101-1000, Foreign Material Exclusion Procedure, Step 4.14.3, requires the Work Group Supervisor (WGS) or designee to visually inspect affected areas prior to installation of components that would impair later inspections. The purpose of this requirement is to verify that the system internal components and parts being installed are free of foreign materials prior to assembly.

Although the required inspections were performed in accordance with the referenced procedure during SL2-19, SL2-20, and SL2-21 reactor reassembly, these were visual inspections of the accessible areas of the UGS and did not utilize cameras to assist in determining the presence of foreign material.

Although the practice of utilizing visual inspections of reactor components during reassembly was consistent with industry practice, the evaluation of the possible travel path of the foreign material suggest that the performance of camera-assisted inspections would have enhanced the programmatic barrier intended to ensure the detection of foreign material prior to entry into the reactor coolant system.

Accordingly, the "Programmatic" aspect is identified as a contributor due to the opportunity to enhance a potential FME barrier (Contributing Cause 1).

However, two points should be made regarding the UGS inspection, whether visually alone or with camera assistance. During reactor assembly/disassembly, the UGS composed of three distinct elements: the upper work platform, the instrument plate, and the actual UGS structure.

The UGS structure and instrument plate is a complex "sandwich" of dozens of Control Element Assembly ("CEA") top hats, extension shafts, and incore instrumentation detectors, all of which are maintained under water at all times. Given the physical geometry of the structure, it is simply not possible to see the entire UGS from any angle/view (or combination of views). Camera-assisted inspections help see more of the internal UGS structure, but even with multiple cameras and multiple angles, can only see approximately 60-70% of the structure's surface area.

During the SL2-19 thimble tube work, Westinghouse separated the instrument plate from the UGS structure for the thimble tube replacement and, consistent with best FME practices for this type of work, utilized camera assisted inspections during reassembly. Station personnel then did an additional visual inspection of the entire structure as it was being inserted in the reactor vessel. Depending on the precise location of the Hurricane Ball at the time of Westinghouse's and the station's inspections, it is certainly possible that the item would go undetected despite the manner/scope of a camera-assisted inspection.

6. Potential Enhancement to the Programmatic Barrier

Procedure MA-AA-101-1000, Foreign Material Exclusion Procedure, Step 4.9.1 states that "[t]he spent Fuel Pool and the Reactor Vessel with the Reactor Head removed are always considered an FMEA 1. However, St. Lucie, like many similar stations, utilizes a temporary reactor vessel head to permit certain RCS work without needing to drain and decontaminate the reactor cavity. This practice, in additional to providing operational flexibility during the outage, also reduces both work radiation dose and radioactive waste.

Prior to and during SL2-21, once the temporary reactor head was in place the Work Group Supervisor (WGS) had the discretion in accordance with other provisions of the procedure to down-post the reactor cavity to an FMEA 2. This practice ensured that the reactor vessel remained as protected as possible (the temporary head providing an actual physical barrier to foreign material), but potentially weakened the programmatic protection barrier because the UGS is being stored on its stand in the reactor cavity (and outside of the FMEA1 boundary). Although FMEA2 programmatic controls are themselves vigorous, the team's benchmarking results show that the more common practice is to maintain the entire reactor cavity as an FMEA 1 any time the permanent reactor head is removed from the vessel (Attachment 6). However, there is no evidence that maintaining the entire cavity in FMEA1 with the temporary head in place during SL2-21 would have prevented this event.

During the SL2-19 UGS thimble tube work performed by Westinghouse, Westinghouse maintained the additional FMEA1 controls (e.g., short and long-term material logs, use of tooling lanyards, etc.) at all times. Yet, in spite of these stricter controls, there was at least one documented incident in which a spray wand nozzle separated itself from the tool and fell into the cavity. Thus, it is likely that this period of extensive work in and around the UGS, utilizing the same stainless steel material later retrieved from the SG 2B channel head, is when the foreign material was first introduced into the system.

Further, this example demonstrates that the potential for this manner of foreign material introduction is completely unrelated to the procedural administrative differences between FMEA1 and FMEA2 – particularly when, as here, Westinghouse maintained the FMEA1 controls in place.

Finally, the fact that there was no UGS work performed during SL2-20 or SL2-21 (with no opportunity for foreign material deposition during these outages regardless of FMEA status) further supports the team's conclusion that maintaining the cavity area FMEA1 is an opportunity for programmatic enhancement and was not a contributor to this event.

Organizational:

There were no organizational issues identified during this evaluation.

Equipment:

There were no "Equipment" issues identified during this evaluation.

The resulting Causal Factor Characterization Matrix is presented below:

Causal Factor Characterization (Each causal factor identified is listed and classified in the appropriate People, Programmatic, Organizational and Equipment categories.)		
Cause Type	**Cause Statement**	**Category**
Root Cause (RC1)	The practice of using of stainless steel nozzles on water lancing equipment within the reactor coolant system envelop.	Programmatic
Contributing Cause (CC1)	Performing camera-assisted FME inspections on the upper guide structure prior to installation into the reactor vessel could have allowed better detection of foreign material prior to entry into the reactor coolant system.	Programmatic

7. Evaluation Attributes

Previous Occurrences:

A search of NAMS, INPO and ICES reports for the previous 8 years was conducted. Although numerous examples of foreign material being introduced into the reactor coolant system and/or steam generators exists, the team was unable to identify any occurrences where an object entered the RCS through the upper reactor internals and was later discovered in the steam generator. However, there are numerous documented events at PSL and elsewhere of foreign material being introduced into the refueling cavity. This issue is resolved with the development of a retrieval plan and the recovery of the foreign material. This has prevented known objects from entering the primary system, and so this is not a repeat event.**Extent of Condition:**

There are only two possible FME entry points into the reactor internals: the reactor cavities of Unit 1 or Unit 2, and only during period in which the vessel is exposed (i.e., with neither the permanent or temporary head in place).

The discontinuance of the use of stainless steel nozzles on water lancing equipment within the reactor coolant system envelop has eliminated the potential for introducing this type of material into the reactor cavity and thus elimnated the potential pathway into the reactor internals (RC1 CAPR).

Site practice, consistent with industry practice, has been to require visual inspections of reactor vessel components prior to reassembly. The purpose of this inspection is to verify that the components being installed are free of foreign materials prior to assembly. The site has taken actions to improve MA-AA-101-1000, Foreign Material Exclusion Procedure to require the use of remote cameras to assist in this inspection (CA for Contributing Cause 1).

Extent of Cause:

The extent of cause included a review of any procedures for conducting inspections on the upper guide structure (CC1).

Safety Culture Evaluation:

During the evaluation it was identified that Resources, H.1 was a contributing attribute and are addressed in the evaluation and subsequent corrective actions. The nuclear safety culture checklist is included as Attachment 7.

Risk/Consequence:

The risk/consequence of the introduction if foreign material into the RCS is the damage to SSCs and the loss of the generating capacity of the station.

Operating Experience:

Upon review of the ICES Reports and the Condition Reports for the previous 8 years, there have been no specific occurrences in the industry involving the type of object found in the primary side of the SG 2B. There have been similar events that have occurred in the Primary Systems, of which the method of introduction into the system was unknown and the foreign objects were unidentifiable or inconclusive. In all cases reviewed, it was determined that the issue was not a repeat problem indicating it was not a major problem with their FME process or monitoring. Some of the corrective actions that were considered were to enhance the training of personnel to include previous OE; consider the Polar Crane hook and anything attached to it an FME1 area when traversing over or near the reactor cavity, and to include more video inspections of components/areas not previously inspected.

Also, OE13865- (Preliminary) Loose Parts in Steam Generator Caused by Apparent Failure of Inconel 750 B Control Rod Guide Tube Support Pin (Split Pin) Assembly, which occurred on 5/10/2002 at Wolf Creek was evaluated and no further actions from the event are required. (Attachment 11)

8. Proof Statement

During reactor coolant pump starts, channels 7 and 8 of Loose Parts Monitoring spiked high into alarm, indicating the presence of foreign material in the steam generator. The foreign material in the steam generator challenged SL2-21 return to service.

(Problem Statement)

is caused by:

The practice and use of stainless steel nozzles on water lancing equipment within the reactor coolant system envelop

(Root Cause)

and is corrected by:

Eliminating the practice of using stainless steel nozzles during water lancing of reactor coolant system components.

(CAPR)

9. Corrective Actions

Category	Causal Statement	NAMS Asgn#	Corrective Action / Assignment	Assignment Type	Assigned Dept or / Individual and Due Date
Root Cause	RC - The practice of using of stainless steel nozzles on water lancing equipment within the reactor coolant system envelop	2	Eliminate the practice of using stainless steel nozzles during water lancing of reactor coolant system components.	CAPR	Completed
Contributing Cause	CC1 - Missed opportunity to use camera inspection tools to assist in performing FME inspections on the upper guide structure prior to reassembly may have allowed foreign material within the reactor coolant system to go undetected.	4	Revise procedure 1/2 GMM-01.28, Upper Guide Structure Removal and Installation to add a supervisory hold point to perform camera assisted inspection of UGS and UGS lift rig prior to installation.	CA	Completed
Other	During reactor coolant pump starts, channels 7 and 8 of Loose Parts Monitoring spiked high into alarm, indicating the presence of foreign material in the steam generator.	1	Interim Engineering Disposition of Steam Generator 2B	CA	Completed AR 01957565
			Locate and retrieve foreign material IAW retrieval plan 04112014 1645	WO 04112014 1645	Completed

FCR-15-05189

Category	Causal Statement	NAMS Asgn#	Corrective Action / Assignment	Assignment Type	Assigned Dept or / Individual and Due Date
	The foreign material in the steam generator challenged SL2-21 return to service		Steam Generator inspections and repairs as required AREVA document 03-9222013, Channel Head Inspection and Retrieval Plan	NA	Completed
			Perform Inspections of hot leg prior to unit start up		

Interim & Compensatory	N/A				
Extent of Condition			Bounded by RC1 CAPR and CA		
Extent of Cause		5 6		CA CA	
Effectiveness Review	RC - The practice of using of stainless steel nozzles on water lancing equipment within the reactor coolant system envelop		Track Effectiveness Review Plan defined in the root cause report.	EFR	FME Site Coordinator Due date: 7/15/15

10. Deferral Justification

Deferral of the corrective action to prevent recurrence is required to allow time to make the procedure changes.

11. Effectiveness Review Plan

Methodology

The method for this effectiveness review would align with continuing monitoring of the FMEA areas in and around the reactor cavity during outages.

Attributes

Procedure adherence as it relates to FME areas and the required procedure changes to implement the CAPR.

Success Criteria

After implementation of the procedure changes for RC1 and CC1, the reactor cavity is maintained as FMEA 1 continuously from prior to flooding the cavity to reinstallation of the reactor head, and no FME is introduced into the reactor coolant system during SL1-26.

Timeline

Effectiveness Review to be conducted during the SL1-26 outage and documentation of results to be completed one month post outage.

12. Attachments

1. Areva Engineering Information Record, Document No.: 51-9222481-000
2. Westinghouse evlaution of St. Lucie U2 loose part identified following SL2021 and attached photos. Westinghouse Report REF. LTR-SEE-II-14-13, Rev. 0
3. AR#1957565 Interim Engineering Disposition (SG2B evaluation)
4. U2 Loose parts monitor Chanel 7&8 Fault Tree
5. AR#1955927 Support Refute Matrix
6. Benchmarking Email Record
7. PI-AA-100-005-F03, Nuclear Safety Culture Evaluation
8. Hazard Barrier Target Analysis
9. Root Cause Charter
10. RCE#1918259, FME Glove Retrieved from Turbine Generator Seal

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that a true and correct copy of the foregoing Direct Testimony of William R. Jacobs, Jr., Ph.D. to Florida Power & Light Company has been furnished by electronic mail on this 22nd day of September, 2015, to the following:

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