



**UNITED STATES  
NUCLEAR REGULATORY COMMISSION**  
REGION II  
245 PEACHTREE CENTER AVENUE N.E., SUITE 1200  
ATLANTA, GEORGIA 30303-1200

October 16, 2019

Mr. John A. Krakuszeski  
Site Vice President  
Brunswick Steam Electric Plant  
Duke Energy Progress, LLC  
8470 River Rd. SE (M/C BNP001)  
Southport, NC 28461

SUBJECT: BRUNSWICK STEAM ELECTRIC PLANT – NRC SUPPLEMENTAL  
INSPECTION REPORT 05000325/2019040 AND ASSESSMENT FOLLOW-UP  
LETTER

Dear Mr. Krakuszeski:

On September 26, 2019, the NRC completed a supplemental inspection using Inspection Procedure 95001, Supplemental Inspection for One or Two White Inputs in a Strategic Performance Area. On September 26, 2019, the NRC inspection team discussed the results of this inspection and the implementation of your corrective actions with you and other members of your staff. The results of this inspection are documented in the enclosed report.

The NRC performed this inspection to review your station's actions in response to the White Reactor Coolant System Leakage performance indicator (PI), which you reported in the first quarter of 2019. On August 20, 2019, you informed the NRC that your station was ready for the supplemental inspection.

The NRC determined that your staff's evaluation identified that the primary root cause of the White PI was the inappropriate selection of Tinel, a titanium-nickel alloy, for long term application in the reactor water level instrument lines due to susceptibility to hydrogen embrittlement. Specifically, a 1" Cryofit (cryogenic) coupling located on the steam side of a reference leg instrument line, experienced a 360-degree circumferential separation. This opened a path for steam from the reactor to leak into the drywell. The licensee performed a reactor shutdown in accordance with licensee procedures. The licensee's immediate corrective action was to replace the failed coupling with a welded connection. Additionally, the licensee replaced all Cryofit couplings in instrument lines that contained steam (most susceptible to hydrogen embrittlement) in both units, to address extent of condition. The corrective actions to prevent recurrence was to revise the Brunswick piping specifications to restrict the use of Cryofit couplings to locations that are not subject to hydrogen embrittlement; and to incorporate hydrogen embrittlement of Cryofit couplings (aging mechanism) into the Aging Management Program.

Based on the results of this inspection, the NRC determined that Brunswick appropriately evaluated and understood the root and contributing causes, and the completed and planned corrective actions were sufficient to address the performance issue that led to the White PI, thus satisfying all objectives found in IP 95001. Additionally, the White PI had since returned to the Green performance band as of the 2<sup>nd</sup> quarter, following isolation of the leak and replacement of the failed coupling with a welded fitting.

Based on the guidance in Inspection Manual Chapter 0305, "Operating Reactor Assessment Program," and the results of this inspection, the White PI will be closed, and Brunswick Unit 1 will transition from the Regulatory Response Column of the NRC's Action Matrix to the Licensee Response Column as of the date of the cover letter to this report.

The NRC inspectors did not identify any finding or violation of more than minor significance.

This letter, its enclosure, and your response (if any) will be made available for public inspection and copying at <http://www.nrc.gov/reading-rm/adams.html> and at the NRC Public Document Room in accordance with 10 CFR 2.390, "Public Inspections, Exemptions, Requests for Withholding."

Sincerely,

**/RA/**

Bradley J. Davis, Chief  
Reactor Projects Branch 4  
Division of Reactor Projects

Docket No. 05000325  
License No. DPR-71

Enclosure:  
As stated

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**U.S. NUCLEAR REGULATORY COMMISSION**  
**Inspection Report**

Docket Number: 05000325

License Number: DPR-71

Report Number: 05000325/2019040

Enterprise Identifier: I-2019-040-0004

Licensee: Duke Energy Progress, LLC

Facility: Brunswick Steam Electric Plant

Location: Southport, NC

Inspection Dates: September 23, 2019 to September 26, 2019

Inspectors: G. Eatmon, Resident Inspector  
D. Jackson, Project Engineer

Approved By: Bradley J. Davis, Chief  
Reactor Projects Branch 4  
Division of Reactor Projects

Enclosure

## SUMMARY

The U.S. Nuclear Regulatory Commission (NRC) continued monitoring the licensee's performance by conducting a 95001 supplemental inspection at Brunswick Steam Electric Plant in accordance with the Reactor Oversight Process. The Reactor Oversight Process is the NRC's program for overseeing the safe operation of commercial nuclear power reactors. Refer to <https://www.nrc.gov/reactors/operating/oversight.html> for more information.

## List of Findings and Violations

No findings or violations of more than minor significance were identified.

## Additional Tracking Items

Type	Issue Number	Title	Report Section	Status
LER	05000325/2019-002-00	LER 2019-002-00 for Brunswick Steam Electric Plant, Unit 1 Regarding Degraded Principal Safety Barrier, Technical Specification Shutdown, and Automatic System Actuation.	71153	Closed

## INSPECTION SCOPES

Inspections were conducted using the appropriate portions of the inspection procedures (IPs) in effect at the beginning of the inspection unless otherwise noted. Currently approved IPs with their attached revision histories are located on the public website at <http://www.nrc.gov/reading-rm/doc-collections/insp-manual/inspection-procedure/index.html>. Samples were declared complete when the IP requirements most appropriate to the inspection activity were met consistent with Inspection Manual Chapter (IMC) 2515, "Light-Water Reactor Inspection Program - Operations Phase." The inspectors reviewed selected procedures and records, observed activities, and interviewed personnel to assess licensee performance and compliance with Commission rules and regulations, license conditions, site procedures, and standards.

## OTHER ACTIVITIES – TEMPORARY INSTRUCTIONS, INFREQUENT AND ABNORMAL

### 71153 - Followup of Events and Notices of Enforcement Discretion

#### Event Report (IP Section 03.02)

The inspectors evaluated the following licensee event report (LER):

- (1) LER 05000325/2019-002-00, Degraded Principal Safety Barrier, Technical Specification Shutdown, and Automatic System Actuation (ADAMS Accession Number ML19143A375). The circumstances surrounding this LER were previously documented in Inspection Report 05000324,325/2019002 Section 71153. (Closed)

### 95001 - Supplemental Inspection for One or Two White Inputs in a Strategic Performance Area

Inspectors reviewed the licensee's root causes, contributing causes, extent of condition, and extent of cause determinations. Inspectors assessed whether the licensee's corrective actions to address the root and contributing causes were sufficient to prevent recurrence. The results of the performance review and NRC's assessment are documented below.

#### 1. Problem Identification

A green self-revealing non-cited violation (NCV) associated with the event which resulted in the reactor coolant system leakage performance indicator (PI) to cross the green-white threshold was previously documented in inspection report 05000324,325/2019002.

- a. The event occurred on March 28, 2019, with Unit 1 operating at 100 percent power. A 1-inch Cryofit (cryogenic) coupling (Tinel- a titanium-nickel alloy), located on an instrument line, experienced a 360-degree circumferential separation. This opened a path for steam from the reactor to leak into the drywell which resulted in increased drywell pressure and drywell floor drain leakage. The coupling failure was determined to be due to hydrogen embrittlement. The increase in leakage resulted in a White PI.

The inspectors reviewed documentation related to the licensee's evaluation of the White PI. The inspectors determined that the root cause evaluation (RCE) documented how the issue was identified and under what conditions the issue was identified.

- b. The licensee's RCE determined the root cause of the event was the selection of Tinel was inappropriate for long term application in the reactor water level instrument lines (RC-1). The issue had existed since selection and installation of the couplings in approximately 1983. The licensee's RCE identified several prior opportunities for potential identification, including:
  - i. Hydrogen Water Chemistry Implementation (1989-1990)
  - ii. Seabrook Event - INPO notice and NRC Information Notice 91-87 (1991)
  - iii. License Renewal Aging Management Review (2004)
  - iv. Online Noble Metal Chemistry Implementation (2014-2015)

The inspectors determined that the licensee's evaluation was adequate with respect to identifying how long the issue existed and prior opportunities for identification.

- c. The licensee's RCE documented the safety significant impacts including nuclear, radiological, and industrial, as listed below:
  - i. The licensee's PRA sensitivity analyses demonstrated that the increase in core damage frequency for this event was less than 1E-06 (Green)
  - ii. Breach of the reactor pressure vessel pressure boundary which caused a loss of inventory and increase in containment pressure
  - iii. Abnormal operating procedure for increased drywell leakage entered
  - iv. Notice of Unusual Event declaration for elevated drywell leakage (more than 10 gpm) for greater than 15 minutes
  - v. Reactor shutdown, in accordance with licensee procedures
  - vi. Slightly increased off site radiological releases (within technical specification limits) due to venting to control containment pressure
  - vii. Individuals received emergent dose to perform repairs in the drywell (within administrative limits)
  - viii. Forced outage on Unit 1 and extension of the refueling outage on Unit 2 to address extent of condition

Additionally, the inspectors reviewed the licensee's Cryogenic Coupling Risk Review which documented for each coupling (by system), the location, consequence of failure and probability of failure. The inspectors determined that the licensee appropriately considered and documented the risk consequences (safety impacts) and compliance concerns associated with the issue.

## 2. Root Cause, Extent-of-Condition, and Extent-of-Cause Evaluation

- a. The licensee used the following investigation techniques to complete RCE 2265623.
  - i. equipment reliability form
  - ii. failure mode - metallurgical report
  - iii. why staircase
  - iv. industry experience
  - v. safety culture evaluation

The inspectors determined that the licensee evaluated the issue using systematic methodologies to identify root and contributing causes.

- b. The licensee's RCE included an event narrative, a description of Cryofit coupling use and installation, historical use of the couplings for the licensee, an operating experience (OE) review, and a metallurgical report of the failed coupling. The

licensee's root cause identified a single item, the selection and installation of Tinel couplings was inappropriate for long term application in the reactor water level instrument lines.

The inspectors determined that the RCE was conducted to a level of detail commensurate with the significance of the problem.

- c. The licensee evaluated prior occurrences and operating experiences within the RCE. There were no prior occurrences of Cryofit coupling failures due to hydrogen embrittlement with this licensee. However, the OE considered was a 1991 Cryofit coupling failure at the Seabrook plant on a sample line in the pressurizer steam space that resulted in the NRC issuing Information Notice (IN) 91-87, Hydrogen Embrittlement of Raychem Cryofit Couplings, and prompted INPO to issue OE as well. The licensee evaluated their internal response to IN 91-87, and recognized a failure to implement a 1991 recommendation by the corporate metallurgist, as a contributing cause in the RCE (CC-1).

The inspectors determined that the RCE appropriately considered prior occurrences of the issue and knowledge of prior operating experience.

- d. The licensee's RCE used the same-similar methodology to concurrently consider the extent of condition and extent of cause, which included:
  - i. The extent of condition determined that other Cryofit couplings are susceptible to hydrogen embrittlement (EOC-AS1).
  - ii. The extent of cause evaluated the susceptibility of other pressure retaining components to hydrogen embrittlement (EOCa-AS2).
  - iii. The extent of cause also evaluated the susceptibility of other pressure retaining components to another degradation mechanism (EOCa-AS1).

The inspectors determined that the licensee's RCE adequately addressed the extent of condition and extent of cause for the issue.

- e. The licensee's review appropriately considered safety culture traits during their determination of the root cause, extent of condition and extent of cause. The licensee determined the issue was a historical issue, and no current safety culture weaknesses were identified. However, the safety culture analysis determined the most relevant aspects included design margins, resolution, and operating experience. Specifically, the licensee identified the resolution aspect (lack of follow-up to resolve an issue) as a contributing cause since the licensee failed to implement a 1991 recommendation by a corporate metallurgist, after evaluating the Seabrook OE.

The inspectors determined that the RCE included an appropriate consideration of whether a weakness in any safety culture component was a root cause or significant contributing cause of the issue.

### 3. Corrective Actions

- a. The licensee corrective actions to address the performance issue:
  - i. The licensee's immediate action to correct the condition was to replace the failed coupling with a welded fitting (COND-AS1). As part of the extent of



- condition, the licensee also replaced Cryofit couplings on instrument lines that contain steam for both Units 1 and 2, with welded fittings (EOC-AS1).
- ii. The licensee revised the piping specification to ensure Cryofit couplings are not installed in process medium that may facilitate hydrogen embrittlement (RC1-AS1). This was a corrective action to preclude repetition (CAPR) to address the root cause.
  - iii. Additionally, the licensee incorporated hydrogen embrittlement of Cryofit couplings (aging mechanism) into the Aging Management Program (AMP) (EOCa-AS4). This action was also a CAPR, to address extent of cause.
  - iv. Planned corrective actions include replacement of a minimum of two Cryofit couplings from different instrument lines in the drywell for each Unit for the next two outages (four outages total) (EOC-AS2/3/4/5), and perform metallurgical analysis on the replaced Cryofit couplings, to further inform the AMP.
  - v. The identified contributing cause was failure to act on a recommendation by the corporate metallurgist in 1991 after the Seabrook plant coupling failure (CC-1). The licensee determined the contributing cause to be a historical issue and concluded that no additional associated corrective actions were necessary.

The inspectors determined that the licensee specified appropriate corrective actions for each root and contributing cause, as well as extent of condition and extent of cause.

- b. The licensee established a program to analyze the Cryofit coupling failure, and a systematic method to evaluate future actions regarding Cryofit couplings based on metallurgical data.
  - i. The actions to address the root cause including the CAPRs were addressed above. Other corrective actions taken and planned to address extent of cause (EOCa) and extent of condition (EOC) include:
    1. Reviewed the piping specification 248-117 'Installation of Piping Systems' to identify legacy issues similar to the Cryofit coupling failure (ENHN1) and verify legacy potential incompatible process fluid operating conditions (EOCa-AS1),
    2. Determined the acceptability of Cryofit couplings identified installed in noncompliant process fluids through specifications for pressure retaining components (EOCa-AS2, ENHN2, ENHN3),
    3. Resolved the temperature difference in the piping specification, 248-117 'Installation of Piping Systems' and design temperatures of the installed couplings (EOCa-AS3),
    4. Incorporated a new aging mechanism, hydrogen embrittlement, to the AMP for Cryofit couplings to ensure the intended function of the coupling is consistent with the license basis (EOCa-AS4),
    5. Shared the unrecognized long-term degradation mechanism with the licensee fleet for potential application to license renewal (ENHN4),
    6. Metallurgical data gathered as part of the AMP will be collected in the following refueling outages: Unit 1, B1R23 in 2020 (EOC-AS2) and R1R24 in 2022 (EOC-AS4), Unit 2, B2R25 in 2021 (EOC-AS3) and B2R26 in 2023 (EOC-AS5). The AMP data will result in evaluations of the Cryofit couplings as a modification to the plant. [planned]

The inspectors noted that all corrective actions above were completed with the exception of EOC-AS2/3/4/5. The inspectors determined the licensee's corrective actions have been appropriately prioritized with respective due dates, and with consideration to risk significance and regulatory compliance in the type of corrective action chosen.

- c. The licensee's corrective actions to address and preclude repetition of hydrogen embrittlement of Cryofit couplings installed in susceptible environments were promptly planned and completed. At the time of inspection, both the CAPRs were completed (RC1-AS1 and EOCa-AS4).

The inspectors determined that the licensee adequately established a schedule and formal tracking mechanism for implementing and completing the taken and planned corrective actions.

- d. The licensee established measures to determine the effectiveness of the corrective actions documented in the RCE.
  - i. The CAPR associated with RC1-AS1 was completed in July 2019, and the effectiveness review will be completed within 6-12 months, with an initial due date of February 2020 (RC1-EREV1).
  - ii. The CAPR associated with EOCa-AS4 was completed in September 2019, and the effectiveness review will be completed after the planned coupling replacements (EOC-AS2/3/4/5), with an initial due date of July 2023 (RC1-EREV2)

The inspectors reviewed the effectiveness review plans, and determined each appropriately specified assessment methods, attributes, quantitative and/or qualitative measures of success and timeliness goals for each CAPR.

- e. There was no notice of violation associated with the White PI. The NRC previously documented a self-revealing Green NCV (05000324,05000325/2019002-04) associated with the Cryofit coupling failure that resulted in the White PI. The inspectors verified that corrective actions adequately addressed the NCV.

#### 4. Evaluation of IMC 0305 Criteria for Treatment of Old Design Issues.

The licensee did not request credit for self-identification of an old design issue; therefore, the risk-significant issue was not evaluated against the IMC 0305 criteria for treatment of an old design issue.

#### 5. Assessment of licensee's evaluation and corrective actions.

The inspectors determined that the licensee performed a comprehensive evaluation of the issue, and understood the root and contributing cause of the issue. The inspectors also determined that completed or planned corrective actions were sufficient to address the issue that led to the White PI. Thus, all objectives in IP 95001 were met. In accordance with IMC 0305, when all objectives of IP 95001 have been met for the performance issue and the PI has returned to Green, the licensee may transition back to the Licensee Response Column (Column 1) as of the date of the assessment follow-up letter.

## **INSPECTION RESULTS**

No findings were identified.

## **EXIT MEETINGS AND DEBRIEFS**

The inspectors verified no proprietary information was retained or documented in this report.

- On September 26, 2019, the inspectors presented the 95001 supplemental inspection results to Mr. John Krakuszeski and other members of the licensee staff.
- On September 26, 2019, NRC management, the Branch Chief, Division of Reactor Projects, Projects Branch 4, held a regulatory performance meeting with Mr. John Krakuszeski, Site Vice President, and other members of the licensee staff, in accordance with IMC 0305, Section 10.02.b.4. The NRC and licensee discussed the issues related to the White PI, including the causes, corrective actions, and extent of condition, extent of cause, and the criteria for returning Brunswick Unit 1 to the Licensee Response Column of the Action Matrix.

## DOCUMENTS REVIEWED

Inspection Procedure	Type	Designation	Description or Title	Revision or Date
95001	Corrective Action Documents	NCR 2265623	Unit 1 Reactor Shutdown Due to Unidentified Drywell Leakage	3/28/2019
		NCR 2267651	Cryogenic Coupling Design Temperature	4/9/2019
		NCR 2269746	Brunswick Unit 1 RCS Leakage NRC PI Indicator Turned White	4/24/2019
		NCR 2286932	Mock 95001 / Self Assessment AFI 1 – Part 21	8/14/2019
		NCR 2286935	Mock 95001/ Self Assessment AFI 2 - RCE Comments	8/14/2019
		NCR 2286939	Mock 95001 / Self Assessment AFI 3 - NCV Closure	8/14/2019
		NCR 2286941	Mock 95001 / Self Assessment AFI 4 - Hardness/Strength	8/14/2019
		NCR 2288231	Mock 95001 / Self Assessment AFI 5&6 – Hydrogen Embrittlement	8/22/2019
		RCE 2265623	Root Cause Evaluation Report - Failure of 1" Cryofit Coupling	3/28/2019, Revision 1
	Corrective Action Documents Resulting from Inspection	2293922	Cryofit coupling evidence of historical moisture	9/25/2019
	Engineering Changes	415249	Evaluation of Cryogenic Fittings Installed in the Brunswick Nuclear Plant Unit 1	
		415268	Evaluation of Cryogenic Fittings Installed in the Brunswick Nuclear Plant Unit 2	
		415807	Cryofit Coupling Hydrogen Embrittlement License Renewal Aging Management Review and Program Update	Revision 1
		416073	Evaluation of Cryogenic Fittings Installed in the Brunswick Nuclear Plant	Revision 0
		UFSAR Change Number 19 FSAR-007	Add a new license renewal program description to the UFSAR of the Cryofit Hydrogen Embrittlement Program	9/18/2019
	Miscellaneous		Presentation: Brunswick Oversight Review Committee, CR 2265623 Cryofit Coupling Failure	
			Aerofit, Aerospace Shape Memory Alloy Fluid Fitting System, Product Handbook & Engineering Data	

Inspection Procedure	Type	Designation	Description or Title	Revision or Date
		0BNP-TR-068	License Renewal Cryofit Coupling Hydrogen Embrittlement Program	0
		0E&RC-2212	Calibration/Operation of Genie Gamma Spectroscopy System, Counting Analysis Data sheet	9/25/2019
		Analysis Number 171771	Email discussion of gamma spectroscopy results of smears from cryogenic couplings	9/26/2019
		EOF Evaluation Serial# B5164	Misapplication of Raychem "Cryofit" Couplings	9/16/1991
		ESR NO 00-00343	Cryofit Fitting, Consult with Dr. Richard Smith on Cryofit Fittings Failures at Seabrook Plant	0
		NEI 99-02 FAQ 19-02	Brunswick RCS Leakage	5/22/2019
		NRC Request 19	Cryogenic Coupling Risk Review	
		NRC Request 35	Summary of Installation Timeframe	
		QP 0583	Qualification Package for Raychem Cryofit Pipe and Tube Couplings	April/1984
		Specification No. 248-108	Purchase and Installation of Cryogenic Mechanical Couplings	5
		Specification No. 248-092	Specification for Instrumentation and Tubing Fittings	6
	NDE Reports		Metallurgy Services, Bend Testing of BNP Cryofit Couplings, Metallurgy File #5960 - Addendum 1	9/10/2019
	Procedures	248-117	Installation of Piping Systems	44
		AD-PI-ALL-0100	Corrective Action Program	21
		AD-PI-ALL-0101	Root Cause Evaluation	6
	Self-Assessments	AR 2283331	BNP Cryofit Coupling Failure 95001 Self-Assessment & Mock Inspection	8/8/2019
	Work Orders	20152403	Unit 1, Replace Cryogenic Coupling during B1R23, on Rx Instrument Line thru X-69D	0
		20152404	Unit 1, Replace Cryogenic Coupling. during B1R23, on Rx Level Instrument line thru X-53A	0
		20153256	Unit 2, Replace Cryogenic Coupling During B2R25, Instrument line to B21-LT-N026A	0

Inspection Procedure	Type	Designation	Description or Title	Revision or Date
		20153257	Unit 2, replace cryogenic couplings during B2R25, on instrument piping 2-B32-710	0
		20319949 01	Unit 1, replace cryogenic coupling on Rx Level Instrument Line	4/3/2019
		20319949 16	Unit 1, replace cryogenic coupling on Rx Level Instrument Line	4/9/2019