Entergy Nuclear Operations, Inc.
Pilgrim Nuclear Power Station
600 Rocky Hill Road
Plymouth, MA 02360

November 18, 2016

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Licensee Event Report 2016-003-02, Spent Fuel Storage Design Feature Exceeded

Pilgrim Nuclear Power Station
Docket No. 50-293
Renewed License No. DPR-35

LETTER NUMBER: 2.16.071

Dear Sir or Madam:

The enclosed Licensee Event Report 2016-003-02, Spent Fuel Storage Design Feature Exceeded, is submitted in accordance with 10 CFR 50.73.

If you have any questions or require additional information, please contact me at (508) 830-8323.

There are no regulatory commitments contained in this letter.

Sincerely,

Everett P. Perkins, Jr.
Manager, Regulatory Assurance

EPP/sc

Attachment: Licensee Event Report 2016-003-02, Spent Fuel Storage Design Feature Exceeded (6 Pages)

IE22
NRR

cc:

Mr. Daniel H. Dorman
Regional Administrator, Region I
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King of Prussia, PA 19406-2713

Ms. Booma Venkataraman, Project Manager
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Mail Stop O-8C2A
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NRC Senior Resident Inspector
Pilgrim Nuclear Power Station

Attachment

Letter Number 2.16.071

Licensee Event Report 2016-003-02

Spent Fuel Storage Design Feature Exceeded

(6 Pages)

NRC FORM 366 (11-2015) U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

APPROVED BY OMB: NO. 3150-0104 EXPIRES: 10/31/2018

1. FACILITY NAME	2. DOCKET NUMBER	3. PAGE
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4. TITLE Spent Fuel Storage Design Feature Exceeded

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO.	MONTH	DAY	YEAR	FACILITY NAME N/A	DOCKET NUMBER N/A
05	12	2016	2016	- 003	- 02	11	17	2016	FACILITY NAME N/A	DOCKET NUMBER N/A

9. OPERATING MODE	11. THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: *(Check all that apply)*			
N	☐ 20.2201(b)	☐ 20.2203(a)(3)(i)	☐ 50.73(a)(2)(ii)(A)	☐ 50.73(a)(2)(viii)(A)
	☐ 20.2201(d)	☐ 20.2203(a)(3)(ii)	☒ 50.73(a)(2)(ii)(B)	☐ 50.73(a)(2)(viii)(B)
10. POWER LEVEL	☐ 20.2203(a)(1)	☐ 20.2203(a)(4)	☐ 50.73(a)(2)(iii)	☐ 50.73(a)(2)(ix)(A)
	☐ 20.2203(a)(2)(i)	☐ 50.36(c)(1)(i)(A)	☐ 50.73(a)(2)(iv)(A)	☐ 50.73(a)(2)(x)
100	☐ 20.2203(a)(2)(ii)	☐ 50.36(c)(1)(ii)(A)	☐ 50.73(a)(2)(v)(A)	☐ 73.71(a)(4)
	☐ 20.2203(a)(2)(iii)	☐ 50.36(c)(2)	☐ 50.73(a)(2)(v)(B)	☐ 73.71(a)(5)
	☐ 20.2203(a)(2)(iv)	☐ 50.46(a)(3)(ii)	☐ 50.73(a)(2)(v)(C)	☐ 73.77(a)(1)
	☐ 20.2203(a)(2)(v)	☐ 50.73(a)(2)(i)(A)	☐ 50.73(a)(2)(v)(D)	☐ 73.77(a)(2)(i)
	☐ 20.2203(a)(2)(vi)	☒ 50.73(a)(2)(i)(B)	☐ 50.73(a)(2)(vii)	☐ 73.77(a)(2)(ii)
		☐ 50.73(a)(2)(i)(C)	☐ OTHER	Specify in Abstract below or in NRC Form 366A

12. LICENSEE CONTACT FOR THIS LER

LICENSEE CONTACT	TELEPHONE NUMER *(Include Area Code)*
Mr. Everett P. Perkins, Jr. – Regulatory Assurance Manager	508-830-8323

13. COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT

CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX

14. SUPPLEMENTAL REPORT EXPECTED		15. EXPECTED SUBMISSION DATE	MONTH	DAY	YEAR
☐ YES *(If yes, complete 15. EXPECTED SUBMISSION DATE)*	☒ NO				

ABSTRACT *(Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines)*

On May 12, 2016, at 16:47 EDT, an assessment of Boron Areal Density Gauge for Evaluating Racks (BADGER) testing results for spent fuel storage racks revealed a single panel, RR35 South with a gap in neutron absorber material that exceeds spent fuel storage design feature assumptions. The assumptions ensure compliance with Technical Specification (TS) Section 4.3.1.1.b to maintain a spent fuel pool K-effective (K_{eff}) of less than or equal to (</=) 0.95. An extent of condition review indicates additional at-risk rack locations that may further challenge compliance with TS 4.3.1.1.b.

The cause of the noncompliance with TS 4.3.1.1.b is Boraflex degradation greater than assumed in the criticality safety analysis. Interim actions include declaring the spent fuel pool rack cells adjacent to the panel RR35 South inoperable, installing blade guides into cells adjacent to panel RR35S, and prohibiting fuel movement in Boraflex racks. An additional corrective action was taken to perform a criticality evaluation of the spent fuel pool (SPF).

This LER supplement is issued to identify that an additional criticality evaluation has been performed to conservatively identify fuel storage configurations within the Boraflex fuel storage racks that will ensure the Boraflex racks K_{eff} will be able to be maintained </= 0.95. Fuel movement will be required to establish these configurations.

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NARRATIVE

BACKGROUND:

Boraflex degradation is a known industry issue that has warranted monitoring and evaluation to ensure the margin to criticality is maintained in the Spent Fuel Pool (SFP). The Boraflex Monitoring Program is described in Final Safety Analysis Report Appendix S, License Renewal Commitments, as a program that assures degradation of the Boraflex panels in the spent fuel racks does not compromise the criticality analysis in support of the design of the spent fuel storage racks. The program relies on (1) neutron attenuation testing, (2) determination of boron loss through correlation of silica levels in SFP water samples and periodic areal density measurements, and (3) analysis of criticality to assure that the required 5% subcriticality margin is maintained.

RACKLIFE is a commercial software program, based on the degradation mechanism of Boraflex, developed to calculate the average Boron loss of a Boraflex panel and to predict the future Boron loss of Boraflex. Boron Areal Density Gauge for Evaluating Racks (BADGER) is a commercial in-situ nondestructive diagnostic tool for measuring the areal density of Boron and the gaps in a neutron absorber as installed in fuel racks. BADGER testing measures the neutron transmission rate through SFP Boraflex panels by placing a neutron source and neutron detectors on opposite sides of a panel. Measured neutron transmission is related to Boron areal density and allows for measurement of gaps in the neutron absorber. Overall, RACKLIFE and BADGER approach the loss of Boron areal density from Boraflex from opposite sides. RACKLIFE calculates the percent of Boron that is lost while BADGER measures the areal density of Boron that remains. To quantify the loss of Boron in spent fuel pool racks, the RACKLIFE and BADGER methods are combined.

The average number of neutrons that cause new fission events is called the effective neutron multiplication factor, denoted by $K_{effective}$ (K_{eff}). When K_{eff} is equal to 1, the assembly is called critical, if K_{eff} is less than 1 the assembly is said to be subcritical, and if K_{eff} is greater than 1 the assembly is called supercritical.

TS 4.3.1.1.a design criteria for acceptable storage of fuel in the spent fuel storage racks are: 1) Fuel must have lattice-average enrichment of 4.6% or less and 2) The $K_{infinity}$ which is a conservative credit of maximum reactivity exposures for fuel burnup in the standard core geometry, calculated at the burn up of maximum bundle reactivity, must be 1.32 or less.

TS 4.3.1.1.b design requirements for spent fuel pool storage provides for a k_{eff} less than or equal to (</=) 0.95. This satisfies the Nuclear Regulatory Commission's (NRC) criteria for fuel storage racks. With K_{eff} </= 0.95 there is an assurance that there can be no sustained fission reaction between fuel assemblies stored in the spent fuel pool, and they therefore remain substantially subcritical.

The design of the fuel storage racks assumes that the neutron absorbing material is consistent with gaps size and areal density losses assumed in the criticality safety analysis. Prior to 2016 in-situ examinations of Boraflex material in the PNPS spent fuel racks confirmed expected gap size and areal density loss assumptions.

EVENT DESCRIPTION:

During a BADGER test campaign conducted in the spent fuel pool from March 28, 2016 to April 5, 2016, a 38 inch cumulative gap was found in panel RR35 South that exceeded the maximum analyzed gap size of 10

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inches, and challenged compliance with TS 4.3.1.1.b SFP storage rack K_{eff} requirement of </=0.95. This result exceeded the previous results and predictions of total gap size. No other panel tested had a cumulative gap size greater than or equal to 6.0 inches nominal. Sixteen panels tested had previously been BADGER tested in 2006 and 2012. None of these panels were found with a total gap greater than anticipated. The 2016 BADGER testing was the first measurement for panel RR35 South which is located in SFP rack E5. Panels in rack E5 were chosen for testing to ensure that the highest dose Boraflex panel in the SFP was tested. Panel RR35 South was not the highest dose panel, but was in the region that was cleared for testing and included in the test population. Previous BADGER test panels were selected to ensure that the highest predicted boron areal density loss panel was tested. Other panels were selected to obtain a sampling of high, medium, and low dose and/or Boron loss panels with consideration for the amount of fuel movement required for the test. This most recent test used the same approach but also included the panel predicted to have the highest dose. There were 71 Boraflex panels tested during the 2016 BADGER testing. These panels were predicted by the RACKLIFE model to have varying degrees of Boron loss and accumulated dose. The panel selection was made jointly by Reactor Engineering, Fuels Engineering and the BADGER test vendor.

Fuels Engineering reviewed the preliminary 2016 BADGER test results and determined that additional testing was not required at that time since 21 other panels with a similar dose and history were tested during this most recent test with a maximum cumulative gap preliminarily reported at 6.7 inches (final value of 6.0 inches). These 21 similar panels included all six panels in cells that share the RR35 South panel, as well as several other panels within the same rack as RR35 South. Since the 2016 BADGER measurements found only one panel out of the 22 similar panels to have a large cumulative gap beyond the analysis basis, the cumulative gap measured in panel RR35 South was considered to be an isolated occurrence. There was no fuel in RR34, RR35 and other surrounding cells as fuel in this area was removed for the BADGER tests. Therefore, based on panel RR35 South test results, the six rack locations surrounding panel RR35 South were declared inoperable and blocked with blade guides to preclude inadvertent loading of fuel adjacent to the defective panel.

In order to evaluate the preliminary 2016 BADGER test results, a conservative Boraflex gap model was developed based on BADGER and blackness testing measurements performed at Pilgrim Nuclear Power Station (PNPS) and blackness testing measurements at Grand Gulf Nuclear Station (GGNS) over the last 28 years. Both GGNS and PNPS use fuel storage racks designed and manufactured by the same manufacturer and installed circa 1986. The model includes site specific factors that affect Boraflex degradation, such as gamma dose absorbed by each panel and the fuel storage history of each storage cell. The other key factor that impacts Boraflex degradation is the rate which SFP water circulates through the rack volume that encapsulates the Boraflex panel. This parameter is a function of the design and manufacturing process so it is common to both sites' racks. Application of this model determined the extent of condition to be that approximately 534 panels were susceptible to gap losses of 10 inches (maximum gap loss considered in the current analysis of record) or larger. Based on these results, all Boraflex racks and any adjacent non-Boraflex cells that credit the neutron absorber in the Boraflex racks were declared inoperable. Preliminary analysis of the pool configuration by the fuel vendor using the Badger Test gap measurements showed that the SFP was maintained subcritical, using actual fuel characteristics, rather than the maximum reactivity allowed by the Technical Specifications. Fuel movement in Boraflex racks has been stopped until completion of additional criticality analysis that supports movement of fuel within the Boraflex racks. This additional criticality evaluation has been performed to conservatively identify fuel storage configurations within the Boraflex fuel

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storage racks that will ensure the Boraflex racks K_{eff} will be able to be maintained </= 0.95. This analysis has projected the condition of the Boraflex panels until September, 2017 using the BADGER test results, RACKLIFE code and the Boraflex gap model. Application of the gap model determined that 886 panels will be susceptible to gap losses of 10 inches or larger as of September, 2017. This analysis takes credit for a degraded Boraflex absorber in rack panels that have been determined to be non-susceptible to gap losses of 10 inches or larger but does not take credit for the Boraflex absorber in susceptible panels. This criticality analysis takes credit for fuel burn-up in determining fuel storage configurations that are less than 0.95 K_{eff}. Fuel will need to be moved to establish the acceptable configurations of this analysis.

CAUSE OF THE EVENT

The cause of the potential noncompliance with TS 4.3.1.1.b is Boraflex gaps greater than assumed in the criticality safety analysis. Boraflex has been observed to be subject to in-service degradation from the combined effects of gamma radiation from spent fuel and long term exposure to the aqueous pool environment. Boraflex polymer shrinks due to irradiation beyond certain dose and forms gaps, which may have caused flow induced washout of the Boraflex material. The synergistic effects of gamma radiation and water cause the chemical composition of the polymer matrix of Boraflex to change from polydimethyl siloxane to amorphous silica, which is somewhat soluble in water. As the transformed matrix dissolves, it releases Boron and crystalline silica filler materials to the interior of the fuel racks and eventually to the SFP, resulting in gap growth. A contributing cause of the event is that water infiltration into cell RR35 South could be higher due to variation in fabrication quality. This cause would contribute to this condition by enabling boron washout.

The apparent cause of the unanalyzed condition is reliance on the method of BADGER Testing / RACKLIFE alone to determine the condition of Boraflex panels in the SFP.

CORRECTIVE ACTIONS

Corrective actions include performing a criticality evaluation to determine acceptable fuel storage configurations in Boraflex racks and achieving a SFP arrangement, in accordance with the criticality evaluation, to meet and maintain SFP K_{eff} </= 0.95 as required by TS 4.3.1.1.b.

The BADGER/RACKLIFE method of prediction of cumulative gap was augmented by a gap model based on PNPS and GGNS gap measurements to determine that approximately 534 locations were susceptible to gaps that could exceed the current analysis assumption. Further criticality analysis utilized BADGER/RACKLIFE and the PNPS and GGNS gap model to predict the cumulative gap size and boron areal density used within analytical models of the Boraflex racks. Application of the gap model determined that 886 panels will be susceptible to gap losses of 10 inches or larger as of September, 2017.

SFP rack cells with Boraflex panels have been declared inoperable, blade guides have been installed into cells adjacent to panel RR35S, and fuel movement in storage racks with Boraflex panels has been discontinued to avoid challenging subcriticality margins. A criticality evaluation has been performed to conservatively identify fuel storage configurations within the Boraflex fuel storage racks that will ensure the Boraflex racks K_{eff} will be maintained </= 0.95. Fuel will be moved to establish the acceptable configurations of this evaluation once an analysis that supports movement of fuel within the fuel storage racks with Boraflex panels has been completed.

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The current TS 4.3.1.1.a allows loading a fuel assembly with K_{inf} as high as 1.32. PNPS has not loaded any assemblies with > 1.27 peak k_{inf}. Since we are unable to show that SFP K_{eff} of </= 0.95 can be met with the highest allowed assembly in-core k_{inf} of 1.32 due to current degraded status of the SFP Boraflex panels, TS 4.3.1.1.a K_{inf} specification of the maximum allowed K_{inf} of 1.32 may be non-conservative for racks with Boraflex panels. While this is non-conservative relative to the PNPS TS, evaluations document the SFP was maintained subcritical and therefore safe.

Corrective action to perform a criticality evaluation to confirm the acceptability of the configurations of the fuel storage racks using the BADGER Test gap measurements in Boraflex panels was completed. A criticality evaluation has been performed to conservatively identify fuel storage configurations within the Boraflex fuel storage racks which will ensure that the Boraflex racks K_{eff} will be maintained </= 0.95 until September, 2017. This analysis was performed without taking credit for the Boron content of the Boraflex panels susceptible to high gap formation.

Additional analysis will be performed to update the criticality analysis of record to either show compliance with the TS as written or we will submit a proposed revision to TS that will cover the characteristics of fuel assemblies currently stored or planned to be stored in the SFP, to meet the </= 0.95 K_{eff} limit for the SFP.

SAFETY CONSEQUENCES

There was no actual safety consequence related to the event because evaluations have demonstrated the current fuel storage configuration is subcritical. This analysis utilized assumptions concerning Boraflex gap size and location based upon the results of the most recent BADGER test to model all fuel storage rack cells with Boraflex panels. In addition, all Boraflex racks and any adjacent non-Boraflex cells that credit the neutron absorber in the Boraflex racks were declared inoperable, blade guides have been installed into cells adjacent to panel RR35S pending the now completed additional analysis. The analysis identifies required fuel configurations and limitations on regions of the Boraflex storage racks and the fuel to be stored in these regions. These fuel configurations ensure that the Boraflex storage racks k_{eff} will remain less than 0.95 with conservative estimates of future Boraflex absorber changes. Fuel movement in Boraflex racks has been stopped until completion of additional analysis that supports movement of fuel within the Boraflex racks.

REPORTABILITY

A condition prohibited by TS occurred when the cumulative gap loss in SFP panel RR35 South invalidated the loss limit in the SFP Nuclear Criticality Boron Loss Study and invalidated the conclusion that the Boron loss projections would assure the SFP K_{eff} less than 0.95 until July 28, 2016. This was a noncompliance with TS 4.3.1.1.b and is reportable in accordance with 10 Code of Federal Regulations (CFR) 50.73(a)(2)(i)(B). Condition Report CR-PNP-2016-02205 addresses the noncompliance. Based on initial extent of condition review, this event was reported under Event Notification Report Number 51924 on May 12, 2016, as an unanalyzed condition in accordance with 10 CFR 50.72(b)(3)(ii)(B). Based on the unknown condition of other panels that are susceptible to gap losses, this condition is reportable as an unanalyzed condition in accordance with 10 CFR 50.73(a)(2)(ii)(B).

NRC FORM 366A (11-2015)	U.S. NUCLEAR REGULATORY COMMISSION	APPROVED BY OMB: NO. 3150-0104 EXPIRES: 10/31/2018
	LICENSEE EVENT REPORT (LER) CONTINUATION SHEET	Estimated burden per response to comply with this mandatory collection request: 80 hours. Reported lessons learned are incorporated into the licensing process and fed back to industry. Send comments regarding burden estimate to the FOIA, Privacy and Information Collections Branch (T-5 F53), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by internet e-mail to Infocollects.Resource@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202, (3150-0104), Office of Management and Budget, Washington, DC 20503. If a means used to impose an information collection does not display a currently valid OMB control number, the NRC may not conduct or sponsor, and a person is not required to respond to, the information collection.

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PREVIOUS EVENTS

None

ENERGY INDUSTRY IDENTIFICATIONSYSTEM (EIIS) CODES

The EIIS codes for Components and Systems referenced in this report are as follows:

COMPONENTS: None CODES: None
SYSTEMS: None CODES: None

REFERENCES: CR-PNP-2016-02205