U.S. NUCLEAR REGULATORY COMMISSION
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EXPIRES: 8/31/85

LICENSEE EVENT REPORT (LER)

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TITLE (4) DEGRADATION OF BORAFLEX NEUTRON ABSORBER IN SURVEILLANCE COUPONS - SUPPLEMENTAL REPORT

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (6)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)
0 8	1 7	9 3	9 3	0 0 7	0 2	0 5	2 3	9 5	N/A	0 5 0 0 0
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OPERATING MODE (9): N

POWER LEVEL (10):

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: *(Check one or more of the following)* (11)

[ ] 20.402(b)	[ ] 20.405(c)	[ ] 50.73(a)(2)(iv)	[ ] 73.71(b)
[ ] 20.405(a)(1)(i)	[ ] 50.36(c)(1)	[ ] 50.73(a)(2)(v)	[ ] 73.71(c)
[ ] 20.405(a)(1)(ii)	[ ] 50.36(c)(2)	[ ] 50.73(a)(2)(vii)	[ ] OTHER (Specify in Abstract below and in Text, NRC Form 366A)
[ ] 20.405(a)(1)(iii)	[ ] 50.73(a)(2)(i)	[ ] 50.73(a)(2)(viii)(A)	
[ ] 20.405(a)(1)(iv)	[X] 50.73(a)(2)(ii)	[ ] 50.73(a)(2)(viii)(B)	
[ ] 20.405(a)(1)(v)	[ ] 50.73(a)(2)(iii)	[ ] 50.73(a)(2)(x)	

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (AREA CODE)
Paul J. Gire	616 764-8913

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

CAUSE	SYSTEM	COMPONENT	MANUFAC-TURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFAC-TURER	REPORTABLE TO NPRDS

SUPPLEMENTAL REPORT EXPECTED (14)

[ ] YES *(If yes, complete EXPECTED SUBMISSION DATE)* [X] NO

EXPECTED SUBMISSION DATE (15): MONTH | DAY | YEAR

ABSTRACT *(Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines)* (16)

On August 17, 1993 the plant was in cold shutdown for refueling. A Boraflex surveillance coupon was removed from the spent fuel pool in order to conduct a visual inspection, neutron attenuation test, and a hardness test. While removing the coupon from the spent fuel pool, a dark debris cloud was observed in the spent fuel pool around the edges of the coupon. Upon removal of the sheet metal coupon cover, the Boraflex material was found to be approximately 90 percent disintegrated or missing. Additional coupons were removed from the spent fuel pool and examined with varying amounts of Boraflex material found missing.

The cause of this event is flow induced deterioration of the full length surveillance coupons due to inadequate holding canister design. The full length surveillance capsules have since been determined to be poor indicators of the actual rack Boraflex condition.

Corrective actions include completion of neutron attenuation testing on the spent fuel pool racks and a change to the surveillance method for verification of rack Boraflex condition.

EVENT DESCRIPTION

On August 17, 1993 the plant was in cold shutdown for refueling. A Boraflex surveillance coupon was removed from the spent fuel pool [DB] in order to conduct a visual inspection, neutron attenuation test, and a hardness test. Boraflex is the trade name of a boron impregnated, polymer-based sheet material that is utilized as a neutron absorber in the construction of spent fuel pool (SFP) storage racks [DB;RK]. The material was manufactured by Brand Industrial Services, Inc. The use of the Boraflex allows minimal center to center cell spacing in the SFP storage racks. The Boraflex is sandwiched between two sheets of stainless steel.

While removing the coupon from the spent fuel pool, a dark debris cloud was observed in the spent fuel pool around the edges of the coupon. Upon removal of the sheet metal coupon cover, the Boraflex material was found to be approximately 90 percent disintegrated or missing. Five additional coupons were removed from the spent fuel pool and examined with varying amounts of Boraflex material found missing.

Boraflex surveillance coupons are not part of the SFP storage racks, but rather are placed in the SFP to be examined and tested periodically to judge the condition of the Boraflex in the SFP storage racks. The first coupon removed on August 17 was being tested to fulfill a five year surveillance interval commitment made to the NRC. In a similar manner to that in the surveillance coupons, the Boraflex in the spent fuel pool storage racks is contained in a stainless steel wrapper. The wrapper assembly is then attached to the walls of the storage cells of the storage racks.

There are two types of coupons at Palisades: Full length coupons and short set coupons. Some full length coupons have the Boraflex bonded to one side of their sheet metal wrapper; in others, the Boraflex is not bonded. Four of the five coupons removed for testing were full length coupons and the other was a short set coupon. Three of the full length coupons had Boraflex bonded to the sheet metal. Material lost from the full length coupons varied from 38 percent to an estimated 90 percent. No significant loss of the Boraflex material in the short set coupon was experienced. The Boraflex material in the full set coupons was from a different batch of material than that used in the short set coupons.

Neutron attenuation testing performed on the Boraflex material remaining in the surveillance coupons showed no loss of boron areal density, within measurement tolerances, from the original condition. There was no thinning of the remaining material.

During the week of January 9, 1995, a program of neutron attenuation testing was performed in selected storage cells of the Region II SFP racks. The purposes of this testing were to verify that the Boraflex in the storage racks was intact and to determine the existence and size of any gaps that may exist in the rack Boraflex material. The cells selected for testing included those that had received the highest radiation exposure and the cells that had received exposure for the longest periods of time. Results of the neutron attenuation testing showed that the tested Boraflex panels in the SFP Region II are intact. A total of 48 Region II storage cells were tested which is approximately 15% of the useable cells. The testing determined that 64% of the Boraflex panels in the inspected cells had no detectable gaps. The minimum detectable gap size for these inspections was 1/2" due to the high boron concentration in the SFP. In the remaining panels which did exhibit gaps the maximum accumulated gap detected in any one panel was 2.3" (including measurement uncertainties). The criticality analysis for SFP Region II contains sufficient margin to compensate for the effects of up to five inches of gap in all four panels of each storage cell in Region II. Attachment 1 contains further details and analysis pertaining to the neutron attenuation testing.

CAUSE OF THE EVENT

The cause of the degradation of the full length surveillance coupons is a poor design of the holding canister. The bolt pattern for the canisters was insufficient to protect the full length Boraflex coupons from flow erosion. The designs of the rack Boraflex and the short set coupon canisters are different from the full length canister design and thus they do provide adequate protection to prevent degradation from flow erosion effects.

ANALYSIS OF THE EVENT

Upon the discovery of the degraded Boraflex coupon, an analysis of the spent fuel pool storage configuration was completed to ensure there was no possibility of a criticality occurring in the spent fuel pool under worst case conditions. The analysis conservatively assumed there was no Boraflex present in the storage racks and no boron in the spent fuel pool water. Based upon the results of the analysis, the 23 most reactive assemblies were moved from the Region II racks and replaced with assemblies which met the analysis assumptions.

Based upon the results of the recent neutron attenuation testing, the Region II storage racks are fully useable for all fuel enrichments and burnups permitted by Technical Specifications. The condition of the degraded full length surveillance coupons is not indicative of the condition of the rack Boraflex material.

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CORRECTIVE ACTION

Corrective actions completed for this event include:

Completed neutron attenuation testing on the Boraflex neutron absorber material in the spent fuel pool Region II storage racks.

Corrective actions to be completed for this event include:

Perform periodic neutron attenuation testing of the Spent Fuel Pool Region II storage racks to monitor the rack Boraflex condition. The next performance of the periodic testing will be approximately the first quarter of 1998. The frequency of subsequent testing will be determined based on known condition of the rack Boraflex and industry experience.

ADDITIONAL INFORMATION

Refer to NRC Information Notice 93-70: "Degradation of Boraflex Neutron Absorber Coupons."

ATTACHMENT 1

Consumers Power Company
Palisades Plant
Docket 50-255

PALISADES ENGINEERING ANALYSIS PERTAINING TO BLACKNESS TESTING RESULTS ON SPENT FUEL POOL REGION II RACKS

7 Pages

PALISADES NUCLEAR PLANT

Consumers Power — POWERING MICHIGAN'S PROGRESS

PALISADES NUCLEAR PLANT
ENGINEERING ANALYSIS COVER SHEET

TITLE: SPENT FUEL POOL REGION II BORAFLEX CONDITION

INITIATION AND REVIEW

Calculation Status: Preliminary ☐ Pending ☐ Final ☒ Superseded ☐

Rev #	Description	Initiated By	Initiated Date	Init. Appd By	Review Method: Alt Calc	Review Method: Det Review	Review Method: Qual Test	Technical Review By	Technical Review Date	Review Appd By
0	Original Issue	[illegible]	3/23/95	ARW		X		RDRadulovich	3/23/95	ARW

PURPOSE

1. Summarize the results of the Blackness Test of the Spent Fuel Pool Region II Boraflex.

2. Present the justification for concluding that the Region II Boraflex is in good condition.

3. Once again take credit for the Boraflex in the Region II criticality analysis and control the storage of fuel assemblies in Region II using the Technical Specifications curve of 1.5 fresh weight percent equivalent.

4. Provide justification for changing the Boraflex surveillance method from the current use of coupons to periodic blackness testing.

SUMMARY OF RESULTS

Results of the Blackness Test showed that the Boraflex panels in the SFP Region II are present and in good condition. 48 cells were tested and 64% of the panels had no gaps greater than 1/2". The maximum amount of gap in any one panel was 2.3" including measurement uncertainties. The Technical Specification basis has been shown to have sufficient margin for 5" of gap per Boraflex panel. The Blackness Test demonstrated that the cells containing multiple gaps and the cell with the maximum amount of gap were located in the accelerated exposure region, so the remaining cells of Region II should not exhibit any worse degradation than that detected in the accelerated exposure region. Other plants with racks containing Boraflex have not experienced significant degradation. The SFP water silica concentration is another Boraflex condition indicator and Palisades' is similar to that measured at other plant's. All indications support the hypothesis that the Boraflex in the Palisades SFP Region II is in very good condition and fully capable of performing its intended criticality function. The movement of fuel assemblies into Palisades SFP Region II will be controlled by the burnup versus enrichment curve in Technical Specifications with a fresh fuel enrichment equivalency value of 1.5 weight percent. Blackness testing demonstrated that the condition of the surveillance coupons are not indicative of the condition of the Boraflex in the Region II racks. Reactor Engineering recommends that the Boraflex surveillance be changed to periodic blackness testing at an appropriate interval to based on the known condition of the Palisades Boraflex and industry experience.

OBJECTIVE

The primary objective of this engineering analysis is to provide documentation to justify that the Boraflex neutron absorbing material in the Palisades Spent Fuel Pool (SFP) Region II racks is in good condition and fully capable of performing its intended criticality control function. The use of Boraflex allows for higher fuel assembly packing density in the SFP Region II rack for the same fuel assembly equivalent enrichment. A second objective is to present reasons for changing the Boraflex surveillance methods from the current use of coupons hanging in the SFP to periodic blackness testing.

REFERENCES

1. LER 93-007, "Degradation of Boraflex Neutron Absorber in Surveillance Coupons"
2. EA-RDR-93-07, Rev. 1, "Determination of the Most Reactive Assemblies in the Region II Spent Fuel Rack"
3. Special Test Procedure Test Report, "Test Report for Special Test Procedure T-350, Spent Fuel Pool Rack Blackness Test"
4. Holtec Report HI-951279, "Blackness Testing of Boraflex in Selected Cells of the Spent Fuel Storage Racks at the Palisades Nuclear Station", Holtec International, March 1995
5. EPRI TR-101986, "Boraflex Test Results and Evaluation", EPRI, February 1993
6. EA-SFP-94-02, "Determination of Reactivity Changes Due to Gaps in Boraflex Panels of Region 2 Spent Fuel Pool Racks"
7. Letter from RWSmedley (CPCo) to NRC, dated August 16, 1988, "Spent Fuel Pool Boraflex Neutron Absorbing Material - Surveillance Coupons"

TITLE: SPENT FUEL POOL REGION II BORAFLEX CONDITION

ASSUMPTIONS

1. Blackness testing at Palisades was able to detect gaps in the Boraflex of 1/2" or larger.
2. The condition of the SFP Region II cells tested are representative of the remaining cells in the Region II rack.
3. The surveillance coupons are not a good indicator of the condition of the Boraflex panels in the Region II rack.

BACKGROUND

On August 17, 1993, Region II Boraflex surveillance coupons were removed from the SFP. Visual observation and subsequent testing at the University of Michigan indicated severe degradation to the Boraflex in the coupons. Based on the significant degradation of the surveillance coupons, the ability of the actual rack Boraflex to perform its criticality control function was conservatively considered to be suspect until such time as the rack Boraflex condition could be verified by blackness testing (Reference 1).

An analysis was performed assuming that no Boraflex was present and no boron in the SFP water to determine whether the Technical Specifications requirement of a five percent subcritical margin was being met (Reference 2). The analysis provided a burnup versus enrichment curve which conservatively estimated that the fresh fuel enrichment equivalency requirement for spent fuel stored in the Region II rack had been reduced from the Technical Specifications value of 1.5 to 1.0 weight percent. Based upon the results of an additional analysis, the most reactive assemblies were removed from Region II such that k_{eff} was shown to be below 0.95 (Reference 2). Until the presence and condition of the Boraflex could be determined, any subsequent movement of assemblies into Region II were required to meet the 1.0 weight percent equivalent enrichment criteria or be shown by reactivity equivalencing to be less reactive than the most reactive assembly considered by the analysis. All movement of fuel into Region II required the approval of Reactor Engineering.

Blackness testing of selected cells in the Region II spent fuel storage rack located in the SFP was performed January 9-14, 1995 (Reference 3). The purpose of this testing was to verify, by testing a representative sample of fuel storage cells, that the Boraflex neutron absorber material was intact and determine its condition; and determine the size and location of any gaps that may have developed. Blackness testing uses a neutron source to verify the presence of Boraflex in the walls of the spent fuel rack. The blackness testing was performed by Holtec International under the direction of Reactor Engineering.

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SPENT FUEL POOL REGION II BLACKNESS TEST

A total of 48 cells were tested using a checkerboard testing pattern. A checkerboard pattern was used because the cells in Region II share walls/Boraflex with adjacent cells. 31 cells were tested using the Test Tool and 17 additional cells were effectively tested because they shared walls with cells that were tested. The Blackness Test results show that the Boraflex panels in the 48 cells tested are present and in good condition. This represents approximately 15% of the usable Region II cells. Of the 98 full length Boraflex panels tested, 63 (64%) panels had no measurable gaps. 45 measurable gaps were distributed among the remaining 35 (36%) panels. The minimum detectable gap size was considered to be approximately 1/2" due to the high boron concentration in the SFP (Reference 4). The SFP boron concentration at the time of the Blackness Test was approximately 3100 ppm due to Dry Fuel Storage (DFS) activities.

The cells blackness tested included cells that have been designated the accelerated exposure region. These cells have received the highest radiation exposure in the Region II rack. Another set of cells tested were cells that have been exposed to radiation for the longest length of time. These two areas of the rack envelope the locations of the surveillance coupons removed from the SFP. These cells have been exposed to the same radiation exposure levels as the coupons and have been exposed to potentially similar flow conditions. Radiation exposure and flow have been demonstrated to be the mechanisms that induce Boraflex degradation (Reference 5).

The main Region II rack is made up of five smaller racks. Cells were tested from three of the five smaller racks. The racks are constructed such that the rack outer walls do not contain Boraflex panels. This allowed for a verification of the blackness testing process. When testing an outer cell, the neutron count rate of the channel from the detector adjacent to the wall without Boraflex should have been higher than the outputs from detectors near walls with Boraflex. Outer corner cells exhibited two outputs with a higher count rate. This difference in count rates verified that the blackness testing process was "seeing" the Boraflex neutron absorber. The test successfully detected the Boraflex-less walls.

Three of the remaining surveillance coupons provided a second verification of the testing process method. These coupons were hanging against the outer wall of cells tested. The affected count rate trace showed significant Boraflex degradation, large distinguishable gaps, in these coupons. This information provided further evidence that blackness testing was able to "see" Boraflex degradation and provide relevant data as to the condition of the Boraflex panels in the rack walls. Clearly, the Blackness Test process was providing good information. The disparity between the rack Boraflex and these three coupons provides additional evidence that the surveillance coupons are not a reliable indicator of the condition of the Boraflex in the rack.

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The majority of Boraflex panels had no gaps or one gap. The average gap size for the 45 measurable gaps was 0.7". The largest single gap measured approximately 1" in the north panel of cell NW-37. All single gaps were less than or equal to one inch. The gaps detected were of the type that have been observed throughout the industry (Reference 5). Gaps of one inch or less are known to occur due to radiation-induced shrinkage of the Boraflex organic binder which results in the subsequent tearing of the Boraflex in response to the shrinkage stresses. The number of Boraflex panels with more than one gap was 7 (7%). They were the east panel of LW-36 (2), the south panel of NW-34 (2), the west panel of MW-33 (3), the north panel of NW-32, the north panel of LW-30 (2), the north panel of NW-30 (2), and the west panel of OW-29 (2).

BORAFLEX SURVEILLANCE COUPON PERFORMANCE

The surveillance coupons were part of an NRC commitment to install the coupons in the SFP and evaluate their usefulness as indicators of the condition of the Region II rack Boraflex (Reference 7). The correlation between the rack and the coupon Boraflex was unknown at the time of installation. The five year surveillance period was based upon industry experience with Boraflex until 1988. The Blackness Test indicated that the Boraflex surveillance coupons that were removed and examined, and those still remaining in the SFP were either poor indicators (full length) of the condition of the Boraflex panels or the correlation between the coupon (short set) and the rack is still unknown.

The full length coupons were of similar construction, but were far more "flimsy" because they did not have the support of adjacent panels as in the rack. This is significant because water flow coupled with radiation exposure have been identified as the major mechanisms of Boraflex degradation. The surveillance coupons were in a relatively high flow area. The flow was high enough that the installation of the coupons in 1988 was difficult. The "flimsiness" of the coupons likely resulted in seams which opened, allowing for higher than normal water exchange rate. This would account for the large areas of wash-out observed in the full length coupons. In contrast, the short set coupon showed very little degradation. This coupon had a container which was constructed such that virtually no flow path existed. The flow of water in the rack panels is mainly due to heat convection and is relatively low, comparable to the flow experienced by the Boraflex in the short set coupon. This is another indication that the Boraflex in the rack is in good condition. The full length coupons have been shown to be a poor indicator of the rack Boraflex condition. Blackness testing is the most effective method of Boraflex surveillance since it "looks" at the actual rack Boraflex panels and does not rely upon secondary methods.

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ANALYSIS AND DISCUSSION

EPRI has collected data from its own test programs and actual plant measurements to study the shrinkage and gap phenomena in Boraflex panels (Reference 5). They have used this database to develop methods for quantifying the reactivity effects of gaps in Boraflex. Their research has determined that small (4") gaps have minimal effects on the reactivity state of SFP racks. EPRI report TR-101986 describes a method of quantifying Boraflex gap reactivity effects by modeling a rack system assuming that each panel develops a gap of four inches. The EPRI KENO5A analysis predicts a reactivity change (Δk_{eff}) of 0.04. A similar analysis using a MONK model of the Palisades Region II rack was performed because the Palisades Region II rack has less neutron poison than that used in the EPRI analysis and assemblies of lower enrichment are stored in the Palisades rack (Reference 6). The MONK analysis calculated a reactivity change of approximately 0.02 for five inches of gap in each of the Boraflex panels in Region II. This is significant because the Technical Specifications basis criticality analysis for SFP Region II calculates a k_{eff} of 0.9155 including all the uncertainties. Thus the Technical Specifications criticality limit has sufficient margin to absorb the effects of up to five inches of gap per Boraflex panel.

The maximum amount of gap detected by blackness testing in any Palisades Boraflex panel was 1.9" as a result of three gaps in cell MW-33. This amount of gap becomes 2.3" with the addition of 20% measurement uncertainty reported by Holtec (Reference 4). A conservative approach would be to take the maximum gap of 2.3" and apply it to each of the Boraflex panels in Region II, tested or untested. The MONK analysis has shown that there is margin in the Region II design basis criticality analysis for up to five inches of gap in each panel. Thus, assuming that 2.3" of gap exists in each Region II panel, this case still results in k_{eff} less than 0.95 and the Region II Technical Specifications requirement of five percent subcritical margin is met.

The condition of the Boraflex in the Region II cells tested should be a good representation of Boraflex condition in the remaining Region II cells. All of the Boraflex panels with more than one gap were located in close proximity to the accelerated exposure region. The cell containing the panel with the maximum amount of gap was also in the accelerated exposure region. The cells tested in the area of longest radiation exposure did not exhibit this condition. This result agrees with the EPRI finding that the amount of exposure is a major contributor to Boraflex degradation. The remaining Region II cells have received less radiation than either of these two areas. Thus, the Boraflex panels not tested should not exhibit any Boraflex degradation significantly greater than that seen in the accelerated exposure region. The flow characteristics in the cells which were not tested in Region II are not significantly different from those in the areas tested, therefore, the contribution of Boraflex degradation from water flow should be similar. If the results of the Blackness Test are extrapolated to the rest of Region II, the Boraflex panels in the cells which were not tested should not be degraded worse than the cells which were blackness tested.

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Other factors also suggest that the Palisades Boraflex is in good overall condition and fully capable of performing its criticality control function. The condition of the surveillance coupons is not indicative of the industry experience with Boraflex. To date, plants with Boraflex in their Region II racks have not experienced major degradation in the form of large gaps or significant shrinkage. Plants which have similar Region II racks as Palisades have not observed major degradation based upon blackness testing results (e.g., Millstone 3, South Texas Project, Turkey Point). Another indicator of the condition of Boraflex in the rack is the historical silica level in the SFP. Silica is a byproduct of the process which occurs when Boraflex is exposed to a radiation field. The silica is "washed" out of the rack and dissolves in the SFP water. SFP silica concentration is proportional to the amount of Boraflex degradation in the rack. The silica levels in the Palisades SFP water have historically been in the range of 1 - 4 ppm. This is within the range of other plants utilizing Boraflex. Palisades SFP silica concentration elevates during DFS activities as the SFP boron concentration level is raised by adding borated water from T-58 and allowing it to evaporate. Silica concentrates at approximately the same rate since T-58 water contains silica in the range of 2-3 ppm.

CONCLUSIONS

The overall condition of the SFP Region II Boraflex is considered to be very good and fully capable of performing its intended criticality control function. The movement of fuel assemblies into Palisades SFP Region II can once again be controlled by the burnup versus enrichment curve in Technical Specifications with a fresh fuel enrichment equivalency value of 1.5 weight percent. Reactor Engineering recommends that the Boraflex surveillance be changed to periodic blackness testing at an appropriate interval which will be based upon the known condition of the rack Boraflex and industry experience.