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October 31, 2016

AEP-NRC-2016-80
10 CFR 50, Appendix A
10 CFR 50.54(f)

Docket Nos.: 50-315
50-316

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555-0001

Donald C. Cook Nuclear Plant, Units 1 and 2
RESPONSE TO NUCLEAR REGULARTORY COMMISSION GENERIC LETTER 2016-01:
MONITORING OF NEUTRON-ABSORBING MATERIALS IN SPENT FUEL POOLS

By Generic Letter (GL) 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated April 7, 2016, the Nuclear Regulatory Commission requested that nuclear power plant licensees submit information, or provide references to previously docketed information, which demonstrates that credited neutron-absorbing materials in the spent fuel pool (SFP) of power reactors and the fuel storage pool, reactor pool, or other wet locations designed for the purpose of fuel storage, as applicable, for non-power reactors, are in compliance with the licensing and design basis, and with applicable regulatory requirements; and that there are measures in place to maintain this compliance.

The purpose of this letter is to provide Indiana Michigan Power Company's (I&M), licensee for Donald C. Cook Nuclear Plant (CNP), Unit 1 and Unit 2 response. I&M has been determined to be a Category 4 licensee in accordance with GL 2016-01. As a Category 4 licensee for CNP, information on the neutron absorber material, criticality analysis of record and neutron absorber monitoring program is requested depending on the type of neutron absorber material present and credited in the SFP. I&M credits Boral for the SFP and therefore is required to provide information in the following areas: Item (1), Item (2) except for (b)(iii), and Item (4). Enclosure 1 to this letter provides an affirmation statement. Enclosure 2 to this letter provides the requested information for CNP, Unit 1 and Unit 2.

This letter contains no new commitments. Should you have any questions, please contact Mr. Michael K. Scarpello, Regulatory Affairs Manager, at (269) 466-2649.

Sincerely,

Quinton S. Lies

Quinton S. Lies
Site Vice President

A158
NRR

DB/mll

Enclosures:

1. Affirmation
2. Response to Nuclear Regulatory Commission Generic Letter 2016-01

c: R. J. Ancona, MPSC
A. W. Dietrich, NRC, Washington, D.C.
MDEQ – RMD/RPS
NRC Resident Inspector
C. D. Pederson, NRC, Region III
A. J. Williamson, AEP Ft. Wayne, w/o enclosures

Enclosure 1 to AEP-NRC-2016-80

AFFIRMATION

I, Q. Shane Lies, being duly sworn, state that I am the Site Vice President of Indiana Michigan Power Company (I&M), that I am authorized to sign and file this request with the U. S. Nuclear Regulatory Commission on behalf of I&M, and that the statements made and the matters set forth herein pertaining to I&M are true and correct to the best of my knowledge, information, and belief.

Indiana Michigan Power Company

Quinton S. Lies

Q. Shane Lies
Site Vice President

SWORN TO AND SUBSCRIBED BEFORE ME

THIS 31 DAY OF October, 2016

Danielle Burgoyne
Notary Public

My Commission Expires 04-04-2018

DANIELLE BURGOYNE
Notary Public, State of Michigan
County of Berrien
My Commission Expires 04-04-2018
Acting in the County of Berrien

Enclosure 2 to AEP-NRC-2016-80

RESPONSE TO NUCLEAR REGULATORY COMMISSION GENERIC LETTER 2016-01

In Generic Letter (GL) 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated April 7, 2016, the Nuclear Regulatory Commission (NRC) requested that nuclear power plant licensees submit information, or provide references to previously docketed information, which demonstrates that credited neutron-absorbing materials in the spent fuel pool (SFP) of power reactors and the fuel storage pool, reactor pool, or other wet locations designed for the purpose of fuel storage, as applicable, for non-power reactors, are in compliance with the licensing and design basis, and with applicable regulatory requirements; and that there are measures in place to maintain this compliance.

As delineated in GL 2016-01, the NRC will accept responses based on categorization. Indiana Michigan Power Company (I&M) has determined that the Donald C. Cook Nuclear Plant (CNP) does not meet Category 1, Category 2, or Category 3 therefore falls into Category 4. As CNP's spent fuel pool rack neutron absorbing material type is Boral, Table 1 of GL 2016-01 requests that the addressee provide responses to Item (1), Item (2) except for (b)(iii), and Item (4).

NRC Item 1

1) Describe the neutron-absorbing material credited in the spent fuel pool (SFP) nuclear criticality safety (NCS) analysis of record (AOR) and its configuration in the SFP, including the following:

   a) manufacturers, dates of manufacture, and dates of material installation in the SFP;

   b) neutron-absorbing material specifications, such as:

      i) materials of construction, including the certified content of the neutron-absorbing component expressed as weight percent;

      ii) minimum certified, minimum as-built, maximum as-built, and nominal as-built areal density of the neutron-absorbing component; and

      iii) material characteristics, including porosity, density, and dimensions;

   c) qualification testing approach for compatibility with the SFP environment and results from the testing;

   d) configuration in the SFP, such as:

      i) method of integrating neutron-absorbing material into racks (e.g., inserts, welded in place, spot welded in place, rodlets); and

      ii) sheathing and degree of physical exposure of neutron-absorbing materials to the SFP environment;

   e) current condition of the credited neutron-absorbing material in the SFP, such as:

i) estimated current minimum areal density;

ii) current credited areal density of the neutron-absorbing material in the NCS AOR; and

iii) recorded degradation and deformations of the neutron-absorbing material in the SFP (e.g., blisters, swelling, gaps, cracks, loss of material, loss of neutron-attenuation capability).

I&M Response

1) The CNP high density SFP storage racks consist of 23 free-standing poisoned rack modules positioned with a prescribed and geometrically controlled gap between them and contain 3,613 storage cells. The cells are composed of Boral absorber panels positioned between an 8.75 inch inside diameter, 0.075 inch thick inner stainless steel box, and a 0.035 inch stainless steel sheath which forms the wall of the adjacent cells. The Boral absorber panels are nominally 7.50 inches wide, 144 inches long, and 0.101 inches thick with a nominal B-10 areal density of 0.0345 g-B^{10}/cm^2. The manufacturing tolerance limit in B-10 content is ± 0.0045 g-B^{10}/cm^2 which assures that at any point, the minimum B-10 areal density will not be less than 0.030 g-B^{10}/cm^2. The fuel assemblies are normally located in the center of each storage cell on a nominal lattice spacing of 8.97 inches.

Reactivity effects of manufacturing tolerances were included in the NCS AOR and are summarized as follows:

- Boron Loading Tolerances: Nominal vendor manufacturing for B-10 areal density is 0.0345 ± 0.0045 g-B^{10}/cm^2 which ensures that at any point, the minimum B-10 areal density will not be less than 0.030 g-B^{10}/cm^2. Calculations result in an incremental reactivity uncertainty of + 0.00614 Δk.

- Boral Width Tolerance: The nominal vendor manufacturing for the Boral panel width is 7.50 ± 0.06 inches. Calculations result in an incremental reactivity uncertainty of + 0.0009 Δk.

- Cell Lattice Spacing Tolerance: The nominal vendor manufacturing for the inner stainless steel box dimension is 8.75 ± 0.04 inches. Calculations result in an incremental reactivity uncertainty of + 0.0015 Δk.

- Stainless Steel Thickness Tolerance: The nominal stainless steel thickness is 0.075 ± 0.005 inches for the inner stainless steel box and 0.035 ± 0.003 inches for the Boral cover plate. Calculations result in an incremental reactivity uncertainty of + 0.0009 Δk.

The CNP NCS AOR for the high density storage racks was submitted via letter from E. E. Fitzpatrick, Vice President, I&M, to NRC Document Control Desk, "Donald C. Cook Nuclear Plant Units 1 and 2, License Nos. 50-315 and 50-316, Docket Nos. DPR-58 and

DPR-74, SFP Reracking Technical Specification Changes," AEP:NRC:1146, dated July 26, 1991, (Reference 1) and approved via letter from U. S. NRC to Mr. E. E. Fitzpatrick, Vice President, I&M, RE: "Donald C. Cook Nuclear Plant, Units 1 and 2 – Amendment Nos. 169 and 152 to Facility Operating License Nos. DPR-58 and DPR-74 (TAC Nos. M80615 and M80616)," dated January 14, 1993, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML021060153), (Reference 2).

The NCS AOR for the high density storage racks assures that the effective neutron multiplication factor (k_{eff}) is equal to or less than 0.95 with the racks fully loaded with fuel of the highest anticipated reactivity, and flooded with unborated water at the temperature within the operating range corresponding to the highest reactivity. The maximum calculated reactivity includes a margin for uncertainty in reactivity calculations including mechanical tolerances. All uncertainties are statistically combined, such that the final k_{eff} will be equal to or less than 0.95 with a 95% probability at a 95% confidence level.

a) Manufacturers:

Design/Licensing/Material Procurement: Holtec International, Cherry Hill, NJ
Fabrication of Rack Modules: U.S Tool & Die Inc., Pittsburgh, PA
Manufacturer (Boral): AAR Brooks & Perkins, Livonia, MI
Manufacturer (Aluminum): Reynolds Metals Company, Louisville, KY
Manufacturer (Aluminum Extrusions): Spectrulite Consortium, Madison, IL

Dates of Manufacturer: 1992

Dates of material installation in the SFP: 1993

b)

i) The principle construction materials for the new racks are SA240-Type 304 stainless steel sheet and plate stock and SA564-630 (precipitation hardened stainless steel) for the adjustable support spindles. The neutron absorber material is a boron carbide and 1100 alloy aluminum-composite called "Boral". It consists of homogenized particulate mixture of boron carbide (B_4C) and aluminum powder sandwiched between thin aluminum sheets using a patented hot rolling process. Boral is a patented product of AAR Brooks & Perkins and is the neutron-absorbing material used in the CNP high density storage racks.

The B_4C and 1100 alloy chemical composition specifications are as follows:

B_4C (weight percent) - Specifications	
Total Boron	70.0 min.
Total B + C	94.0 min.
B-10 isotopic content in natural boron	18.0
Boric oxide	3.0 max.
Iron	2.0 max.

Aluminum (type 1100) (weight percent) - Specifications

Aluminum	99.00 min.
Silicone and Iron	1.00 max.
Copper	0.05-0.20 max.
Manganese	0.05 max.
Zinc	0.10 max.
Others (each)	0.15 max.

The certified chemical analysis of the as-manufactured B_4C and aluminum is as follows:

Boral (B_4C) (weight percent) – Material Content

Lot Number	M-92	M-93	M-94	M-95	M-96	M-97	M-98
B-10 (isotopic wt %)	18.56	18.57	18.58	18.58	18.57	18.57	18.59
Total Boron	77.2	77.5	77.4	77.3	76.9	77.3	76.2
Total B + C	96.45	95.85	98.26	98.24	97.27	97.73	98.27
B-10 content	20.04	20.05	20.06	20.06	20.05	20.05	20.07
Boric Oxide	1.46	1.48	1.10	0.91	1.10	0.93	0.74
Iron	0.015	0.15	0.21	0.19	0.22	0.19	0.57
Fluoride (≤ ppm)	3	3	3	3	3	1	3
Chloride (=ppm)	7	10	6	4	8	10	8

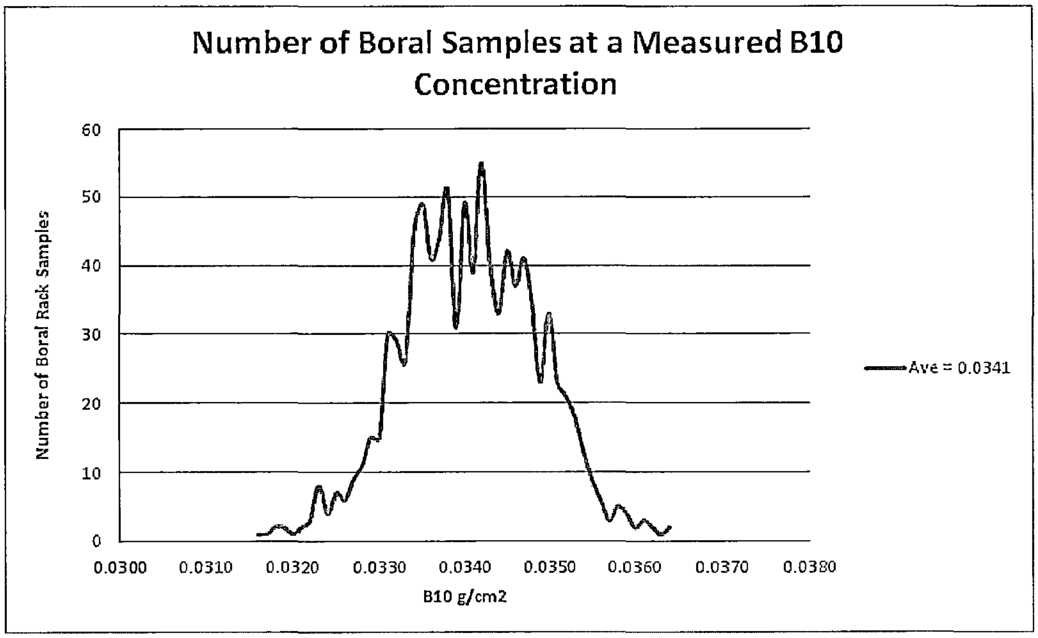
Aluminum (type 1100) (weight percent) – Material Content

Lot Number	9898	9987	0057
Aluminum	99.77	99.74	99.82
Iron as Fe	0.13	0.14	0.12
Silicon as Si	0.04	0.04	0.02
Copper	trace	trace	trace
Manganese	trace	0.01	trace
Magnesium	trace	trace	trace
Chromium	trace	trace	trace
Nickel	0.01	0.01	trace
Zinc	0.02	0.03	0.02
Titanium	0.01	0.01	0.01
Gallium	0.02	0.02	0.01

ii) A total of 978 Boral neutron-absorbing material samples were taken of the CNP high density storage racks. The results are as follows and presented in Figure 1:

Minimum certified: Holtec specifications were a nominal areal density of 0.0345 g-B^{10}/cm^2 with a tolerance limit of ± 0.0045 g-B^{10}/cm^2.
Minimum certified as-built: 0.0305 g-B^{10}/cm^2
Maximum certified as-built: 0.0375 g-B^{10}/cm^2
Nominal as-built of 978 samples: 0.0341 g-B^{10}/cm^2

Figure 1



iii) The Boral neutron absorber consists of homogenized particulate mixture of boron carbide (B_4C) and aluminum powder sandwiched between thin aluminum (Al) sheets using a patented hot rolling process. The hot rolling process compresses the Al/B_4C powders into a cermet with a density about 90-95% of the theoretical density of the composite. Most of the porosity of the core is in the form of small voids in the cermet, but some is interconnected, forming micro-pathways into the core. There have been occasional occurrences of blisters forming in the cladding of Boral in spent fuel pool applications. Blisters can form from water which penetrates into the core through the interconnected porosity and reacts with exposed aluminum powder surfaces in the core to form aluminum oxide, Al_2O_3, and hydrogen. Usually the hydrogen gas escapes from the core through the porosity; however, in some cases the hydrogen becomes trapped in the void space. If enough hydrogen accumulates, the pressure causes the clad to separate slightly from the core, causing a blister. The blisters are generally no larger than the diameter of a quarter and no more than 1/8 inch high. There have been numerous test and evaluations performed on blisters by the Boral manufacturer, utilities, and other organizations which have found the Boral core under blisters remains intact with no reduction in the core's ability to absorb thermal neutrons.

The Boral contains a nominal vendor manufacturing for B-10 areal density of 0.0345 ± 0.0045 g-B^{10}/cm^2. The Boral (B_4C and aluminum clad) is affixed to the sides of the individual stainless steel inner rack cells using a stainless steel sheath. The Boral has a width of 7.5 ± 0.06 inches and a thickness of 0.101 ± 0.005 inches and spans axially 144 inches.

c) The materials used in the construction of the CNP high density storage racks have an established physical, chemical, and radiological compatibility of in-pool usage. Their

physical, chemical and radiological compatibility with the pool environment is an established fact at this time. Austenitic stainless steel (304) is widely used in nuclear power plants.

Boral is the thermal neutron absorbing material composed of boron carbide and 1100 alloy aluminum. Boron carbide is a compound having high boron content in a physically stable and chemical inert form. The 1100 alloy aluminum is a light-weight metal with high tensile strength which is protected from corrosion by a highly resistant oxide film developed from exposure to water. This film prevents the loss of metal from general corrosion or pitting corrosion and remains stable between a pH range of 4.5 to 8.5. The two materials, boron carbide and aluminum, are chemically compatible and ideally suited for long-term use in the radiation, thermal, and chemical environment of a spent fuel pool. The racks are also constructed to allow for full venting of the Boral space as the passivation process of Boral in an aqueous environment results in the generation of hydrogen gas that could cause swelling of Boral to occur. Passivation is a chemical treatment of metal to form a protective oxide film over the material. This same effect occurs naturally over a short period of time (days or weeks) for aluminum, after being introduced to an acidic environment, such as the spent fuel pool. The current spent fuel racks were installed at CNP in the early 1990's.

The water in the SFP is included in the CNP Primary and Secondary Water Chemistry Control Program. Aluminum alloys are susceptible to cracking from stress corrosion and intergranular attack in corrosive environments with high chloride concentrations. This aging effect is prevented by the Primary and Secondary Water Chemistry Program, which controls SFP water quality by maintaining chemistry levels (i.e., chlorides, fluorides, and sulfates) within acceptable limits. Therefore, the Primary and Secondary Water Chemistry Control Program is adequate to manage this aging effect for aluminum, such that the Boral will continue to maintain its component intended function.

The Electric Power Research Institute (EPRI) Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Application (Document number 1019110 dated November 2009) provides summaries of Boral qualification testing and surveillance coupon experience for Boral manufactured by AAR Brooks and Perkins. The conclusion states and noting that Region 1 racks refer to flux trap design racks that are not installed at CNP:

"While BORAL is subject to both generalized corrosion and local corrosion in spent fuel pools, the overall performance to date has been acceptable. This conclusion is based on the data from utility coupon surveillance programs which have shown no reduction in boron-10 loading due to these effects.

"Similarly, in-pool blistering of BORAL has, to date, provided to be primarily an esthetic effect; however, the potential effects on fuel assembly clearance and the reactivity state of Region 1 racks have been noted. In addition, it has been noted that, in a few instances, rack cell wall deformation has occurred making it difficult to remove fuel. With plant life extension now the norm at most LWRs [Light Water Reactors] in the U. S., some BORAL, which originally had a design service life of 40 years will be in service more than 60 years. This suggests a prudent course of

continued vigilance and surveillance so that onset of any degradation can be detected early and appropriate mitigation measures applied."

EPRI is also conducting several notable projects. The first is a Boral coupon accelerated corrosion test program initiated in 2013 and continue until 2018. The objective is to simulate and increase understanding of long term performance and potential corrosion of Boral in spent fuel pools. Tests are being conducted on more than 200 coupons placed in test baths and conducted at elevated temperatures to accelerate corrosion. To date, a number of coupons have been pulled and the most important finding of the project was that the removed coupons showed no sign of degradation. Pulled coupons are re-inserted and will be re-analyzed at the end of year five. The second is a comparative analysis using Zion Power Station's actual SFP rack panels. The objective is to determine the condition of real panels that reside in the spent fuel pool over 20 years and to evaluate adequacy of monitoring approaches. The project was started in 2014 and included in-situ measurements of spent fuel rack panels (BADGER testing), Boral coupon collection, and removal of some Boral panels from the spent fuel pool racks. The panels were in good condition with general corrosion, flow patterns, some pitting but no evidence of significant degradation. There was very good agreement between panel and coupon areal density values. The BADGER analysis is ongoing with some concerns related to discrepancies between BADGER and panel results. A final EPRI report on Zion coupons, in-situ measurements and panel analyses is expected in 2017.

On October 31, 2003, I&M submitted a license renewal application (LRA), "Donald C. Cook Nuclear Plant Units 1 and 2, Docket No. 50-315 and 50-316, Application for Renewed Operating Licenses," (Reference 3), requesting renewal of the CNP Unit 1 (License No. DRP-58) and Unit 2 (License No. DRP-74) operating license for a period of 20 years beyond the October 25, 2014, and December 23, 2017, expiration dates, respectively. The Safety Evaluation Report (SER) issued to CNP and documented under NUREG-1831, "Safety Evaluation Report Related to the License Renewal of the Donald C. Cook Nuclear Plant, Units 1 and 2," (Reference 4) Section 3.0.3.3.3, related to the license renewal of the CNP Units 1 and 2, made the following conclusion when addressing the CNP Boral Surveillance Program:

"Based on its review of the applicant's Boral Surveillance Program, the staff finds that the program addresses the 10 program elements defined in BTP RLSB-1 in Appendix A.1 to the SRP-LR, and that the program will adequately manage the aging effects for which it is credited. The staff also reviewed the UFSAR Supplement for this AMP and finds that it provides an adequate summary description of the program, as required by 10 CFR 54.21(d.)

"Therefore, based on its review, the staff finds that the applicant has demonstrated that the Boral Surveillance Program will adequately manage the effects of aging so that the intended functions of SC will be maintained consistent with the CLB for the period of extended operation, as required by 10 CFR 54.21(a)(3)."

NUREG-1831 Section 3.3.2.2.10, related to reduction of neutron-absorbing capacity and loss of material due to general corrosion, made the following conclusion:

> "The applicant used the Boral Surveillance Program (CNP AMP B.1.3) and the Water Chemistry Control – Primary and Secondary Water Chemistry Control Program (CNP AMP B.1.40.1) to manage neutron-absorbing capacity and loss of material. Sections 3.0.3.3.3 and 3.0.3.2.15 of this SER, respectively, document the staff's evaluation of these programs. The staff finds the use of the Boral Surveillance and Water Chemistry Control Programs acceptable for mitigating this aging affect. The staff finds that the applicant has demonstrated that it will adequately manage the effects of aging so that the intended functions will be maintained consistent with the CLB during the period of extended operation, as required by 10 CFR 54.21(a)(3)."

NUREG-1831 Section 3.3.2.3.1, related to the SFP poison's material aluminum, made the following statement with respect to I&M response to RAI 3.3.2.1.1-1:

> "By letter dated June 8, 2004, the applicant stated that the water in the SFP is included in the Primary and Secondary Water Chemistry Control Program (not the Auxiliary Systems Water Chemistry Control Program). In LRA Section B.1.40.1, the applicant identified the Primary and Secondary Water Chemistry Control Program as managing the cracking of components. Table 3.3.2-1 of the LRA (page 3.3-32) conservatively identifies cracking as an AERM since aluminum alloys are susceptible to cracking from stress corrosion and IGA in corrosive environments with high chloride concentrations. The Primary and Secondary Water Chemistry Program, which controls SFP water quality by maintaining chemistry levels (i.e., chlorides, fluorides, and sulfates) within acceptable limits, prevents this aging effect. Therefore, the Primary and Secondary Water Chemistry Control Program is adequate to manage this aging effect for aluminum, such that the boral will continue to maintain its component intended function through the period of extended operation. Based on its review, the staff finds the applicant's response to RAI 3.3.2.1.1-1 acceptable because the response clarifies water chemistry control of the SFP and aging management of its related components susceptible to cracking; therefore, the staff's concerns described in RAI 3.3.2.1.1-1 are resolved.
>
> "On the basis of its review of the information provided in the LRA, the staff finds that the applicant has identified appropriate AMPs for managing the aging effect of the SFP system component type that are addressed in this section. In addition, the staff finds the program descriptions in the UFSAR supplement acceptable."

NUREG-1831 Section 3.3.2.3.1 concludes as follows:

> "On the basis of its review, the staff concludes that the applicant has adequately identified the aging effects, and the AMPs credited with managing the aging effects, for the SFP system components identified in this section. The intended functions will be maintained consistent with the CLB for the period of extended operation, as required by 10 CFR 54.21(a)(3).

The staff also reviewed the applicable UFSAR Supplement program description and concludes that the UFSAR Supplement adequately describes the AMPs credited with managing aging in these components, as required by 10 CFR 54.21(d)."

d)

i) The design objective calls for installing Boral with minimal surface loading. This is accomplished by forming a "picture frame sheathing". This stainless steel sheathing is 0.035 inches thick and is made to precise dimension such that the offset is 0.005 inches to 0.010 inches greater than the thickness of the Boral. This guarantees that the Boral will not be subject to surface compression. The Boral panel material is placed within the customized flat depression region of the sheathing, which is next laid on a side of a 0.075 inch thick stainless steel box manufactured to an inside dimension of 8.75 inches. The sheathing is then accurately positioned on the side of the box and flanges on the sheathing (on all four sides) are attached to the box using skip welds. The edges of the sheathing and the box are welded together to form a smooth edge. The box, with integrally connected sheathing, is then arranged and welded in a checkerboard array to form individual rack modules of varying sizes.

ii) The Boral neutron-absorbing material is sandwiched between the rack cells stainless steel box wall (0.075 inches thick) and an outer stainless steel sheath (0.035 inches thick). The gap between the box wall and the sheath is 0.109 inches allowing for the 0.101 inch thick Boral absorber. The passivation process of Boral in an aqueous environment results in the generation of hydrogen gas. If the generation rate of hydrogen is too rapid, then swelling of Boral may occur. AAR Brooks & Perkins, the Boral manufacturer, has instituted strict monitoring of the chemistry of boron carbide used in the manufacturing of Boral minimizing impurities such as sodium hydroxide and boron oxide in the boron carbide powder to ensure that no swelling will occur. Studies have shown that hydrogen generation is a strong function of these so-called impurities.

Industry experience has found that venting of the racks is a design feature that can help prevent a key aging effect (bulging). Venting of the sheathing in the storage racks allows the escape of corrosion-generated gas thus helpful in preventing bulging of the storage racks. The CNP SFP racks allow for full venting of the Boral absorber space and are exposed to SFP water. A vented design of Boral sheathings will prevent the corrosion generated hydrogen from building up pressures that could cause distortion of the fuel cells and the program of Boral surveying will ensure that timely corrective actions could be taken should its degradation be detected.

e) Results from six coupon tests from 1994 through 2015 have shown no decrease in the Boral areal density beyond the measurement acceptance criteria of less than 5% and no recorded degradation and/or deformations of the neutron-absorbing coupons. Based on these results, no degradation or loss of the current credited neutron-absorbing material in the spent fuel pool racks is occurring and the Boral panels continue to perform their intended function.

i) The 978 Boral neutron-absorbing material samples points taken of the CNP high density storage racks had a minimum, maximum, and nominal as-built areal density of 0.0305 g-B^{10}/cm^2, 0.0375 g-B^{10}/cm^2, and 0.0341 g-B^{10}/cm^2 respectively. Results from CNP Boral Surveillance Program's testing of coupons provide no indication of loss of the Boral's neutron absorbing material. Therefore, the estimated current minimum areal density used in the NCS AOR is the same as when the material was fabricated and installed in the spent fuel pool.

ii) The CNP NCS AOR used a nominal areal density of 0.0345 ± 0.0045 g-B^{10}/cm^2 which ensures that at any point, the minimum B-10 areal density will not be less than 0.0300 g-B^{10}/cm^2. The reactivity effect of the ± 0.0045 g-B^{10}/cm^2 tolerance uncertainty is therefore accounted for in the analysis.

iii) There is no recorded degradation, deformations, or loss of neutron-attenuation capability of the neutron-absorbing material in the SFP. CNP's Boral Surveillance Program is used for testing of coupons to monitor and demonstrate performance of the neutron-absorbing material Boral used in the racks. The Boral Surveillance Program assesses parameters such as blisters, swelling, gaps, cracks, loss of material and loss of neutron-attenuation capability using surveillance coupons. Results taken from six coupon tests under the program are presented in the Item 4(b) response and no degradation, deformations, or loss of neutron-attenuation capabilities are noted.

NRC Item 2

2) Describe the surveillance or monitoring program used to confirm that the credited neutron-absorbing material is performing its safety function, including the frequency, limitations, and accuracy of the methodologies used.

   a) Provide the technical basis for the surveillance or monitoring method, including a description of how the method can detect degradation mechanisms that affect the material's ability to perform its safety function. Also, include a description and technical basis for the technique(s) and method(s) used in the surveillance or monitoring program, including:

      i) approach used to determine frequency, calculations, and sample size;

      ii) parameters to be inspected and data collected;

      iii) acceptance criteria of the program and how they ensure that the material's structure and safety function are maintained within the assumptions of the NCS AOR;

      iv) monitoring and trending of the surveillance or monitoring program data; and

      v) industry standards used.

b) For the following monitoring methods, include these additional discussion items.

i) If there is visual inspection of inservice material:

(1) describe the visual inspection performed on each sample; and

(2) describe the scope of the inspection (i.e., number of panels or inspection points per inspection period).

ii) If there is a coupon-monitoring program:

(1) provide a description and technical basis for how the coupons are representative of the material in the racks. Include in the discussion the material radiation exposure levels, SFP environment conditions, exposure to the SFP water, location of the coupons, configuration of the coupons (e.g., jacketing or sheathing, venting bolted on, glued on, or free in the jacket, water flow past the material, bends, shapes, galvanic considerations, and stress-relaxation considerations), and dimension of the coupons;

(2) provide the dates of coupon installation for each set of coupons;

(3) if the coupons are returned to the SFP for further evaluation, provide the technical justification for why the reinserted coupons would remain representative of the materials in the rack; and

(4) provide the number of coupons remaining to be tested and whether there are enough coupons for testing for the life of the SFP. Also provide the schedule for coupon removal and testing.

iii) N/A

iv) If in-situ testing with a neutron source and detector is used (e.g., BADGER testing, blackness testing):

(1) describe the method and criteria for choosing panels to be tested and include whether the most susceptible panels are chosen to be tested. Provide the statistical sampling plan that accounts for both sampling and measurement error and consideration of potential correlation in sample results. State whether it is statistically significant enough that the result can be extrapolated to the state of the entire pool;

(2) state if the results of the in-situ testing are trended and whether there is repeat panel testing from campaign to campaign;

(3) describe the sources of uncertainties when using the in-situ testing device and how they are incorporated in the testing results. Include the uncertainties outlined in the technical letter report titled "Initial Assessment of Uncertainties

Associated with BADGER Methodology," September 30, 2012, (ADAMS Accession No. ML12254A064). Discuss the effect of rack cell deformation and detector or head misalignment, such as tilt, twist, offset, or other misalignments of the heads and how they are managed and accounted for in the analysis; and

(4) describe the calibration of the in-situ testing device, including the following:

(a) describe how the materials used in the calibration standard compare to the SFP rack materials and how any differences are accounted for in the calibration and results;

(b) describe how potential material changes in the SFP rack materials caused by degradation or aging are accounted for in the calibration and results; and

(c) if the calibration includes the in-situ measurement of an SFP rack "reference panel," explain the following:

(i) the methodology for selecting the reference panel(s) and how the reference panels are verified to meet the requirements;

(ii) whether all surveillance campaigns use the same reference panel(s); and

(iii) if the same reference panels are not used for each measurement surveillance, describe how the use of different reference panels affects the ability to make comparisons from one campaign to the next.

I&M Response

2) The function of preventing criticality by storage rack geometry in the spent fuel pool is completed by the racks and the neutron absorber (Boral). The spent fuel pool Boral racks received an aging management review in support of the LRA (Reference 3) and SER (Reference 4) for plant life extension. Aging management effects include change in material properties, cracking, and loss of material. The CNP specific aging management program (AMP), Boral Surveillance and Water Chemistry Control programs, and SFP Maintenance Rule, will effectively manage any reduction of neutron absorbing capacity or loss of material due to general corrosion.

The CNP Boral Surveillance Program was established to manage aging of the Boral neutron absorber in the spent fuel pool. The Boral Surveillance Program monitors changes in neutron attenuation, dimensional measurements, and weight and specific gravity of representative coupon samples. The Boral coupon samples are located in the spent fuel pool, surrounded by freshly discharged fuel assemblies, to monitor performance of the absorber material without disrupting the integrity of the storage system. Over the duration of the coupon testing program, the coupons accumulate more radiation dose than the

expected lifetime dose of the functional Boral panels in the storage cells. Coupons are removed on a prescribed schedule and certain physical and chemical properties are measured. The periodic inspection measurements and analysis are compared to values of previous measurements and analysis to provide data for trend analysis. From this data, the stability and integrity of Boral in the storage cells are assessed.

The Boral coupon parameters that would be monitored or inspected are neutron attenuation, dimensions (length, width, and thickness), weight, and specific gravity. These program elements are considered acceptable because experience has shown that Boral degradation in the SFP environment occurs slowly and can be detected in the early stages. The measurements of neutron attenuation, physical distortion, and weight change would detect coupon degradation that would precede a loss of functionality in the Boral panels (neutron absorption and fuel assembly spacing.) Moreover, unacceptable coupon results would initiate an engineering evaluation and, if considered necessary, direct testing of the storage racks (i.e. blackness testing). Adverse conditions are evaluated as part of the Corrective Action Program. In addition, the Boral Surveillance Program corrective actions include an investigation and engineering evaluation if the coupon acceptance criteria are not met. Additional testing of the storage racks may be performed based on the engineering evaluation.

The Primary and Secondary Water Chemistry Control Program's objective is to mitigate damage caused by corrosion and stress corrosion cracking. This Water Chemistry Program relies on monitoring and control of water chemistry based on EPRI guidelines which effectively mitigates aging effects by managing the loss of aluminum in the Boral due to corrosion.

The CNP Boral Surveillance Program and Water Chemistry Control Program were reviewed by NRC as part of the review of the CNP License Renewal Application to renew the operating licenses for CNP, Units 1 and 2 (Reference 3).

NUREG-1831 Section 3.0.3.3.3 made the following conclusion when addressing CNP's Boral Surveillance Program and its use of the Corrective Action Program:

> "Section B.0.3 of the LRA discusses the corrective actions, which are common to all AMPs. The applicant stated that the corrective actions are consistent with the GALL Report. The Boral Surveillance Program description provides additional information about the corrective actions for that program. The applicant stated that, in addition to implementing the CNP Corrective Action Program, the Boral Surveillance Program corrective actions will include an investigation and engineering evaluation if the coupon acceptance criteria are not met. Additional testing, such as blackness testing of the storage racks, may be performed based on the engineering evaluation."

NUREG-1831 Section 3.0.3.3.3 made the following conclusion when addressing the CNP Boral Surveillance Program:

> "Based on its review of the applicant's Boral Surveillance Program, the staff finds that the program addresses the 10 program elements defined in BTP RLSB-1 in Appendix A.1 to the SRP-LR, and that the program will adequately manage the aging effects for

which it is credited. The staff also reviewed the UFSAR Supplement for this AMP and finds that it provides an adequate summary description of the program, as required by 10 CFR 54.21(d.)

"Therefore, based on its review, the staff finds that the applicant has demonstrated that the Boral Surveillance Program will adequately manage the effects of aging so that the intended functions of SCs will be maintained consistent with the CLB for the period of extended operation, as required by 10 CFR 54.21(a)(3)."

NUREG-1831 Section 3.3.2.2.10, related to reduction of neutron-absorbing capacity and loss of material due to general corrosion, made the following conclusion:

"The applicant used the Boral Surveillance Program (CNP AMP B.1.3) and the Water Chemistry Control – Primary and Secondary Water Chemistry Control Program (CNP AMP B.1.40.1) to manage neutron-absorbing capacity and loss of material. Sections 3.0.3.3.3 and 3.0.3.2.15 of this SER, respectively, document the staff's evaluation of these programs. The staff finds the use of the Boral Surveillance and Water Chemistry Control Programs acceptable for mitigating this aging effect. The staff finds that the applicant has demonstrated that it will adequately manage the effects of aging so that the intended functions will be maintained consistent with the CLB during the period of extended operation, as required by 10 CFR 54.21(a)(3)."

NUREG-1831 Section 3.3.2.3.1, related to the SFP poison's material aluminum, made the following statement with respect to I&M response to Request for Additional Information (RAI) 3.3.2.1.1-1:

"By letter dated June 8, 2004, the applicant stated that the water in the SFP is included in the Primary and Secondary Water Chemistry Control Program (not the Auxiliary Systems Water Chemistry Control Program). In LRA Section B.1.40.1, the applicant identified the Primary and Secondary Water Chemistry Control Program as managing the cracking of components Table 3.3.2-1 of the LRA (page 3.3-32) conservatively identifies cracking as an AERM since aluminum alloys are susceptible to cracking from stress corrosion and IGA in corrosive environments with high chloride concentrations. The Primary and Secondary Water Chemistry Program, which controls SFP water quality by maintaining chemistry levels (i.e., chlorides, fluorides, and sulfates) within acceptable limits, prevents this aging effect. Therefore, the Primary and Secondary Water Chemistry Control Program is adequate to manage this aging effect for aluminum, such that the boral will continue to maintain its component intended function through the period of extended operation. Based on its review, the staff finds the applicant's response to RAI 3.3.2.1.1-1 acceptable because the response clarifies water chemistry control of the SFP and aging management of its related components susceptible to cracking; therefore, the staff's concerns described in RAI 3.3.2.1.1-1 are resolved.

"On the basis of its review of the information provided in the LRA, the staff finds that the applicant has identified appropriate AMPs for managing the aging effect of the SFP system component type that are addressed in this section. In addition, the staff finds the program descriptions in the UFSAR supplement acceptable."

The CNP SFP System Maintenance Rule (10 CFR 50.65) functions include the monitoring of the neutron absorption feature of the spent fuel pool storage racks. The storage rack geometry was determined to be a design feature inherent in the design of the geometry of the spent fuel pool storage racks. Monitoring of the neutron absorption feature ensures that the spent fuel pool remains in a subcritical configuration at all times.

a)

i) The coupon removal/evaluation schedule, based on vendor recommendations, is intended to allow coupons to accumulate more radiation dose than the expected lifetime dose for normal storage. Accelerated dose is accomplished by re-installing the coupon tree in a new location surrounded by freshly discharged fuel assemblies that have been among the higher specific power assemblies in the core. This allows for the monitoring of performance of the absorber material without disrupting the integrity of the storage system.

In accordance with plant procedures, surveillance coupons are typically removed for evaluation one or two months prior to a reactor refueling for either unit. At that time, the coupon tree is moved to a region where it will be surrounded by freshly discharged fuel assemblies upon completion of fuel off-load. This coupon tree relocation process was initiated at the time of the first fuel off-load following installation of the coupon tree and had been repeated for each coupon removal/evaluation, at a minimum. If future evaluations determine that dose acceleration is no longer required, coupon evaluations may continue without relocating the coupon tree.

In accordance with the Boral Surveillance Program procedure, the next coupon is scheduled to be removed prior to the end of 2020, and one of the remaining coupons will be removed every five years through the duration of wet storage. The five-year removal frequency is also based on vendor recommendations, and is further justified by the lack of coupon degradation noted to date. Periodicity of coupon removal may be adjusted depending on coupon inspection results.

NUREG-1831 Section 3.0.3.3.3 made the following conclusion when addressing CNP's Boral Surveillance Program and its Boral coupon removal and evaluation dates:

> "Regarding the schedule and past results, the applicant responded in the January 21, 2005, letter that coupon removal and evaluation dates are based on vendor recommendations intended to produce more radiation dose than the expected lifetime dose for normal storage. During the period of extended operation, the evaluations interval will be 5 years, which the applicant stated is recommended by the Boral vendor and supported by the coupon results. The staff reviewed results from coupons tested in 1994 and 2001 and confirmed that there were no significant changes in coupon dimensions, weight, density, or Boron-10 areal density."

ii) The parameters inspected and data collected was based on vendor recommendations. The vendor recommended coupon surveillance program is intended to monitor changes in physical properties of the Boral absorber material by performing the following measurements on a pre-planned schedule:

- Visual Observation and Photography,
  The coupons shall be examined visually with special attention to any edge or corner defects and to any discoloration or surface pitting that might exist. Color photographs of the coupons shall be obtained, using such magnification as may be desirable to clearly describe and document any defects that may be observed.

- Neutron Attenuation and (optional) Radiography,
  Neutron attenuation measurements provide a means of confirming that the neutron absorbing nuclide (Boron-10) is being retained in the Boral. The neutron attenuation measurements are compared with measurements on a reference standard Boral coupon. These measurements are an instrumental method of dry chemical analysis for Boron-10 content. The optional neutron radiography is intended to confirm the uniformity of boron distribution within the Boral and/or to identify areas where there might be a local reduction in boron concentrations. The optional wet chemical analysis, a gravimetric method for determining the B_4C content, may occasionally be performed on specimens cut from a surveillance coupon as an independent means of verifying the boron loading.

- Dimensional Measurements (length, width and thickness),
  The following measurements are made on the coupons at several locations: length with an accuracy of ± 0.04 inches, width with an accuracy of ± 0.02 inches, and thickness with an accuracy of ± 0.002 inches. Concurrent with the dimensional measurements, calibrated measuring instruments provide the capability to measure to an accuracy that meets or exceeds the Boral Surveillance Program specifications.

- Weight and Specific Gravity
  The weight of the coupons, before and after irradiation, and before and after drying should be measured with an accuracy of ± 0.5 percent. The weight gain is a measure of the extent of aluminum oxidation (corrosion) in the pool environment. Specific gravity (by immersion technique) should be obtained within ± 2 percent. Specific gravity is used to identify early indications of Boral degradation.

The most significant measurements taken are the Boral thickness used to monitor for swelling and neutron attenuation used to confirm the concentration of Boron-10 in the absorber material. The Boron-10 content of the coupon should not decrease more than 5% as determined by neutron attenuation. This is tantamount to a requirement for no loss in boron within the accuracy of the measurement. The thickness of the coupon should not increase by more than 10% of the initial

thickness at that point. Changes in excess of either of these two criteria requires investigation and engineering evaluation which may include early retrieval and measurement of one or more of the remaining coupons to provide corroborative evidence that the indicated change(s) is real. If the deviation is determined to be real, an engineering evaluation would be performed to identify further testing or any corrective action that may be necessary.

The remaining measurement parameters are used to detect early indications of degradation and may prompt a change in the measurement schedule. These include; 1) visual or photographic evidence of unusual surface pitting, corrosion or edge deterioration, 2) unaccountable weight loss in excess of the measurement accuracy, and 3) existence of areas of reduced boron density in the neutron radiograph.

Options exist for the re-use of coupons provided the coupon has not been destructively analyzed by wet-chemical processes. The coupon can be returned to the SFP and re-mounted on the coupon tree. It would then be available for subsequent investigation of defects, should any be found. In addition, an option exists to perform in-service inspections by directly testing the Boral panels in the storage racks by neutron logging (sometimes called "Blackness Testing"). This technique is able to detect significant areas of boron loss or the existence of gaps in the Boral. Normally, Blackness Testing should not be needed. In the event that the surveillance coupon program shows a confirmed indication of degradation, blackness testing may be one of the techniques employed to investigate the extent of degradation, if any, to the racks.

NUREG-1831 Section 3.0.3.3.3 made the following conclusion when addressing CNP's Boral Surveillance Program and its use of Boral coupon parameters for monitoring purposes:

> "The applicant listed the boral coupon parameters that would be monitored or inspected as neutron attenuation, dimensions (length, width, thickness), weight, and specific gravity. Since the program seeks to manage aging of boral panels by monitoring coupons believed to accurately represent the panels, the staff asked the applicant, in RAI B.1.3-1 by letter dated May 19, 2004, to discuss the relationship between the boral coupon measurements and the integrity of the boral panels.
>
> "In a letter dated August 11, 2004, the applicant responded that the coupon tree is moved each refueling outage to be surrounded by the highest power discharged fuel assemblies. The applicant stated that the boron coupons degrade faster than the boral panels because the coupons are exposed to a higher cumulative radiation dose, and the coupons therefore provide a definitive indication of the acceptability of the boral panels in the storage racks. Since the applicant should ensure that the boral coupons receive a higher radiation dose than the boral panels, the staff agrees that monitoring the coupons should provide an early indication of potential degradation of the boral panels in the storage racks.

"In RAI B.1.3-1, the staff also asked the applicant to explain its use of the measured values of coupon specific gravity to manage aging. The UFSAR Supplement (see page A-12 of the LRA) and the Boral Surveillance Program (see page B-23 of the LRA) list specific gravity as one of the parameters monitored. However, the applicant did not discuss specific gravity as part of the acceptance criteria in the AMP. According to the applicant, specific gravity is one of the physical parameters used to identify early indications of boral degradation. An unexplained decrease in specific gravity could indicate loss of material and would result in an engineering evaluation and possibly a change in the measurement schedule.

"The staff considers this program element acceptable because experience has shown that boral degradation in the SFP environment occurs slowly and can be detected in the early stages by the methods proposed. The measurements of neutron attenuation, physical distortion, and weight change would detect coupon degradation that would precede a loss of functionality in the boral panels (neutron absorption and fuel assembly spacing). Moreover, unacceptable coupon results would initiate an engineering evaluation and, if considered necessary, direct testing of the storage racks (i.e. blackness testing)."

iii) The following is the acceptance criteria of the program:

- The Boron-10 content of the coupon should not decrease more than 5% as determined by neutron attenuation. This is tantamount to a requirement for no loss in boron within the accuracy of the measurement.
- The thickness of the coupon should not increase by more than 10% of the initial thickness at that point.

The technical basis for the 5% decrease in Boron-10 areal density is because this is the limit of precision in the measurement and it is also within the usual uncertainty tolerance applied in the NCS analyses. The 5% variation is conservative because the Boron-10 density assumed in the CNP NCS AOR (0.0300 g-B^{10}/cm^2) is 15% less than the nominal Boron-10 density of the absorber panels (0.0345 g-B^{10}/cm^2). The neutron attenuation measurements are compared with measurements on a reference standard Boral coupon thus there is no accuracy component on the neutron attenuation measurement that would be required to detect degradation of the Boral panels in the spent fuel pool.

With respect to the coupon thickness measurement, the 10% increase in coupon thickness is sensitive enough to detect coupon swelling or blistering before the Boral panels could swell or blister enough to cause binding of fuel assemblies. The swelling or blistering does not affect the functionality (reactivity control) of the Boral.

Changes in excess of either of these two criteria requires investigation and engineering evaluation which may include early retrieval and measurement of one

or more of the remaining coupons to provide corroborative evidence that the indicated change(s) is real. If the deviation is determined to be real, an engineering evaluation would be performed to identify further testing or any corrective action that may be necessary.

Additional parameters are examined for early indications of potential Boral degradation and possibly a change in measurement schedule, including visual or photographic evidence of surface deterioration (general or pitting corrosion, edge deterioration), unaccountable weight loss, and areas of reduced boron density in neutron radiographs.

NUREG-1831 Section 3.0.3.3.3 made the following conclusion when addressing CNP's Boral Surveillance Program and its Boral coupon acceptance criteria:

> "The applicant identified the acceptance criteria as a decrease of no more than 5 percent Boral-10 content, as determined by neutron attenuation, and a maximum increase of 10 percent thickness at any point over the initial thickness at that location. The applicant identified additional parameters that are examined for early indications of potential boral degradation and possibly a change in measurement schedule, including visual or photographic evidence of surface deterioration (general or pitting corrosion, edge deformation), unaccountable weight loss, and areas of reduced boron density in neutron radiographs.
>
> "In a public meeting on September 1, 2004, documented as follow-up item to RAI B.1.3-1 in a letter dated September 29, 2004, the staff asked the applicant to provide the technical basis for the acceptance criteria (5-percent maximum Boron-10 decrease and 10-percent maximum thickness increase). The staff asked the applicant to provide a reference if the NRC previously reviewed and approved the Boral Surveillance Program at CNP. In a letter dated October 18, 2004, the applicant stated that the CNP Boral Surveillance Program had not previously been reviewed and approved by the NRC, but similar programs had been approved for two other plants. The applicant stated in the October 18, 2004, letter that it selected a 5-percent decrease in Boron-10 areal density because this is the limit of precision in the measurement and it is also within the usual uncertainty tolerance applied in the nuclear criticality safety analyses. In a letter dated January 12, 2005, the staff requested that the applicant confirm that the 5-percent variation in Boron-10 areal density was used in the most recent criticality safety analysis for CNP. In a letter dated January 21, 2005, the applicant responded that a 5-percent variation is conservative because the Boron-10 density assumed in the most recent fuel pool criticality analysis (0.030 g/cm^2) is 15-percent less than the nominal Boron-10 density for the absorber panels (0.0345 g/cm^2).
>
> "With respect to the coupon thickness measurement, the applicant stated that a 10 percent increase (0.0075 inches) in coupon thickness is sensitive enough to detect coupon swelling or blistering before the boral panels could swell or blister enough to cause binding of fuel assemblies. The applicant also noted

that swelling or blistering does not affect the functionality (reactivity control) of the boral. The staff finds these criteria acceptable because they measure changes small enough to provide reasonable assurance that corrective actions could be taken before a loss of functionality occurs."

In addition, NUREG-1831 Section 3.0.3.3.3 made the following conclusion when addressing CNP's Boral Surveillance Program and its ability to detect degradation:

> "The staff asked the applicant, in RAI B.1.3-1 by letter dated May 19, 2004, to discuss the accuracy of the neutron attenuation and thickness measurements that would be used to monitor the coupons, as well as the accuracy required to detect degradation of the panels in the fuel racks. According to the acceptance criteria listed in the LRA, the applicant must be able to detect a 5-percent decrease in Boron-10 content and a 10-percent increase in thickness. In a letter dated August 11, 2004, the applicant responded that the required accuracy for the thickness measurement is ± 0.005 inches, and the actual measurement accuracy is ± 0.001 inches. In a letter dated January 21, 2005, responding to related RAI B.1.3-2, the licensee confirmed that the thickness and Boron-10 measurement capabilities meet or exceed the program specifications. The applicant explained that neutron attenuation is compared on a relative basis to a boral reference standard. The staff finds these acceptable because the accuracy of the measurement techniques is compatible with the acceptance criteria."

iv) The coupon removal/evaluation schedule was based on vendor recommendations. The Boral coupon inspection measurements and analysis results are compared to previous measurements and analysis result to provide data for trending. Coupon size and Boron-10 areal density measurements are used to identify trends in degradation based on exposure time. Measurements are taken using calibrated instruments capable of measuring length, width, and thickness to ± 0.04, 0.02, and 0.002 inches, respectively, all of which are smaller than the 10% acceptance criterion. The Boral Surveillance Program procedure 12-THP-6020-CSP-203 would require an investigation, engineering evaluation, and perhaps additional testing (such as blackness testing of the storage racks) if either a decrease of more than 5% in Boron-10 content or increase of more than 10% in the coupon thickness is determined. These conditions would require an Action Request be initiated under the CNP Corrective Action Program.

NUREG-1831 Section 3.0.3.3.3 made the following conclusion when addressing CNP's Boral Surveillance Program and its Boral coupon monitoring and trending:

> "The applicant stated that it would conduct trending analysis by comparing the periodic inspection measurements and analysis to previous results. In a public meeting on September 1, 2004, the staff asked the applicant to confirm that the prescribed schedule for coupon removal and evaluation would include the extended operating period. In an email dated Septembe 27, 2004, the applicant responded that the program does continue during the extended operating period. The applicant stated that the

"Conclusion" section of the program confirms this with the phrase "continued implementation," which refers to the period of extended operation.

"A November 2004 AMP inspection raised a concern that the applicant may not be performing trending of the coupon measurements, and that the applicant's measurement capabilities may be inadequate for trending. In a letter dated January 12, 2005, the staff requested that the applicant clarify its capability for evaluating coupon thickness, provide the results of past coupon evaluations, and confirm that the 5-percent uncertainty in Boron-10 areal density is within the uncertainty tolerance used in the most recent criticality safety analysis. The staff also asked the applicant to provide dates for removal and evaluation of coupons in the past, as well as an explanation of how coupon removal and evaluation times are determined. In a letter dated January 21, 2005, the applicant responded that the calibrated measurement instruments are capable of measuring length, width, and thickness to ± 0.04, 0.02, and 0.002 inches, respectively, all of which are smaller than the 10% acceptance criterion. The applicant also stated that the limit of 5-percent Boron-10 areal density variation is conservative with respect to the SFP criticality analysis. The applicant uses the coupon size and Boron-10 areal density measurements to identify trends in degradation based on exposure time.

"Regarding the schedule and past results, the applicant responded in the January 21, 2005, letter that coupon removal and evaluation dates are based on vendor recommendations intended to produce more radiation dose than the expected lifetime dose for normal storage. During the period of extended operation, the evaluations interval will be 5 years, which the applicant stated is recommended by the Boral vendor and supported by the coupon results. The staff reviewed results from coupons tested in 1994 and 2001 and confirmed that there were no significant changes in coupon dimensions, weight, density, or Boron-10 areal density.

"In the section of the LRA that discusses operating experience, the applicant stated that it noted minor corrosion pitting during the most recent inspection. The staff asked the applicant, in RAI B.1.3-1 by letter dated May 19, 2004, to describe this pitting and discuss the trending procedure required to ensure that the pitting will not increase to affect the functionality of the boral. In a letter dated August 11, 2004, the applicant responded that, after visual inspection, eight blisters formed on the coupon surface during heating to remove residual moisture. The applicant stated that the blisters resulted from localized damage to the aluminum cladding by mechanical impacts during manufacturing or by corrosion pitting. Following penetration of the cladding, moisture entered the core of the coupon at the location of the hole or pit. According to the applicant, subsequent corrosion sealed the moisture in the core, and heating caused the cladding to separate from the core and form a blister. Microscopy revealed a pit or small hole in the cladding at each blister location. The applicant stated that this amount of corrosion pitting would not affect the boral functionality. The applicant compares coupon test results

with baseline data and past test results to ensure that boral function is not adversely affected. The applicant evaluates adverse conditions as part of the Corrective Action Program. The staff finds this element acceptable because the applicant monitors parameters that would indicate degradation and identifies trends in the parameters by comparison to baseline and interim test results."

v) The coupon removal and testing schedule, coupon sample sizes, parameters to be inspected, data to be collected, and acceptance criteria were all based on vendor recommendations. CNP's Boral Surveillance Program requires off-site coupon testing of Boral coupons to be performed as safety related.

Inspections and testing of CNP Boral surveillance coupons is currently performed by Northeast Technology Corporation (NETCO), a business segment of Scientech Curtiss-Wright under their approved 10 CFR Part 50, Appendix B Quality Assurance Program. NETCO certifies that all inspection, testing and documentation were performed in conformance with the requirements of all applicable elements of the NETCO quality assurance program and consequently, all applicable provisions of 10 CFR 50 Appendix B. All Gage Blocks, Masses, and Instruments are calibration certified. Several ASTM Standards are used and are as follows:

- C992 Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks
- C1187 Standard Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Pools
- E6 Definitions of Terms Relating to Methods of Mechanical Testing
- G1 Recommended Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
- G4 Guide for Conducting Corrosion Coupon Tests in Plant Equipment
- G15 Definitions of Terms Relating to Corrosion and Corrosion Testing
- G69 Practice for Measurement of Corrosion Potentials of Aluminum Alloys

b)

i) CNP does not perform scheduled visual inspection of in-service rack materials. The Boral Surveillance Program uses coupon monitoring in the program.

ii)

(1) The intent of the CNP Boral Surveillance Program is to monitor changes in the integrity and performance of the Boral absorber material on a continuing basis and to assure that slow, long-term synergistic effects, if any, do not become significant. As such, certain properties of Boral are characterized with the objective of providing data necessary to assure the Boral panels in the racks performed their intended function of controlling system reactivity. The surveillance program will take measurements on representative coupon

samples that have been placed in a high flux radiation location within the spent fuel pool.

The Boral is from the same production runs as the Boral panels used for the CNP high density storage racks. The Boral coupon is approximately 7.5 inches by 15 inches and rectangular in shape. The Boral coupon thickness is the same thickness as in the racks and is 0.101 inches. The Boral coupon is encased in a stainless steel sheath (of the same alloy used in manufacture of the racks), simulating as nearly as possible, the actual in-service geometry, physical mounting, materials, and flow conditions of the Boral in the storage racks. A series of machine screws retain the Boral coupon within the sheath cover plates. Prior to encasing the coupons in their stainless steel sheaths, the coupons are carefully pre-characterized with respect to the measurements to be performed subsequently on the irradiated coupons.

Twelve Boral neutron-absorbing coupons were obtained from the same production runs as the poison panels used in the high density spent fuel pool racks. The coupon measurement program started with ten coupons mounted on a "tree" and placed in a designated cell. Two coupons were preserved as archive samples for subsequent comparison with test coupon measurements. The guidance for the removal and evaluation is intended to allow coupons to accumulate more radiation dose than the expected lifetime dose for normal storage. Accelerated dose is accomplished by re-installing the coupon tree in a new location surrounded by freshly discharged fuel assemblies that have been among the higher specific power assemblies in the core.

Changes in physical properties of the Boral absorber material are assessed by performing inspections and measurements on a pre-planned schedule. The most significant measurements are the thickness (to monitor for swelling) and neutron attenuation (to confirm the concentration of Boron-10 in the absorber material). Acceptance criterion on the Boron-10 content is that it should not decrease more than 5% as determined by neutron attenuation. This is tantamount to a requirement for no loss in boron within the accuracy of the measurement. Acceptance criterion on the thickness of the coupon is that it should not increase by more than 10% of the initial thickness at that point. Changes in excess of either of these two criteria requires investigation and engineering evaluation which may include early retrieval and measurement of one or more of the remaining coupons to provide corroborative evidence that the indicated change(s) is real. If the deviation is determined to be real, an engineering evaluation shall be performed to identify further testing or any corrective action that may be necessary.

The materials utilized in the fabrication of racks have proven durability and compatibility with the pool water environment. Separate from the structural stainless steel rack materials the racks employ Boral, a patented product of AAR Brooks & Perkins, as the thermal neutron absorber material. Boral is a thermal neutron absorbing material composed of boron carbide and 1100 alloy aluminum. Boron carbide is a compound having a high boron content in a

physically stable and chemical inert form. The 1100 alloy aluminum is a light-weight metal with high tensile strength which is protected from corrosion by a highly resistant oxide film. The two materials, boron carbide and aluminum, are chemically compatible and ideally suited for long-term use in the radiation, thermal, and chemical environment of a spent fuel pool. Boral's use in the spent fuel pool as the neutron absorbing material can be attributed to the following reasons:

(i) The content and placement of boron carbide provides a very high removal cross section for thermal neutrons.
(ii) Boron carbide, in the form of fine particles, is homogeneously dispersed throughout the central layer of the Boral.
(iii) The boron carbide and aluminum materials in Boral do not degrade as a result of long-term exposure to gamma radiation.
(iv) The thermal neutron absorbing central layer of Boral is clad with permanently bonded surfaces of aluminum.
(v) Boral is stable, strong, durable, and corrosion resistant.

The characteristics of the Boral material are as follows:

- Aluminum – It has high resistance to corrosion in industrial and marine atmospheres. The excellent corrosion resistance of the 1100 alloy aluminum is provided by the protective oxide film that develops on its surface from exposure to the atmosphere or water. The film prevents the loss of metal from general corrosion or pitting corrosion and the film remains stable between a pH range of 4.5 to 8.5.
- Boron carbide – The boron carbide contained in Boral is a fine granulated powder that conforms to ASTM C-750-80 nuclear grade Type III.

All materials used in the construction of the racks have an established history of in-pool usage and their physical, chemical and radiological compatibility with the pool environment is an established fact at the time CNP's racks were manufactured. Boral has been used in both vented and unvented configurations. The CNP rack construction allows full venting of the Boral space. Austenitic stainless steel (304) is widely used in nuclear power plants.

As discussed in the Item (1)(c) response, the materials used in the construction of the CNP high density storage racks are Boral (boron carbide) and aluminum. Boron carbide is a compound having high boron content in a physically stable and chemical inert form. The 1100 alloy aluminum is a light-weight metal with high tensile strength which is protected from corrosion by a highly resistant oxide film developed from exposure to water. This film prevents the loss of metal from general corrosion or pitting corrosion and remains stable between a pH range of 4.5 to 8.5. Boron carbide and aluminum are chemically compatible and ideally suited for long-term use in the radiation, thermal, and chemical environment of a spent fuel pool. Passivation is a chemical treatment of metal to form a protective oxide film over the material. This same effect occurs naturally over a short period of time (days or weeks) for aluminum, after being introduced to an acidic environment, such as the spent fuel pool. The current

spent fuel racks were installed at CNP in the early 1990's; therefore, even if the aluminum in the spent fuel racks was not properly passivated before installation, the process would have already been completed naturally by this time.

As discussed in the Item (1)(b)(iii) response, there have been occasional occurrences of blisters forming in the cladding of Boral in spent fuel pool applications. Blisters can form from water which penetrates into the core through the interconnected porosity and reacts with exposed aluminum powder surfaces in the core to form aluminum oxide, Al_2O_3, and hydrogen. Usually the hydrogen gas escapes from the core through the porosity; however, in some cases the hydrogen becomes trapped in the void space. If enough hydrogen accumulates, the pressure causes the clad to separate slightly from the core, causing a blister. The blisters are generally no larger than the diameter of a quarter and no more than 1/8 inch high. There have been numerous test and evaluations performed on blisters by the Boral manufacturer, utilities, and other organizations which have found the Boral core under blisters remains intact with no reduction in the core's ability to absorb thermal neutrons.

Finally, as discussed in the Item (2) response, the CNP specific AMP, Boral Surveillance and Water Chemistry Control programs, and Spent Fuel Pool Maintenance Rule, will effectively manage any reduction of neutron absorbing capacity or loss of material due to general corrosion. The Primary and Secondary Water Chemistry Control Program's objective is to mitigate damage caused by corrosion and stress corrosion cracking and effectively mitigate aging effects by managing the loss of aluminum in the Boral due to corrosion. The Primary and Secondary Water Chemistry Program, which controls SFP water quality by maintaining chemistry levels (i.e. chlorides, fluorides, and sulfates) within acceptable limits, prevents this aging effect. NUREG-1831 Section 3.3.2.2.10 notes the NRC staff's finding that CNP's use of the Boral Surveillance Program and the Water Chemistry Control – Primary and Secondary Water Chemistry Control Program demonstrates that it will adequately manage the effects of aging related to neutron-absorbing capacity and loss of material. NUREG-1831 Section 3.3.2.3.1 notes the NRC staff's finding that CNP's use of the Primary and Secondary Water Chemistry Control Program demonstrates that it adequately manages the aging effect of aluminum alloys susceptibility to cracking from stress corrosion and IGA in corrosive environments with high chloride concentrations.

(2) The twelve coupons were inserted into the spent fuel pool in 1993.

(3) The vendor recommendation allows coupons, which have not been destructively analyzed by wet-chemical processes, the option to be returned to the spent fuel pool and re-mounted on the coupon tree for subsequent investigation of defects. One CNP coupon was analyzed in 1994, returned to the spent fuel pool, and again analyzed in 2002.

(4) There are presently 7 coupons that have not yet been tested as part of CNP's Boral Surveillance Program. Five of the coupons are schedule for removal and testing at 5 year intervals therefore these five would be sufficient to last until the Unit 1 and Unit 2 operating license expire in the years 2035 and 2039 respectively. Two additional coupons remain and could be used if and when needed. At this time there are no plans for coupons to be returned to the SFP for further evaluation.

The inspection plans for these remaining coupons are as follows:

Coupon ID	Scheduled Removal Date for Testing
ED211136-1-5	2020
FD212314-2-5	2025
GD212449-1-4	2030
HD213224-2-3	2035
HD213224-2-5	2040
GD212449-1-3	presently not scheduled
FD212314-2-4	presently not scheduled

iii) N/A

iv) In-situ testing is not used. CNP's Boral Surveillance Program uses off-site testing of Boral coupons to monitor and demonstrate performance of the neutron-absorbing material Boral used in the racks. The CNP Boral Surveillance Program does include the option of in-service testing of the Boral in the racks. In-service testing involves directly testing the Boral panels in the storage racks by neutron logging (sometimes called "Blackness Testing"). This technique is able to detect significant areas of boron loss or the existence of gaps in the Boral, but cannot determine other physical properties such as those measured in the coupon program. Normally the Blackness Testing should not be needed. In the event that the surveillance coupon program shows a confirmed indication of degradation, blackness testing may be one of the techniques employed to investigate the extent of degradation, if any, to the racks.

NRC Item 4

4) For any Boraflex, Carborundum, Tetrabor, or Boral being credited, describe how the crediting neutron-absorbing material is modeled in the SFP NCS AOR and how the monitoring or surveillance program ensures that the actual condition of the neutron-absorbing material is bounded by the NCS AOR.

   a) Describe the technical basis for the method of modeling the neutron-absorbing material in the NCS AOR. Discuss whether the modeling addresses degraded neutron-absorbing material, including loss of material, deformation of material (such as blisters, gaps, cracks, and shrinkage), and localized effects, such as non-uniform degradation.

   b) Describe how the results of the monitoring or surveillance program are used to ensure that the actual condition of the neutron-absorbing material is bounded by the SFP NCS AOR. If a coupon monitoring program is used, provide a description and technical basis

for the coupon tests and acceptance criteria used to ensure the material properties of the neutron-absorbing material are maintained within the assumptions of the NCS AOR. Include a discussion on the measured dimensional changes, visual inspection, observed surface corrosion, observed degradation or deformation of the material (e.g., blistering, bulging, pitting, or warping), and neutron-attenuation measurements of the coupons.

c) Describe how the bias and uncertainty of the monitoring or surveillance program are used in the SFP NCS AOR.

d) Describe how the degradation in adjacent panels is correlated and accounted for in the NCS AOR.

I&M Response

4) The CNP NCS AOR used a nominal areal density of 0.0345 ± 0.0045 g-B^{10}/cm^2 which ensures that at any point, the minimum B-10 areal density will not be less than 0.0300 g-B^{10}/cm^2. The reactivity effect of the ± 0.0045 g-B^{10}/cm^2 tolerance uncertainty is therefore accounted for in the analysis.

The NCS analysis accounts for 0.0345 ± 0.0045 g-B^{10}/cm^2 in the Boral areal density and also accounts for manufacturing tolerances of 7.50 ± 0.06 inches on the Boral width, 0.101 ± 0.005 inches on the Boral thickness, 8.75 ± 0.04 inches on the inner stainless steel box dimension, and 0.035 ± 0.003 inches on the outer stainless steel sheath. An eccentric fuel assembly positioning is also included in the NCS analysis which accounts for the effect of changes in moderation when a fuel assembly is not centered within a rack cell.

The purpose of the Boral Surveillance Program is to characterize certain properties of the Boral with the objective of providing data necessary to assure the capability of the Boral panels in the racks to continue to perform their intended function and be capable of detecting the onset of any significant degradation with ample time to take such corrective action as may be necessary. The surveillance program will take measurements on representative coupon samples that have been placed in a high flux radiation location within the SFP. These coupons are from the same production runs and are of the same thickness as the Boral panels used for the CNP high density storage racks. The most significant measurements are the thickness (to monitor for swelling) and neutron attenuation (to confirm the concentration of Boron-10 in the absorber material). The thickness of the coupon is measured at five locations on the coupon and an increase of no greater than 10% is indicative of satisfactory performance. The Boral areal density of the coupon is measured via neutron attenuation testing at five locations on the coupon and a reduction in the B-10 content of no greater than 5% is indicative of satisfactory performance. Changes in excess of either of these two criteria requires investigation and engineering evaluation which may include early retrieval and measurement of one or more of the remaining coupons to provide corroborative evidence that the indicated change(s) is real. If the deviation is determined to be real, an engineering evaluation is performed to identify further testing or any corrective action that may be necessary.

a) The NCS is not modelled in a level of detail to address degradation in the neutron-absorbing material. CNP's Boral Surveillance Program uses off-site testing of Boral

coupons to monitor and demonstrate performance of the neutron-absorbing material Boral used in the SFP racks and modeled and credited in the NCS AOR. The monitoring is performed on a continuing basis to assure that slow, long-term synergistic effects, if any, do not become significant. As such, certain properties of Boral are characterized with the objective of providing data necessary to assure the Boral panels in the racks performed their intended function of controlling system reactivity.

The surveillance program takes measurements on representative coupon samples that have been placed in a high flux radiation location within the spent fuel pool. The high flux radiation location allows coupons to accumulate more radiation dose than the expected lifetime dose for normal storage. Neutron attenuation measurements provide a means of confirming that the neutron absorbing nuclide (Boron-10) is being retained in the Boral. The optional neutron radiography is intended to confirm the uniformity of boron distribution within the Boral and/or to identify areas where there might be a local reduction in boron concentrations. Thickness measurements provide a means of detecting the onset of significant swelling or blistering. The only consequence of excessive swelling, should it occur, would potentially be in binding of the fuel assembly. Additional parameters are examined for early indications of potential Boral degradation and possibly a change in measurement schedule, including visual or photographic evidence of surface deterioration (general or pitting corrosion, edge deterioration), unaccountable weight loss, and areas of reduced boron density in neutron radiographs.

b) The CNP NCS AOR for the high density storage racks includes a margin for uncertainty in reactivity calculations including manufacturing tolerances, as described in the Item (1) response. The CNP Boral Surveillance Program is used to assess and ensure that the neutron-absorbing material properties are not degrading and do not impact the NCS AOR. Any coupon test result that does not meet acceptance criteria would be entered into the Corrective Action Program, as described in the Item (2) response. The corrective actions include an investigation and engineering evaluation if the coupon acceptance criteria are not met. Thus, with regards to the neutron-absorbing material, the NCS AOR explicitly accounts for manufacturing tolerances and the Boral Surveillance Program provides data necessary to assure the capability of the Boral panels in the racks to continue to perform their intended function. The coupon tests conducted as part of the Boral Surveillance Program, and as recommended by the vendor, include dimensional measurements, dry weight, density, neutron attenuation (areal density), and visual examinations. The tests are presently conducted by Northeast Technology Corporation (NETCO) under approved procedures. The test sequence is as follows:
   1. Unpack the shipped coupon and perform initial decontamination.
   2. Perform visual inspections and high resolution photography
   3. Conduct as-opened and immersed weight measurements to determine the density
   4. Measure coupons dimensions
   5. Conduct neutron attenuation testing
   6. Perform blister characterization necessary
   7. Dry coupon and measure coupon dry weight
   8. Clean coupon as necessary
   9. Perform pit characterizations as necessary

10. Perform optical microscopy and take photomicrographs of any anomalies

Each coupon parameter tested is described as follows:

Dimensional: Dimensions of the coupon are measured at the locations shown in Figure 2. Three measurements are taken on the length, three on the width, and five on the thickness. The required accuracy of the measurements is ± 0.04, ± 0.02, and ± 0.002 inches, respectively.

Dry Weight: The coupon is dried using a method of successive drying cycles using a heat and soak approach. The cooling steps are performed until there is no weight difference between successive dryings thus the true dry weight is determined.

Density: The specific density of the coupon is obtained using immersed weight measurements.

Neutron-Attenuation: The coupon is placed under a neutron beam from the testing laboratory and count rates are determined and adjusted for background count rates. The neutron attenuation measurement is compared with measurements on a reference standard Boral coupon and adjusted to establish the coupons measured areal density (g-B^{10}/cm^2).

Pit characterization: Visual examination for pits on the coupon is documented and measurements of pit width (at the widest point) and depth (at deepest point) are performed as required.

Blister characterization: Visual examination for blisters on the coupon is documented. All identified blisters to be measured are photographed using high resolution digital photography prior to the measurements of the height of the blister.

Visual Inspections: The coupon is inspected with any anomalies such as corrosion films, pitting, blisters or discolorations noted. A high resolution color photograph is taken on each side and additional photographs may be taken of any anomalies.

The most important coupon measurements are thickness (to monitor for swelling of the Boral samples) and neutron attenuation (to confirm the concentration of Boron-10 content). As an option, wet chemical analysis may occasionally be performed on specimens cut from a surveillance coupon, as an independent means of verifying the boron loading.

The thickness of the coupon should not increase by more than 10% of the initial thickness at that point. The purpose of this limit is to detect significant swelling or blistering. The vendor Holtec has stated that this amount of swelling would cause no problems in performance of the Boral panels because (1) it is within the available space and no binding of the fuel assembly would occur and (2) swelling or blistering does not affect the neutron absorption capability (i.e., reactivity control) of the Boral. The only consequence of excessive swelling, should it occur, would potentially be in binding of the fuel assembly.

The Boron-10 areal density of the Boral surveillance coupons is to be within 5% of the design value. Boron-10 areal density is commonly determined by neutron attenuation measurement which is performed on the CNP coupons. The vendor Holtec has stated that a 5% precision in determining the Boron-10 areal density is tantamount to a requirement for no loss in boron within the accuracy of such measurements. Furthermore, a 5% variation in Boron-10 areal density is within the usual uncertainty

tolerance applied in the NCS analyses. CNP's spent fuel pool NCS AOR accounts for a variation in Boron-10 areal density of 15% (based on B-10 areal density of 0.0345 ± 0.0045 g-B^{10}/cm^2).

The additional parameters are examined for early indications of potential Boral degradation and possibly a change in measurement schedule, including visual or photographic evidence of surface deterioration (general or pitting corrosion, edge deterioration), unaccountable weight loss, and areas of reduced boron density in neutron radiographs.

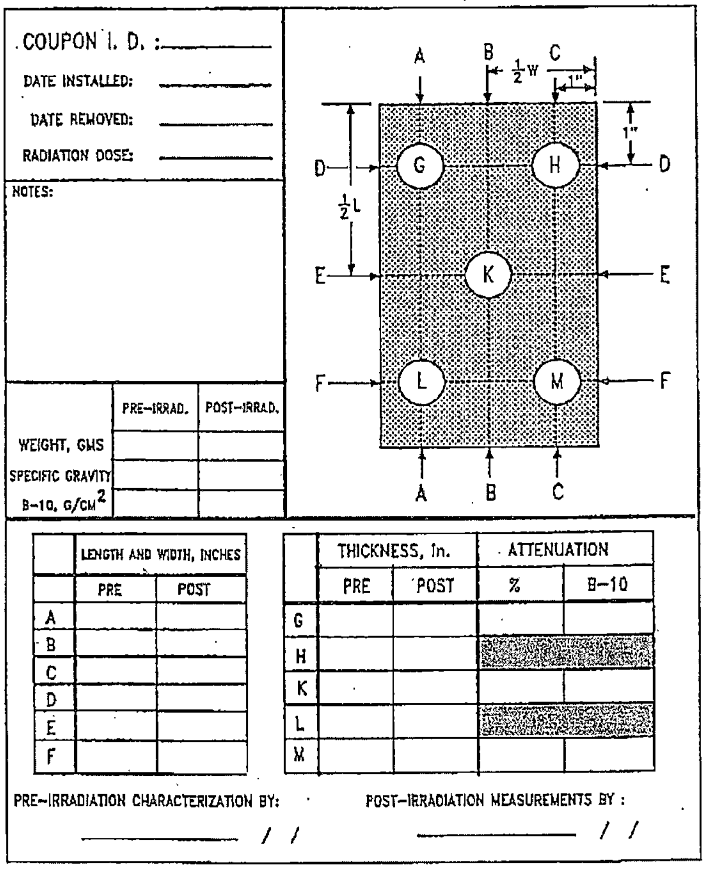
Coupon Results:
A total of six coupon surveillance measurements were taken on five coupons. The coupons were measured at the locations shown in Figure 2. One coupon to date was removed and tested in 1994, returned back to the pool, and again tested in 2002. There were no significant pre- and post-irradiation changes in the coupon lengths or widths. The small differences in length and width are within the measurement uncertainty and may be attributable to the presence of an oxide layer on the edge of the coupon and/or irregularities in the coupon edges. The slight increases in thickness may be attributable to a light oxide film. All thickness measurements met the acceptance criteria that the thickness of the coupon should not increase by more than 10% of the initial thickness.

The boron-10 areal density of the coupon was measured via neutron attenuation. All measurements met the acceptance criteria on the Boron-10 content that it should not decrease more than 5% as determined by neutron attenuation. This is tantamount to a requirement for no loss in boron within the accuracy of the measurement. This difference is not significant and is within the precision of the measurements. The results to date on the surveillance coupons are indicative of satisfactory coupon performance.

Below is a summary of the results of the six surveillance coupon tests conducted for CNP from 1994 to 2015. The differences are based on the post-irradiation coupon measurement and the pre-irradiation coupon measurement.

	Diff = ((Post-Pre)/Pre)*100	
Boral Length:	Range from -0.05 % to 0.09%	
Boral Width:	Range from -0.16% to 0.11%	
Boral Thickness:	Range from -2.40% to 1.98%	Acceptance Criteria (≤ 10%)
Dry Weight:	Range from 0.28% to 0.72%	
Density (g/cm^2):	Range from -0.48% to 1.96%	
Areal Density (g-B^{10}/cm^2):	Range from -2.93% to 5.91%	Acceptance Criteria (≥ -5%)

Figure 2
BORAL COUPON DATA SHEET



A summary of each individual coupon surveillance test is presented below. Provided is a brief discussion on the dimensional changes, visual inspection, observed surface corrosion, observed degradation or deformation of the material (e.g., blistering, bulging, pitting, or warping), and neutron-attenuation measurements of each coupon.

Coupon ID DD210285-1-5 inspected in 2015

Dimensional:

The dimensions of the coupon were measured at the locations shown in Figure 2. There were no significant pre- and post-irradiation changes in the coupon lengths or widths. The thickness of the coupon decreased an average of 0.0003 inches or 0.31%. This decrease is quite small and within the measurement uncertainty, thus it can be assumed that there was no distinguishable difference in thickness. The average length and width varied by 0.07% and 0.05% respectively when comparing pre- and post-irradiation values.

Dry Weight:
The pre-irradiation weight of the coupon was 465.75 grams and the post-irradiation weight after drying was 469.09 grams for an increase in weight of 0.72%.

Density:
The coupon was subjected to a density measurement via immersion weighing. The pre-irradiation density was 2.501 g/cm^3 and the post-irradiation density was 2.55 g/cm^3 for an increase in density of 1.96%.

Neutron-Attenuation:
The boron-10 areal density of the coupon was measured via neutron attenuation testing at five locations as shown in Figure 2. The average pre-irradiation areal density was 0.0345 g-B^{10}/cm^2 and the post-irradiation areal density was 0.0365 g-B^{10}/cm^2 for an increase in areal density of 5.91%. The change is indicative of satisfactory coupon performance.

Blistering, bulging, pitting, or warping:
The coupon is in good condition with some visual pitting and blistering and no indications of bulging or warping on the coupon. Eight small blisters were observed. The front side was somewhat shiny, medium grey across most of the surface with dull opaque translucent lighter colored oxide around pits and around edges of coupon. Minor scratching was observed across surface from wear. Oxide is light with some rust-colored staining at top of coupon. The back side overall surface is shiny with longitudinal scratches most likely from rolling. In the area of top to center across the coupon width is a patch of thick translucent-opaque oxide with small patches of significant height. This oxide flakes off readily when abraded.

Pitting corrosion was identified on high resolution photographs of the coupon. Pit diameter and depth measurements were taken and the results of the pitting analysis showed an average depth of 0.0060 inches and width of 0.0428 inches on the front side and an average depth of 0.0059 inches and width of 0.0421 inches on the back side.

The coupon displayed relatively minor blistering, five blisters on the front and three on the back. The largest blister was 0.0370 inches in height and the combined (Front & Back) height average was 0.0235 inches. The eight small blisters do not point to any degradation in overall coupon performance and the results of the areal density of the coupon are indicative of satisfactory coupon performance. Results of the blistering analysis showed an average height of 0.0211 inches, area of 0.0581 in^2, and volume of 0.0007 in^3 on the front side and an average height of 0.0275 inches, area of 0.0942 in^2, and volume of 0.0014 in^3 on the back side of the coupon.

<u>Coupon ID DD210285-1-4 inspected in 2010</u>
Dimensional:
The dimensions of the coupon were measured at the locations shown in Figure 2. There were no significant pre- and post-irradiation changes in the coupon lengths or widths. The thickness of the coupon increased an average of 0.0010 inches or 0.97%. The small differences in length and width may be attributable to the presence of an oxide layer on the edge of the coupon and/or irregularities in the coupon edges. The slight

increase in thickness may be attributable to a light oxide film. The average length and width varied by 0.01% and 0.04% respectively when comparing pre- and post-irradiation values.

Dry Weight:
The pre-irradiation weight of the coupon was 473.23 grams and the post-irradiation weight after drying was 476.32 grams for an increase in weight of 0.65%.

Density:
The coupon was subjected to a density measurement via immersion weighing. The pre-irradiation density was 2.5031 g/cm^3 and the post-irradiation density was 2.519 g/cm^3 for an increase in density of 0.64%.

Neutron-Attenuation:
The boron-10 areal density of the coupon was measured via neutron attenuation testing at five locations as shown in Figure 2. The average pre-irradiation areal density was 0.0348 g-B^{10}/cm^2 and the post-irradiation areal density was 0.0367 g-B^{10}/cm^2 for an increase in areal density of 5.24%. The change is indicative of satisfactory coupon performance.

Blistering, bulging, pitting, or warping:
The coupon is in good condition with some minor corrosion pitting and blistering and no indications of bulging or warping on the coupon. Both the front and back of the coupon appear as slightly discolored mill finish aluminum with numerous small corrosion pits on both sides. There are approximately 60 such pits on each side and each pit was surrounded by a lighter coloration which may be a heavier oxide film The light areas on the coupon and capsule are tear shaped indicating flow into the capsule at the bottom and upward along the surface of the coupon exiting the capsule at the top. The pits are relatively shallow and do not penetrate the Boral clad.

The front of the coupon had two small blisters in the clad of the Boral, one in the lower right corner and one approximately 4 inches above it. One is approximately a 1/4 inch in diameter, and the other 3/16 of an inch in diameter. There were also two small blisters on the back of the coupon, one about 4 inches above the lower left corner and the other about 4 inches down from the upper left corner. Both blisters are approximately 1/4 inch in diameter.

<u>Coupon ID ED211136-1-4 inspected in 2005</u>
Dimensional:
The dimensions of the coupon were measured at the locations shown in Figure 2. There were no significant pre- and post-irradiation changes in the coupon lengths or widths. The thickness of the coupon increased an average of 0.0011 inches or 1.10%. The small differences in length and width may be attributable to the presence of an oxide layer on the edge of the coupon and/or irregularities in the coupon edges. The slight increase in thickness may be attributable to a light oxide film. The average length and width varied by 0.05% and 0.08% respectively when comparing pre- and post-irradiation values.

Dry Weight:
The pre-irradiation weight of the coupon was 464.73 grams and the post-irradiation weight after drying was 466.32 grams for an increase in weight of 0.34%.

Density:
The coupon was subjected to a density measurement via immersion weighing. The pre-irradiation density was 2.5222 g/cm^3 and the post-irradiation density was 2.51 g/cm^3 for a decrease in density of 0.48%.

Neutron-Attenuation:
The boron-10 areal density of the coupon was measured via neutron attenuation testing at five locations as shown in Figure 2. The average pre-irradiation areal density was 0.0341 g-B^{10}/cm^2 and the post-irradiation areal density was 0.0331 g-B^{10}/cm^2 for a decrease in areal density of 2.93%. This difference is not significant and is within the precision of the measurements.

Blistering, bulging, pitting, or warping:
The coupon is in good overall condition with no gross anomalies or missing material. Both flat surfaces have the appearance of slightly discolored aluminum with numerous corrosion pits each surrounded by a lighter area that could be aluminum oxide. There are approximately 75 such pits on each side and each pit was surrounded by a lighter coloration which may be an oxide film. The pits are relatively shallow and do not penetrate the Boral clad. The lighter areas are tear shaped indicating flow into the bottom of the capsule and out of the top left corner of the capsule.

Coupon ID ID213616-1-3 inspected in 2002
Dimensional:
The dimensions of the coupon were measured at the locations shown in Figure 2. There were no significant pre- and post-irradiation changes in the coupon lengths or widths. The thickness of the coupon increased an average of 0.0004 inches or 0.41%. The slight increase thickness may be attributable to a light oxide film. The average length and width varied by 0.00% and 0.05% respectively when comparing pre- and post-irradiation values. The small differences in length and width may be attributable to the presence of an oxide layer on the edge of the coupon and/or irregularities in the coupon edges.

Dry Weight:
The pre-irradiation weight of the coupon was 468.08 grams and the post-irradiation weight after drying was 470.60 grams for an increase in weight of 0.54%.

Density:
The coupon was subjected to a density measurement via immersion weighing. The pre-irradiation density was 2.4974 g/cm^3 and the post-irradiation density was 2.51 g/cm^3 for an increase in density of 0.50%.

Neutron-Attenuation:
The boron-10 areal density of the coupon was measured via neutron attenuation testing at five locations as shown in Figure 2. The average pre-irradiation areal density was

0.0336 g-B^{10}/cm^2 and the post-irradiation areal density was 0.0349 g-B^{10}/cm^2 for an increase in areal density of 3.65%. This difference is not significant and is within the precision of the measurements.

Blistering, bulging, pitting, or warping:
The coupon is in good overall condition with a very light uniform oxide film on both sides. Both sides of the coupon have, what appears to be corrosion pits. Two pits on each side were examined under a microscope and noted the pits as fairly deep, 0.018 inches and 0.0216 inches on the front side and 0.0048 inches and 0.018 inches on the back side of the coupon.

Six blisters on the front side and two blisters on the back side developed during the coupon drying process. Microscopy revealed either a pit or a small hole in the cladding at each blistered location. It was speculated that moisture entered the core of the Boral at the location of the hole or pit. Subsequent corrosion of the hole or pit sealed the moisture or corrosion produced hydrogen in the core. When the coupons were heated, the moisture and/or hydrogen expanded causing the aluminum skin of the Boral to lift off the core forming a blister. Requisite for blister formation is a breach of the clad caused either by mechanical impacts during manufacturing or the formation of a subsequent corrosion pit.

Coupon ID ID213616-1-3 inspected in 1994
Dimensional:
The dimensions of the coupon were measured at the locations shown in Figure 2. There were no significant pre- and post-irradiation changes in the coupon lengths or widths. The thickness of the coupon decreased an average of 0.0011 inches or 1.07%. The small differences in length and width may be attributable to the presence of an oxide layer on the edge of the coupon and/or irregularities in the coupon edge and surface conditions. The average length and width varied by 0.06% and 0.00% respectively when comparing pre- and post-irradiation values.

Dry Weight:
The pre-irradiation weight of the coupon was 468.08 grams and the post-irradiation weight after drying was 469.40 grams for an increase in weight of 0.28%.

Density:
The coupon was subjected to a density measurement via immersion weighing. The pre-irradiation density was 2.4974 g/cm^3 and the post-irradiation density was 2.508 g/cm^3 for an increase in density of 0.42%.

Neutron-Attenuation:
The boron-10 areal density of the coupon was measured via neutron attenuation testing at five locations as shown in Figure 2. The average pre-irradiation areal density was 0.0336 g-B^{10}/cm^2 and the post-irradiation areal density was 0.0351 g-B^{10}/cm^2 for an increase in areal density of 4.24%. This difference is not significant and is within the precision of the measurements.

Blistering, bulging, pitting, or warping:
The coupon had very light uniform oxide film on both sides. The front side had several dark pits. The aluminum skin around these pits was lighter in color, perhaps indicating a thicker local oxide film. Examination of the pits under a microscope indicated that some of these pits were particles of boron carbide which apparently had been pressed into the aluminum during manufacture. Results of microscopy show pit depths up to 0.0039 inches and pit sizes of 0.0060 inches by 0.0040 inches. The back had fewer pits and the color and surface condition were more uniform. There were no blister results noted for this coupon.

Coupon ID ID213616-1-5 inspected in 1994
Dimensional:
The dimensions of the coupon were measured at the locations shown in Figure 2. There were no significant pre- and post-irradiation changes in the coupon lengths or widths. The thickness of the coupon decreased an average of 0.0011 inches or 1.08%. The small differences in length and width may be attributable to the presence of an oxide layer on the edge of the coupon and/or irregularities in the coupon edge and surface conditions. The average length and width varied by 0.07% and 0.04% respectively when comparing pre- and post-irradiation values.

Dry Weight:
The pre-irradiation weight of the coupon was 469.13 grams and the post-irradiation weight after drying was 470.50 grams for an increase in weight of 0.29%.

Density:
The coupon was subjected to a density measurement via immersion weighing. The pre irradiation density was 2.508 g/cm^3 and the post-irradiation density was 2.515 g/cm^3 for an increase in density of 0.28%.

Neutron-Attenuation:
The boron-10 areal density of the coupon was measured via neutron attenuation testing at five locations as shown in Figure 2. The average pre-irradiation areal density was 0.0343 g-B^{10}/cm^2 and the post-irradiation areal density was 0.0351 g-B^{10}/cm^2 for an increase in areal density of 2.23%. This difference is not significant and is within the precision of the measurements.

Blistering, bulging, pitting, or warping:
The coupon had very light uniform oxide film on both sides. The front side had several dark pits. The aluminum skin around these pits was lighter in color, perhaps indicating a thicker local oxide film. Examination of the pits under a microscope indicated that some of these pits were particles of boron carbide which apparently had been pressed into the aluminum during manufacture. Results of microscopy show pit depths up to 0.0023 inches and pit sizes of 0.0030 inches by 0.0030 inches. The back had fewer pits and the color and surface condition were more uniform. There were no blister results noted for this coupon.

c) The thickness of the Boral surveillance coupons is limited to an increase of no more than 10% of the initial thickness. This purpose of this limit is to detect significant swelling or

blistering. The vendor has stated that this amount of swelling would cause no problems in performance of the Boral panels because (1) it is within the available space and no binding of the fuel assembly would occur and (2) swelling or blistering does not affect the neutron absorption capability (i.e., reactivity control) of the Boral. The only consequence of excessive swelling, should it occur, would potentially be in binding of the fuel assembly. While a smaller swelling criterion could be measured under laboratory conditions, the 10% criterion is adequate and a smaller criterion would be difficult under field conditions with contaminated coupons. The Boral absorber, boron carbide (B_4C) and aluminum powdered sandwiched between thin aluminum sheets, has an overall thickness of 0.101 ± 0.005 inches.

Boron-10 areal density of the coupon is commonly determined by neutron attenuation measurement as is performed on the CNP coupons. The neutron attenuation measurements are compared with measurements on a reference standard Boral coupon. The Boron-10 areal density of the Boral surveillance coupons is to be within 5% of the design value. The vendor Holtec has stated that a 5% precision in determining the Boron-10 areal density is tantamount to a requirement for no loss in boron within the accuracy of such measurements. Furthermore, a 5% variation in Boron-10 areal density is within the usual uncertainty tolerance applied in the NCS analyses. CNP's spent fuel pool NCS AOR accounts for a variation in Boron-10 areal density of 15% (based on B-10 areal density of 0.0345 ± 0.0045 g-B^{10}/cm^2).

d) The NCS is not modelled in a level of detail to address degradation in the neutron-absorbing material. The B-10 content measured by neutron attenuation and Boral thickness measurements on surveillance coupons are the most important parameters measured. Additional measurements taken on the surveillance coupon include dimensions on the coupon length, width, weight, and density. Visual and photographic examinations are also performed on the surveillance coupon to assess blistering, bulging, pitting, or warping and weighting parameters monitored on the surveillance coupon would indicate degradation. The CNP Boral Surveillance Program dictates that any adverse condition is evaluated as part of the Corrective Action Program. Corrective actions include an investigation and engineering evaluation if the coupon acceptance criteria are not met. Additional testing of the storage racks may be performed based on the engineering evaluation.

References

1. Letter from E. E. Fitzpatrick, Vice President, Indiana Michigan Power Company, to Nuclear Regulatory Commission Document Control Desk, "Donald C. Cook Nuclear Plant Units 1 and 2, License Nos. 50-315 and 50-316, Docket Nos. DPR-58 and DPR-74, Spent Fuel Pool Reracking Technical Specification Changes," AEP:NRC:1146, dated July 26, 1991.

2. Letter from U. S. NRC to Mr. E. E. Fitzpatrick, Vice President, Indiana Michigan Power Company, RE: "Donald C. Cook Nuclear Plant, Units 1 and 2 – Amendment Nos. 169 and 152 to Facility Operating License Nos. DPR-58 and DPR-74 (TAC Nos. M80615 and M80616)," dated January 14, 1993, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML021060153)

3. Letter from M. K. Nazar, Senior Vice President and Chief Nuclear Officer, Indiana Michigan Power Company, to U. S. Nuclear Regulatory Commission Document Control Desk, "Donald C. Cook Nuclear Plant Units 1 and 2, Docket No. 50-315 and 50-316 , Application for Renewed Operating Licenses," AEP:NRC:3034, dated October 31, 2003, (ADAMS Accession No. ML033070177).

4. NUREG-1831, "Safety Evaluation Report Related to the License Renewal of the Donald C. Cook Nuclear Plant, Units 1 and 2," dated May 2005, (ADAMS Accession No. ML052230442).