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DTE

Proprietary Information – Withhold Under 10 CFR 2.390

September 5, 2019 10 CFR 50.90
NRC-19-0004

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

Fermi 2
NRC Docket No. 50-341
NRC License No. NPF-43

Subject: License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

References: 1) "Summary of June 27, 2018, Public Meeting with DTE Electric Company Regarding Upcoming License Amendment Request to Revise a License Condition Related to Boraflex Storage Racks (EPID L-2018-LRM-0031)", dated July 16, 2018 (ML18194A540).

In accordance with the provisions of 10 CFR 50.90, "Application for amendment of license, construction permit, or early site permit," DTE Electric Company (DTE) requests an amendment to the Renewed Facility Operating License NPF-43 for Fermi Unit 2 (Fermi 2) and its Appendix A, Technical Specifications (TS).

The Renewed Facility Operating License NPF-43 issued on December 15, 2016 contains a License Condition regarding the Boraflex material in the spent fuel pool (SFP) storage racks. The License Condition is to discontinue reliance on the Boraflex material to perform a neutron absorption function by replacing the SFP storage racks containing Boraflex with racks containing Boral. As an alternative to rack replacement, DTE proposes to utilize neutron absorbing inserts (i.e., NETCO SNAP-IN® rack inserts) in the racks containing Boraflex. A new criticality safety analysis has been performed which takes no credit for the Boraflex material to perform a neutron absorption function and instead relies upon the neutron absorbing inserts.

Enclosure 4 contains Proprietary Information – Withhold Under 10 CFR 2.390.
When separated from Enclosure 4, this document is decontrolled.

This submittal requests modification of the Renewed Facility Operating License to eliminate the License Renewal License Condition based upon this proposed alternative. This submittal also requests revision of TS requirements associated with the spent fuel pool (SFP) storage racks based on the new criticality safety analysis. In addition, approval of the new criticality safety analysis, including methodology, is requested.

In accordance with 10 CFR 50.91, a copy of this application, with enclosures, is being provided to the designated Michigan State Official.

Enclosure 1 provides a detailed description and evaluation of the proposed changes, including an analysis of the significant hazards considerations using the standards of 10 CFR 50.92. DTE has concluded that the changes proposed herein do not result in a significant hazards consideration. Enclosure 2 provides the existing Operating License (OL) and TS pages marked up to show the proposed changes. Enclosure 3 provides revised (clean) OL and TS pages. There are no TS Bases revisions associated with this request.

Enclosure 4 provides a summary of the criticality safety analysis and contains proprietary information as defined by 10 CFR 2.390. Global Nuclear Fuel (GNF) and Curtiss-Wright (CW), as owners of the proprietary information, have executed the affidavits in Enclosure 6, which identify that the enclosed proprietary information has been handled and classified as proprietary, is customarily held in confidence, and has been withheld from public disclosure. The proprietary information was provided to DTE in a GNF transmittal that included the affidavits. The proprietary information has been faithfully reproduced in the enclosed documentation such that the affidavits remain applicable. GNF and CW herein request as set forth in the enclosed Affidavits of Lisa Schichlein and Karl Leuenroth, respectively, that the enclosed proprietary information be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390. A non-proprietary version of the documentation in Enclosure 4 is provided in Enclosure 5. Enclosure 7 provides a completed version of the Nuclear Energy Institute (NEI) 12-16 checklist for the criticality safety analysis in Enclosures 4 and 5.

Enclosure 8 provides a material qualification report associated with the NETCO SNAP-IN® rack inserts. Note that Enclosure 8 is identical to the same report which has been previously provided to the NRC (ADAMS Accession No. ML13199A039) and is being provided again with this submittal only for convenience.

This license amendment request does contain new regulatory commitments, which are identified in Enclosure 9.

A public pre-submittal meeting was held with the NRC on June 27, 2018 (Reference 1) to discuss this request. Feedback and comments received during the pre-submittal meeting have been addressed in the enclosed request.

DTE requests approval of the proposed license amendment by October 1, 2020, with the amendment being implemented within 90 days following either NRC approval or complete installation of the neutron absorbing inserts, whichever is later.

Should you have any questions or require additional information, please contact Mr. Jason R. Haas, Manager – Nuclear Licensing, at (734) 586-1769.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on September 5, 2019

Paul Fessler
Senior Vice President and CNO

Enclosures:

1. Evaluation of the Proposed License Amendment
2. Marked-up Pages of Existing Fermi 2 OL and TS
3. Clean Pages of Fermi 2 OL and TS with Changes Incorporated
4. NEDC-33889P – SFP Criticality Safety Analysis with Inserts (Proprietary Version)
5. NEDO-33889 – SFP Criticality Safety Analysis with Inserts (Non-Proprietary Version)
6. Global Nuclear Fuel and Curtiss-Wright Affidavits for Enclosure 4
7. Completed NEI 12-16 Checklist for NEDC-33889P
8. Material Qualification of NETCO SNAP-IN® Rack Inserts
9. Regulatory Commitments

cc: NRC Project Manager
NRC Resident Office
Reactor Projects Chief, Branch 5, Region III
Regional Administrator, Region III
Michigan Public Service Commission
Regulated Energy Division (kindschl@michigan.gov)

Enclosure 1 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

Evaluation of the Proposed License Amendment

Evaluation of the Proposed License Amendment

<u>Contents</u>

Acronym List

BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
DTE	DTE Electric Company
EDP	Engineering Design Package
EPRI	Electric Power Research Institute
FHA	Fuel Handling Accident
GDC	General Design Criterion
GEH	General Electric – Hitachi
GL	Generic Letter
GNF	Global Nuclear Fuel
ICP	Inductively Coupled Plasma
ISFSI	Independent Spent Fuel Storage Installation
ISG	Interim Staff Guidance
LAR	License Amendment Request
LRA	License Renewal Application
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
OL	Operating License
PEO	Period of Extended Operation
PWR	Pressurized Water Reactor
QA	Quality Assurance
RG	Regulatory Guide
SER	Safety Evaluation Report
SFP	Spent Fuel Pool
SRP	Standard Review Plan
SSE	Safe Shutdown Earthquake
STS	Standard Technical Specifications
TS	Technical Specifications
UFSAR	Updated Final Safety Analysis Report

1.0 SUMMARY DESCRIPTION

In accordance with the provisions of Title 10 of the Code of Federal Regulations (CFR) 50.90, "Application for amendment of license, construction permit or early site permit," DTE Electric Company (DTE) is submitting a request for an amendment to the Renewed Facility Operating License No. NPF-43 for Fermi 2 and its Appendix A, Technical Specifications (TS).

This submittal requests modification of the Renewed Facility Operating License to eliminate the License Renewal License Condition based upon a proposed alternative to install neutron absorbing inserts (i.e., NETCO SNAP-IN® rack inserts) in the spent fuel pool (SFP) storage racks containing Boraflex. This submittal also requests revision of TS requirements associated with the SFP storage racks based on a new criticality safety analysis. In addition, approval of the new criticality safety analysis, including methodology, is requested.

A public pre-submittal meeting was held with the Nuclear Regulatory Commission (NRC) on June 27, 2018 (Reference 6.1) to discuss this request. Feedback and comments received during the pre-submittal meeting have been addressed in this request.

2.0 DETAILED DESCRIPTION

The Fermi 2 SFP contains two types of high-density storage racks. The first type was supplied by Joseph Oat Corporation (Joseph Oat) and utilizes Boraflex as the neutron absorbing material. These racks have a nominal 6.22 inch center-to-center distance between assemblies (pitch). There are thirteen racks of this type, with a total storage capacity of 2197 cells. The second type was supplied by Holtec International (Holtec) and utilizes Boral as the neutron absorbing material. These racks have a nominal 6.23 inch pitch. There are nine racks of this type, with a total storage capacity of 1393 cells. Thus the Fermi 2 SFP has a capacity of 3590 storage cells. No changes are being proposed in this license amendment request (LAR) to the number of racks or to the total capacity of the Fermi 2 SFP. Additional details regarding the neutron absorbing materials in the Fermi 2 SFP storage racks was recently provided to the NRC in the Fermi 2 response to Generic Letter (GL) 2016-01 (Reference 6.2).

Fermi 2 was issued a Renewed Facility Operating License (No. NPF-43) on December 15, 2016 (Reference 6.4). The Renewed Facility Operating License contains three License Renewal License Conditions. One of the License Renewal License Conditions addresses the SFP storage racks containing Boraflex (i.e., the Joseph Oat type racks). The License Condition requires DTE to discontinue reliance on Boraflex to perform a neutron absorption function prior to the period of extended operation (PEO) which begins on March 20, 2025. The License Condition requires that this discontinued reliance be achieved by replacing the racks containing Boraflex with racks containing Boral (i.e., the Holtec type racks). This License Condition was consistent with a commitment DTE made to the NRC by letter dated September 24, 2015 (Reference 6.5) and discussed in Section 3.0.3.2.2 of the Safety Evaluation Report (SER) for the Fermi 2 License Renewal (Reference 6.6). When making the commitment, DTE noted that an alternative to rack

replacement may be considered in the future based on further analyses and subject to NRC approval.

DTE has now identified an alternative to replacing the Boraflex racks with Boral racks. The existing Boraflex does not currently perform any other function other than to provide neutron absorption. Neutron absorbing inserts can be inserted into the Boraflex racks. Once installed, these neutron absorbing inserts will provide sufficient neutron absorption such that reliance on the Boraflex to perform a neutron absorption function is no longer required. DTE proposes to install NETCO SNAP-IN® neutron absorbing inserts, similar to those that have been installed in SFPs at several other nuclear power plants (see Section 4.2). The inserts will be installed in all cells of the Boraflex racks. DTE plans to perform the physical installation of the inserts under the provisions of 10 CFR 50.59 as has been done at other plants (see Section 3.1.5). However, NRC review and approval of the new criticality safety analysis provided with this LAR is required prior to crediting these inserts to perform a neutron absorption function.

Note that the inserts are not required in the Boral racks and DTE is not proposing any modifications to the Boral racks in this LAR. The new criticality safety analysis provided with this LAR describes how there is no neutronic interaction between the Boraflex racks and Boral racks or other SFP equipment. In addition, DTE is not proposing any changes which would increase the maximum number of stored fuel assemblies in the Fermi 2 SFP. This license amendment request also does not involve a re-rack of the Fermi 2 SFP. Furthermore, there are no changes being proposed to the Fermi 2 independent spent fuel storage installation (ISFSI).

2.1 Proposed Changes to Operating License

Renewed Facility Operating License No. NPF-43 License Renewal License Condition (c) states that:

> DTE Electric Company shall fully implement the Boraflex rack replacement approved in Amendment No. 141 before the PEO (i.e., March 20, 2025), so that the Boraflex material in the spent fuel pool will not be required to perform a neutron absorption function. DTE Electric Company shall submit a letter to the NRC, within 60 days following completion of the removal of the Boraflex material and installation of the Boral material, as described in Amendment No. 141, confirming the removal of the Boraflex material and discontinued reliance on its neutron absorption function.

As indicated by the License Condition, DTE was previously granted approval in License Amendment No. 141 (Reference 6.7) to replace the Boraflex racks with Boral racks. As described in the SER for Amendment No. 141, the activity was planned to be performed over three campaigns. The first two campaigns were previously completed by DTE in 2001 and 2007, but the third (and final) campaign was not implemented. The License Condition requires DTE to complete the third campaign so that credit for Boraflex is no longer required.

Once NETCO SNAP-IN® neutron absorbing inserts have been fully installed, the Boraflex material will no longer be required to perform a neutron absorption function since it will no

longer be credited in the criticality safety analysis (see Section 3.2) and the Boraflex does not perform any other function. This meets the intent of this License Condition without requiring replacing the Boraflex racks with Boral racks. Therefore, the License Condition will no longer be required. DTE proposes to eliminate License Renewal License Condition (c) entirely. The License Condition also required DTE to notify the NRC within 60 days following completion of the removal of the Boraflex removal. This would no longer be necessary upon NRC approval and DTE implementation of this LAR. DTE would not implement the license amendment, once approved, until installation of all the inserts was complete. This would ensure that the above License Condition remains in force until the time that it is no longer applicable.

See Enclosure 2 for the marked-up Operating License (OL) pages that reflects the proposed changes described above. Enclosure 3 provides the clean pages with the proposed changes incorporated.

2.2 Proposed Changes to Technical Specifications

Fermi 2 TS requirements for the SFP storage racks are found in Section 4.3, "Fuel Storage." These TS requirements reflect physical parameters associated with the racks as well as requirements associated with the criticality safety analysis. DTE proposes the following revisions to TS Section 4.3:

- The maximum k-infinity for fuel assemblies in storage racks in TS 4.3.1.a is revised from 1.31 to 1.30. This change is required to reflect the new criticality safety analysis (see Section 3.2), which uses a maximum k-infinity of 1.30 in its calculations for the Boraflex racks with NETCO SNAP-IN® neutron absorbing inserts. Note that the TS maximum k-infinity value applies to fuel assemblies stored in an SFP storage rack regardless of the neutron-absorbing material of the rack. The proposed maximum k-infinity value of 1.30 is also acceptable for the Boral racks since it is conservatively bounding of the criticality safety analysis for the Boral racks which utilizes a value of approximately 1.34.
- The description of the neutron absorbing material in the Joseph Oat high density storage racks in TS 4.3.1.c is revised from Boraflex to BORALCAN™. Following implementation of this LAR once approved, the Boraflex in these racks will not be credited to perform a neutron absorption function (although the Boraflex material will still be physically present). Instead, the neutron absorption function will be performed by the NETCO SNAP-IN® neutron absorbing inserts. Therefore, it is necessary to revise TS 4.3.1.c to indicate the actual material that will perform the neutron absorption function. BORALCAN™ is the appropriate descriptive name for the neutron absorbing material in the Fermi 2 NETCO SNAP-IN® inserts (see Section 3.3).
- The low density storage racks and defective fuel assembly storage rack described in TS 4.3.1.c are deleted. As described above, the re-rack approved by the NRC in License Amendment No. 141 consisted of three campaigns. The SER indicated that the second campaign would include the removal of the defective fuel storage rack and low density storage racks. Consistent with the SER, the low density storage racks and defective fuel assembly storage rack were physically removed from the SFP in 2007 during Cycle 12 (see Section 3.10). Therefore, these TS requirements are obsolete and may be removed.

In addition, the Fermi 2 TS contain programmatic requirements for the SFP in Section 5.5.13, "High Density Spent Fuel Racks." TS 5.5.13 describes the required program for the high density storage racks containing Boraflex. The purpose of the program is to monitor degradation of the Boraflex. The details of the program were recently provided to the NRC in the GL 2016-01 response (Reference 6.2). Following installation of the NETCO SNAP-IN® neutron absorbing inserts, the Boraflex will no longer be credited to perform a neutron absorption function. Future degradation of the Boraflex will not impact the criticality safety analysis. Therefore, the programmatic activities and commitments associated with Boraflex monitoring are no longer required and the requirements may be removed from the TS. DTE will also delete regulatory commitments associated with Boraflex monitoring that are not captured in the TS as discussed in Enclosure 9. The program that will be used for monitoring the new neutron absorbing inserts is the Neutron-Absorbing Material Monitoring Program described in Section 3.8.5. The Neutron-Absorbing Material Monitoring Program is a License Renewal program that currently applies to the Boral racks (details of Boral rack monitoring activities were also provided in the GL 2016-01 response) but will also apply to the new neutron-absorbing inserts as described in detail in Section 3.8.5.

See Enclosure 2 for the marked-up TS pages that reflect the proposed changes described above. Enclosure 3 provides the clean TS pages with the proposed changes incorporated. There are no TS Bases associated with these TS sections and therefore no TS Bases changes are required or provided. The Fermi 2 Updated Final Safety Analysis Report (UFSAR) will also be revised, upon implementation of the approved amendment, in accordance with 10 CFR 50.71(e). Some, but not all, of the UFSAR revisions associated with this amendment have been identified as commitments in Enclosure 9.

3.0 TECHNICAL EVALUATION

As described above, Fermi 2 has a License Renewal License Condition which requires replacement of Boraflex racks with Boral racks to eliminate credit for Boraflex as a neutron absorbing material prior to the PEO. Installation of NETCO SNAP-IN® neutron absorbing inserts into the Boraflex racks is a safe and effective alternative to rack replacement. Once the inserts are installed, the criticality safety analysis will no longer credit the Boraflex to perform a neutron absorption function. Technical evaluations of the proposed changes are provided in each of the sections below.

3.1 Background and Approach

The following subsections provide a description of the current SFP design basis, issues with Boraflex that led to the current License Condition, and the proposed resolution to install NETCO SNAP-IN® neutron absorbing inserts into the Boraflex racks.

3.1.1 Current Spent Fuel Pool Design Basis

The Fermi 2 UFSAR (Reference 6.9), Section 9.1.2, describes the current design bases and safety evaluation for storage of spent fuel at Fermi 2. A summary of current information from UFSAR Section 9.1.2 is provided below.

The spent fuel assemblies are placed in high-density fuel storage racks designed to ensure a k-effective of less than or equal to 0.95 with the SFP filled with unborated water for both normal and abnormal storage conditions. The calculated k-effective includes margins for uncertainty, including mechanical tolerances, which are statistically combined such that k-effective will be less than 0.95 with a 95 percent probability at a 95 percent confidence level.

The Fermi 2 SFP contains two types of high-density storage racks. The first type was supplied by Joseph Oat and utilizes Boraflex as the neutron absorbing material. These racks have a nominal 6.22 inch center-to-center distance between assemblies (pitch). There are thirteen racks of this type, with a total storage capacity of 2197 cells. The second type was supplied by Holtec and utilizes Boral as the neutron absorbing material. These racks have a nominal 6.23 inch pitch. There are nine racks of this type, with a total storage capacity of 1393 cells. Thus the Fermi 2 SFP has a capacity of 3590 storage cells. This capacity is less than the storage capacity limit of 4608 fuel assemblies defined in TS 4.3.3. No changes are being proposed in this LAR to the number of racks or to the total capacity of the Fermi 2 SFP. A table showing the detailed breakdown of cells in each rack is provided in the text of UFSAR Section 9.1.2.2.1.

The Joseph Oat high-density racks are of welded stainless steel construction with the Boraflex neutron absorber sandwiched between the stainless steel sheets. The Holtec high-density racks are square cross-section boxes with Boral neutron absorber panels on its sides to form a composite box. Additional details regarding the neutron absorbing materials in the Fermi 2 SFP storage racks were recently provided to the NRC in the Fermi 2 response to GL 2016-01 (Reference 6.2).

For the Boraflex racks, the k-effective less than or equal to 0.95 criterion will be satisfied if the maximum k-infinity calculated in the normal reactor core configuration (standard cold core geometry) is less than or equal to 1.3113. For the Boral racks, the 0.95 criterion will be satisfied if the maximum k-infinity is less than or equal to 1.3392 in standard cold core geometry. The net result is the k-infinity condition to meet the 0.95 criterion is higher for the Boral racks than for the Boraflex racks (i.e., the Boraflex racks are more limiting). Both of these maximum k-infinity values in the normal reactor core configuration at cold conditions are bounded by the value of 1.31 currently in the Technical Specifications.

The high-density fuel storage racks are supported at four corners. The supports elevate the rack base plate above the pool floor level, thus creating a water plenum for coolant inventory. The high-density fuel storage racks are designed to meet Category I requirements. They are required to remain functional during and after a safe-shutdown earthquake (SSE). The high-density fuel storage racks are neither anchored to the pool floor nor attached to the side walls. The individual rack modules are not interconnected. Analyses are performed to establish the structural margins

of safety. The racks are designed as freestanding and the effects of rack slide are addressed. Thermal-hydraulic analyses of the SFP are also performed. These analyses evaluate bulk temperature, loss-of-forced cooling scenarios, and local temperature.

3.1.2 Boraflex Degradation and License Renewal License Condition

Degradation of Boraflex has been identified in several industry-wide communications, most recently in GL 2016-01. The Fermi 2 UFSAR also acknowledges degradation of Boraflex, including its potential to shrink and develop gaps. The potential for Boraflex degradation is addressed in the current criticality safety analysis for the Boraflex racks. In addition, Fermi 2 maintains a program for monitoring the Boraflex throughout the life of the plant to verify the continued presence of sufficient Boraflex to meet the k-effective less than or equal to 0.95 criterion. This monitoring program is also described in TS 5.5.13. Additional details regarding the Boraflex monitoring program was provided to the NRC in the Fermi 2 response to GL 2016-01 (Reference 6.2).

At the time of the Fermi 2 License Renewal Application (LRA), DTE had intended to continue utilizing the Boraflex monitoring program described in the UFSAR and TS 5.5.13 throughout the PEO. However, as described previously, DTE made a commitment to the NRC by letter dated September 24, 2015 (Reference 6.5) to discontinue reliance on Boraflex to perform a neutron absorption function during the PEO. The DTE letter also identified that a Boraflex monitoring program would no longer be required during the PEO as a result of that commitment. When the Renewed Facility Operating License (No. NPF-43) was issued to DTE by the NRC on December 15, 2016 (Reference 6.4), it contained the License Condition requiring DTE to discontinue reliance on Boraflex to perform a neutron absorption function prior to the PEO which begins on March 20, 2025. The License Condition requires that this discontinued reliance be achieved by replacing the racks containing Boraflex with racks containing Boral (i.e., the Holtec type racks). As an alternative to rack replacement, DTE proposes to install NETCO SNAP-IN® neutron absorbing inserts in order to satisfy the intent of the License Condition.

The NRC reviewed the Fermi 2 response to GL 2016-01 and responded by letter (Reference 6.3) indicating that the Fermi 2 response adequately addressed the GL. The NRC close-out letter discussed the above license renewal activities as pertinent to the GL response and identified that corrective actions were being taken to manage degradation and maintain subcriticality. The NRC close-out letter also identified that follow-up inspections through the baseline reactor oversight process would be performed to ensure that Fermi 2 is properly managing the Boraflex degradation and maintaining the subcriticality of the SFP. As a result, DTE is not providing any interim analysis or proposing any interim configuration in this submittal. Instead, the purpose of this submittal is to satisfy the License Condition, as indicated above.

3.1.3 NETCO SNAP-IN® Neutron Absorbing Inserts Design Description

The NETCO SNAP-IN® neutron absorbing inserts are to be installed in the existing Boraflex racks. Once installed, these inserts become permanently affixed to the racks. The NETCO SNAP-IN® neutron absorbing inserts are made entirely of an aluminum boron carbide

composite. The neutron absorbing material is boron carbide (B_4C), with boron carbide particles homogeneously distributed in the metal. The rack insert encompasses the full length of the active fuel region of the fuel assembly when installed in the storage rack cell. The rack inserts are nominally the same length as a rack cell (approximately 175 inches).

Enclosure 8 Figures 2-1 and 2-2 show a typical NETCO SNAP-IN® insert and how they are installed in a SFP storage rack cell. The NETCO SNAP-IN® inserts are chevron-shaped and formed with a greater than 90-degree bend angle. This requires compression of the rack insert to install it into the SFP storage rack cell. After installation, the insert will conform to the 90-degree angle between adjacent spent fuel storage rack cell walls. When installed, the rack insert wings abut against the two adjacent faces of the SFP storage rack cell wall. With each insert installed in the same configuration, every face of all fuel assemblies will have neutron absorber material between it and one face of the adjacent fuel assemblies. The width of each wing of the chevron is slightly less than the minimum inside dimension of the fuel storage cell. Each edge of the wing is curled and it is this feature that accommodates cell-to-cell variations in inside dimensions. Near the top of the insert is a hole in each wing that engages the installation tool. The insert is designed to become an integral part of the fuel rack once it has been installed. This is achieved through the elastic deformation of the insert bearing against the rack cell wall and the associated friction force. The force between the insert wings and the rack cell walls in conjunction with the static friction between these surfaces serves to retain the insert.

The Fermi 2 inserts have a nominal boron content of 23 volume percent B_4C with a minimum specified ^{10}B areal density of 0.0157 g/cm^2. The nominal thickness is provided in Enclosure 4. The insert design was developed to fit the nominal Fermi 2 SFP Boraflex rack cell. Note that as the insert project continues, minor dimensional alterations to the current insert design may be made, as necessary, to accommodate fit or installation issues for specific SFP storage cells as described in the following subsection. Additional details regarding the design of the inserts, as well as a comparison of the Fermi 2 inserts to other industry inserts, are provided in Section 3.3.

3.1.4 Rack Insert Demonstration and Testing Activities

The project to install the NETCO SNAP-IN® inserts includes several demonstration and testing activities that will take place prior to actual installation. These activities are described as follows.

Clean pool testing was performed in December 2018. The clean pool tests were performed at the Curtiss-Wright (i.e., CWND, NETCO) facility using specially made, full scale test cells that were fabricated using design specifications of the SFP rack cells at Fermi 2. During the clean pool testing, test inserts made from non-borated, 3000 series aluminum, were installed and removed from each test cell in order to verify that the design specifications for each insert size had been met. The clean pool testing utilized the insert installation and removal tools (see Section 3.9 for additional details). The clean pool testing successfully demonstrated how inserts can be installed in an SFP rack cell such that it becomes an integral part of the cell but can also be removed later if required.

Insert sizing verification was performed in March 2019. The sizing verification took place in the Fermi 2 SFP. The test inserts for the sizing verification were made from non-borated, 3000 series aluminum. Approximately 40 of these sizing inserts were used to check sizing in 60 or more cells of the Joseph Oat storage racks. The main purpose of these test installations was to provide a basis for determining the appropriate size of the wing width and initial bend angle needed for one or more insert designs that will later be installed in the Fermi 2 SFP. Load tests were performed during the removal of these test inserts to determine the force required to remove the insert, but the results will not be identical to those of the prototype inserts made from the aluminum-boron carbide composite material (BORALCAN™) due to slight differences in mechanical properties of the materials. However, the results will still be used as a guide to ensure the final design of the absorber inserts will meet the minimum force required to remove an insert. Once the preliminary insert design(s) are determined based on the test results of the 3000 series aluminum test inserts, future load tests will be performed with prototype inserts made from the BORALCAN™ neutron absorber material to verify the retention force requirements as described below. As part of the testing, a dummy fuel assembly was also used to check for fuel interference. No significant interference between the insert and dummy fuel assembly was identified. Note that the wing widths of the inserts used for the sizing verification are all greater than the minimum wing width assumed in the criticality safety analysis. In addition, the initial bend angle is not an input to the criticality analysis. Therefore, it was not expected that the results of this sizing verification would impact the analyses already performed prior to the sizing verification as described in this LAR. Although unlikely, if any dimensional changes are required based on further review of the results of this sizing verification, the critical insert parameters (e.g., areal density, retention force, etc.) will be validated against the analyses to confirm that the results remain acceptable.

Prototype installation is scheduled to take place in October 2019. The prototype installation will take place in the Fermi 2 SFP to provide final verification of the insert design. Sixty prototype inserts made with the final design dimensions will be installed into selected cell locations that encompass different modules in the population of the Joseph Oat storage racks. These prototype inserts will be made from actual BORALCAN™, such that they are identical to those that will be manufactured for permanent installation. The prototype inserts will be subjected to clean pool testing, similar to that described above, prior to delivery to Fermi 2. For each of the sixty prototype inserts, the key parameters to be validated during this activity will be insertion success and retention force. In addition, either dummy and/or actual fuel assemblies will be used to test fuel assembly insertion and removal for at least a sample of the prototype inserts in order to confirm lack of fuel interference. The prototype inserts may remain installed in the Fermi 2 SFP following completion of this activity provided that all acceptance criterion are met, all quality assurance documentation has been completed, and the provisions of 10 CFR 50.59 have been met. However, no credit will be taken for the prototype inserts to perform a neutron absorption function until implementation of the license amendment as described in Section 3.1.5.

Successful completion of all these activities will provide reasonable assurance that the NETCO SNAP-IN® inserts will perform their intended safety function when installed. The actual installation will be performed per the schedule discussed in the following subsection.

3.1.5 Installation and Implementation Schedule

Installation of the inserts requires access to the SFP. The schedule therefore must be coordinated with other major activities that may also utilize the SFP, including refueling outages. Installation is currently scheduled to begin in the summer of 2020. Installation is currently scheduled to be completed by the summer of 2021.

DTE has requested that this LAR be approved by October 1, 2020 which would not be prior to the currently scheduled start of installation in the summer of 2020. Since the LAR is not expected to be approved prior to the currently scheduled start of installation, DTE plans to perform the physical installation of the inserts under the provisions of 10 CFR 50.59 as has been done at other plants. However, NRC review and approval of the new criticality safety analysis provided with this LAR is required prior to crediting these inserts to perform a neutron absorption function. In addition, since the new criticality safety analysis is performed for the final configuration with all inserts installed, the Boraflex will still be relied upon until installation is fully complete. Therefore, DTE will not implement the amendment, once approved, until after installation is fully complete.

3.2 Criticality

A criticality safety analysis was performed by General Electric – Hitachi (GEH) / Global Nuclear Fuel (GNF) to support the storage of spent fuel in the Fermi 2 SFP with the NETCO SNAP-IN® neutron absorbing inserts installed in the Boraflex racks. A summary of the analysis is provided in Enclosure 4 (proprietary version) and Enclosure 5 (non-proprietary version). The analysis demonstrates that the effective neutron multiplication factor, k-effective, does not exceed 0.95, at a 95 percent probability, 95 percent confidence level, with the following assumptions:

1. A maximum cold uncontrolled peak in-core eigenvalue (i.e., corresponding to the maximum k-infinity in TS 4.3.1.a) of 1.30 is used. Since this value is less than the value currently specified in TS 4.3.1.a, revision to the TS is required. The proposed change to TS 4.3.1.a is to use a value of 1.30 to ensure consistency with this analysis.
2. The Boraflex storage racks are fully loaded with a fuel design that bounds any fuel currently in the Fermi 2 SFP. This covers legacy fuel types and the current fuel type which is GE14. In addition, the analysis includes consideration of the planned future fuel type of GNF3. Although GNF3 fuel is not currently present in the Fermi 2 SFP, introduction of GNF3 is expected to begin in Cycle 21 (approximately 2020) and this fuel type was therefore considered in the analysis.
3. A minimum Boron-10 (^{10}B) areal density of 0.0157 g/cm^2 is used for each NETCO SNAP-IN® neutron absorbing insert.
4. No negative reactivity credit is taken for the Boraflex in the rack cells (i.e., Boraflex is conservatively modeled as water).
5. NETCO SNAP-IN® rack inserts are installed in all SFP storage rack cells containing Boraflex, with a specified insert orientation to isolate the racks from neutron interactions with the Boral racks.
6. The Fermi 2 SFP assumed to be flooded with unborated water.

7. Quantification of credible normal and abnormal conditions with consideration of biases, rack/fuel tolerances, and computational uncertainties are considered (see Section 3.2.2).

3.2.1 Criticality Safety Analysis Methodology

The criticality safety analysis summarized in Enclosure 4 (proprietary version) and Enclosure 5 (non-proprietary version) utilizes the computer codes MCNP-05P (the GEH/GNF proprietary version of MCNP5) and TGBLA06. TGBLA06 solves two-dimensional diffusion equations with diffusion parameters corrected by transport theory to provide system multiplication factors and perform burnup (depletion) calculations. MCNP-05P has been validated and verified for SFP storage rack evaluations by benchmarking calculations of light water reactor critical experiments (included as part of Enclosures 4 and 5). MCNP-05P implements a robust geometry representation that can model complex components in three dimensions. Thus this methodology has the flexibility to model changes in input parameters, such as rack and fuel geometry. The NRC has previously approved the MCNP-05P/TGBLA06 code package for use in a similar SFP criticality safety analysis involving NETCO SNAP-IN® neutron absorbing inserts for Peach Bottom Units 2 and 3 (see Section 4.2).

3.2.2 Nuclear Energy Institute 12-16 Guidance

The criticality safety analysis was performed using the guidance in Nuclear Energy Institute (NEI) 12-16 (Reference 6.8). The NEI 12-16 guidance is intended to provide more permanent guidance than that provided in Interim Staff Guidance (ISG) DSS-ISG-2010-01. NEI 12-16 Appendix C is a criticality safety analysis checklist to ensure that all applicable subject areas of NEI 12-16 are addressed. The completed NEI 12-16 Appendix C checklist for the criticality safety analysis described above and summarized in Enclosures 4 and 5 is provided as Enclosure 7 to this LAR. The checklist in Enclosure 7 includes cross-references to the relevant sections in Enclosures 4 and 5 where additional details can be found. Note that the version of NEI 12-16 utilized (i.e., Revision 2, Draft B) was the most recent version that had been submitted to the NRC at the time of beginning the analysis. Although a new revision to NEI 12-16 (i.e., Revision 3) has been subsequently submitted to the NRC, a review of the differences between the two revisions did not identify any items that would require changing or updating the analysis.

3.3 Materials

The NETCO SNAP-IN® BORALCAN™ composite rack insert material must ensure that the neutron absorber remains in place over the lifetime of the SFP storage racks during normal operation and abnormal events. Enclosure 8 provides a detailed evaluation of the BORALCAN™ composite material supplied by Rio-Tinto-Alcan. The report demonstrates that the material is suitable as a neutron absorber to maintain the SFPs within design and regulatory limits over the life of the SFP storage racks. Qualification testing has been performed to confirm its acceptability and the monitoring programs described in Section 3.8 will be established to confirm its continued acceptability to perform its required design functions in the Fermi 2 SFP.

The production process for manufacturing the rack inserts is described in detail in Enclosure 8. The rack insert is made from one sheet of the BORALCAN™ composite material. Rio-Tinto-Alcan developed a technique to produce a homogeneous distribution of B_4C in the finished product.

Coupons will be cut from each rolled rack insert blank which is of sufficient size to manufacture two rack inserts. Coupons will be subjected to: 1) neutron attenuation testing to verify the as-manufactured ^{10}B areal density; and 2) tensile and bend testing to verify mechanical properties. Inductively Coupled Plasma (ICP) Analysis is performed to verify material composition prior to manufacturing.

3.3.1 Areal Density of Boron-10

The insert manufacturing quality assurance (QA) testing lower limit for the areal density of boron in the BORALCAN™ composite made by Rio-Tinto-Alcan is given in terms of ^{10}B, and is 0.0157 g/cm^2. Verification of the minimum certified areal density of ^{10}B in the rack inserts is performed during manufacturing as described below. Verification of the areal density of ^{10}B over the lifetime of the racks will be performed through the long-term coupon monitoring program described in Section 3.8.

CWND, NETCO performs 100% areal density sample size testing. Two inserts and one areal density coupon are cut from each rolled sheet of BORALCAN™ material. Traceability of each insert and coupon to the appropriate material sheet are maintained throughout the entire manufacturing process. The testing and data collection for each coupon is performed in accordance with CWND, NETCO procedures using CWND, NETCO qualified areal density standards. The data collected during the controlled testing are processed by CWND, NETCO qualified engineers in accordance with CWND, NETCO procedures. The test report will be issued to Fermi 2 upon delivery of the inserts.

The test coupons are subjected to neutron attenuation areal density testing at the CWND, NETCO Penn State Laboratory. For each coupon, a specific measured areal density value is obtained. For each coupon, the 3σ (99.7%) uncertainty is subtracted from the measured value to determine the minimum measured areal density value. The uncertainty is calculated by the propagation of the independent uncertainties associated with the parameters used to calculate the areal density. The uncertainties taken into account include those of the certified areal density standards (i.e., material density, material thickness, weight percent of boron in B_4C, and weight percent of ^{10}B in boron) and those of the testing (i.e., number of counts and count time). Therefore, the areal density uncertainty is not statistically determined; however, uncertainty associated with count rate is subject to statistical evaluation.

The measurement uncertainty of the neutron attenuation testing is taken into account when determining the acceptability of a given test result. Individual tested coupons must meet or exceed the 0.0157 g/cm^2 ^{10}B limit with this uncertainty subtracted from the measured value. Inserts are rejected if their corresponding coupon has a minimum measured ^{10}B areal density value less than 0.0157 g/cm^2.

Given the 100% sampling and 99.7% confidence level for the uncertainty, DTE has assurance that the areal density of each insert that is installed in the Fermi 2 SFP will meet or exceed the minimum certified value assumed in the criticality safety analysis (see Section 3.2) at the 3σ level. As a result, no restrictions are required for specific inserts to be placed in specific rack cells during installation.

Note that Enclosure 8, Section 3.4, refers to a ^{10}B areal density limit of 0.0087 g/cm^2 for the QA test program. This value is for the NETCO SNAP-IN® rack inserts manufactured for LaSalle, which was the first use of the inserts. All of the NETCO SNAP-IN® rack inserts manufactured for a particular customer have the same minimum required ^{10}B areal density, but that value may differ by customer. The 0.0087 g/cm^2 is an example value used in the material qualification report and is not indicative of the minimum required ^{10}B areal density in all NETCO SNAP-IN® rack inserts for all customers. The ^{10}B areal density in the inserts for a given plant is customized for that plant's needs based on the criticality safety analysis and rack design. Each customer specifies the minimum required ^{10}B areal density for their plant's inserts in the procurement specification, specifically, the value used in the criticality safety analysis. For Fermi 2, the minimum required manufactured ^{10}B areal density value is 0.0157 g/cm^2.

3.3.2 Corrosion

Resistance to material loss, pitting, cracking, and blistering is important to ensuring that the ^{10}B will not be lost, and that distortion of the rack insert will not interfere with future fuel movement. Therefore, an accelerated corrosion test program was performed to determine the susceptibility of the BORALCAN™ composite made by Rio-Tinto-Alcan to general (i.e., uniform) and localized (i.e., pitting) corrosion in SFPs. This program is described in detail in Enclosure 8. The material qualification program included material at 16 volume percent and 25 volume percent loadings of boron carbide. The range of as-tested boron carbide loadings of the test coupons bound the loading to be used at Fermi 2 (23 volume percent B_4C). Three types of coupons were tested: (1) rectangular general coupons, to determine the rate at which a uniform oxide film forms; (2) bend coupons, intended to simulate the bend section of the NETCO SNAP-IN® rack insert, to determine whether or not bend deformation and stress adversely affect the corrosion susceptibility of the BORALCAN™ material; and (3) galvanic (i.e., bi-metallic) coupons, prepared with the BORALCAN™ composite and 304L stainless steel, Inconel 718, and Zircaloy materials to evaluate the potential for galvanic corrosion. Coupons have been tested at the CWND, NETCO laboratory in deionized water, simulating BWR pool conditions at 195°F (90.5°C) for greater than 8000 hours to accelerate any corrosion effects. Coupons were removed after approximately 2000, 4000, 6000, and 8000 hours and subjected to testing. This test program has been completed and the evaluation is presented in Enclosure 8, Table 5-7.

Prior to testing, the coupons were pre-characterized with respect to thickness, weight, and ^{10}B areal density. After testing, the coupons were subjected to post-test characterization of these same attributes. The testing results are described in Enclosure 8. Measured corrosion rates were very low. The reason for the low corrosion rates is that the oxide film is largely self-passivating, limiting the rate of subsequent oxidation of the base metal and also as a result of maintaining

SFP water chemistry within the limits of Electric Power Research Institute (EPRI) Water Chemistry Guidelines. This property of the oxide film leads to the excellent corrosion resistance of AA1100 aluminum alloy. It is noted that the conversion of a thin, uniform layer to the oxide does not result in a loss of the boron carbide neutron absorber. This is confirmed by the neutron attenuation measurement results that show no change in ^{10}B areal density.

Optical microscopy was performed to verify that the oxide films were substantially removed prior to determining coupon weight loss and prior to inspecting for any anomalies along the outer bend radii of the bend coupons. Optical microscopy of the inside and outside radius of the bend coupons before and after acid cleaning revealed no cracks or other anomalistic corrosion behavior.

Once installed, the NETCO SNAP-IN® rack inserts assume a constant strain condition within the SFP storage rack cell. This compression leads to internal stresses, especially at the bend, that might make the rack inserts susceptible to stress corrosion cracking. An examination of the literature on the subject (i.e., References 5-5 and 5-6 in Enclosure 8) indicates that, in general, high-purity aluminum and low-strength aluminum alloys are not susceptible to stress corrosion cracking. However, bend coupons to be placed in the SFP will be maintained under the same strain conditions to provide indication of any unexpected crack phenomena (see Section 3.8).

3.3.3 Insert Dimensions and Physical Properties

Enclosure 8 Figures 2-1 and 2-2 show a typical NETCO SNAP-IN® insert and how they are installed in a SFP storage rack cell. The specific NETCO SNAP-IN® rack inserts to be used in the Fermi 2 SFP will have the dimensions and physical properties as indicated in Table 3.3-1 below. The table also compares these dimensions and physical properties to those used at the other selected plants (see Section 4.2) that have installed NETCO SNAP-IN® rack inserts. The Fermi 2 length and thickness values are very similar to the values for the other plants. The ^{10}B areal density for Fermi 2 is higher, however it is almost identical to the ^{10}B areal density utilized in the Palo Verde inserts (see Section 4.2). The B_4C loading for Fermi 2 is also higher, but is bounded by the loading value of 25% used in the material qualification report in Enclosure 8.

Table 3.3-1: Fermi 2 Inserts Compared to Other Plant Inserts

Dimension or Property	**Fermi 2 Value**	**Exelon Plants* Range of Values**	**River Bend Value**
Nominal Length (inches)	175	165 – 169	169
Nominal Thickness (inches)	See Enclosure 4	0.065 – 0.085	0.080
^{10}B Minimum Areal Density (g/cm^2)	0.0157	0.0087 – 0.0116	0.0129
Nominal B_4C Loading (volume %)	23	17 – 19	21

**Exelon plants include Quad Cities, Peach Bottom, and LaSalle – see Section 4.2*

3.4 Mechanical

3.4.1 Fuel Assembly Clearances

Placement of the rack inserts in a SFP storage rack cell slightly reduces the cell inside dimensions available for fuel assembly insertion (see Figure 2-1 in Enclosure 8). The prototype testing that will be performed as described in Section 3.1.4 will confirm adequate clearance between a fuel assembly and rack cells containing inserts.

If there is unexpected warping or bowing of the rack insert after installation that reduces the fuel assembly-to-SFP storage rack insert clearance, then the fuel handler would notice increased force indicated on the hoist when attempting to raise (i.e., remove) the fuel assembly. If the rack insert would inadvertently come out of an SFP storage rack cell with an assembly, this temporary condition would be bounded by the missing rack insert evaluation in the criticality safety analysis (see Section 5.5.2 of Enclosure 4). DTE has also identified operating experience from the LaSalle plant regarding this potential for an insert to be inadvertently removed. In February 2013, an insert was inadvertently removed while moving a fuel assembly. It was identified that the cause of this event was that the fuel assembly channel fastener came in contact with the insert. To reduce the potential for occurrence of a similar type event at Fermi 2, DTE plans to administratively control insert and channel fastener orientation. Procedures will ensure that fuel assemblies are oriented with the channel fastener at the opposite corner from the inserts when placing a fuel assembly into an SFP storage rack cell with an insert. The criticality safety analysis consideration of a missing insert as described above would bound a single missing insert resulting from an inadvertent removal if one were to potentially occur despite the additional administrative controls proposed by Fermi 2. Inadvertent removal of a rack insert would be entered into the Fermi 2 Corrective Action Program for resolution of the condition.

If a channeled spent fuel assembly cannot fit into the SFP storage rack cells containing rack inserts due to mechanical clearances, the fuel assembly could be placed into the other SFP storage rack cells (i.e., the Boral racks). Alternatively, if it is not desired to place the fuel assembly in the Boral racks, the fuel assembly could be de-channeled and stored.

3.4.2 Mechanical Wear

Minimal insert material wear is expected within the active fuel region due to adequate clearance between the fuel assembly and rack insert. The combined effects of adequate clearance and infrequent fuel assembly movement will preclude significant wear of the rack insert. A rack insert in a high-duty rack cell location (i.e., one with a relatively high number of fuel assembly insertions and removals) will be inspected for wear as described in Section 3.8.4.

Manufacturing experience with the inserts has shown that handling and environmental damage may lead to scratches and surface imperfections locally along the insert length. Minor local effects would be bounded by the criticality safety analysis which conservatively assumes that an entire insert is missing from a cell (see Section 3.7.1). Because the clearance between the fuel and rack insert will be verified by prototype testing as described in Section 3.1.4, it is unlikely

that a significant number of those events would result in any contact leading to uniform degradation of the insert face.

3.4.3 Insertion and Retention Forces

As described in Section 3.1.4, the project to install the NETCO SNAP-IN® inserts includes several demonstration and testing activities that will take place prior to actual installation. These activities include clean pool testing (completed in December 2018), sizing verification (completed in March 2019), and prototype installation (to be performed in October 2019). Collectively, these activities will confirm the insertion forces required to install the inserts, including lack of fuel interference, and verify retention forces which hold the inserts in place following insertion. Successful completion of these activities will ensure that there is no condition that would prevent the inserts from performing their intended safety function.

Insertion Force – The insertion or installation force is developed through the installation tool. This force is developed by the weight of the tool. The combined weight of the installation tool and insert will weigh less than 1000 pounds to maintain a load under the limit used for the hoist for the refueling bridge. Installation of the insert will not damage the existing SFP storage rack structural integrity or the rack insert itself (see Section 3.5). When using the installation tool to install an insert, the only force that is applied to the racks is through the NETCO SNAP-IN® rack insert itself. Also, the installation tool and insert combined weight of less than 1000 pounds is less than the limit for moving loads above the fuel stored in the Fermi 2 SFP.

Retention Force – Acceptance testing will be performed to measure the force required to remove an insert from a fuel storage rack cell once installed (i.e., the retention force). That force will be required to be greater than or equal to 250 lbf which meets the Fermi 2 specific design criteria for seismic accelerations and stress relaxation (see Section 3.4.4 below).

Drag Force – The drag force or interference between the fuel assembly and insert has been previously measured during the prototype testing at other plants. These drag force measurements have been significantly less than 50 lbs (see Reference 6.14). Similarly small drag forces will be confirmed during the Fermi 2 testing by a lack of fuel assembly interference. As a result, the maximum drag force will be significantly less than the retention force, such that there is adequate margin to ensure that an insert would not be removed during fuel assembly withdrawal given the minimum observed retention force.

In summary, the prototype testing to be performed, along with the testing previously completed, will be used to confirm the conclusions of the structural analysis and provide reasonable assurance that NETCO SNAP-IN® rack inserts will perform their intended safety function when installed in the Fermi 2 SFP.

3.4.4 Stress Relaxation in the Absorber Rack Inserts

During installation, the NETCO SNAP-IN® rack inserts are compressed from an initial bend angle of greater than 90 degrees to fit in the square dimensions of the SFP storage rack cell

interior. Once installed, the internal stresses in the rack inserts may be susceptible to relaxation over time. This relaxation would result in less force against the SFP storage rack cell wall and lower retention force. An analysis of stress relaxation in aluminum alloys has been performed to establish the expected performance of the rack inserts in this regard (see Enclosure 8, Section 4.1).

Data for Type AA1100-H112 series aluminum alloy was analyzed to estimate total stress relaxation after 20 years of service in Enclosure 8. The results of that analysis showed that the Type AA1100-H112 series aluminum alloy is expected to experience an approximate stress reduction of 50 percent over 20 years. Discussion of a similar analysis done at approximately 93°F in Reference 6.14 identified an approximate stress reduction of 60 percent over 20 years. Note that the average bulk water temperature of the Fermi 2 SFP over the past two years (i.e., early 2017 to early 2019) was approximately 94°F and is therefore very similar to the temperature used for that analysis. Given the expected reduced elongation of the Rio-Tinto-Alcan W1100N-series composite material in comparison with AA1100-H112 series aluminum alloy, this stress relaxation (i.e. 60%) is considered a reasonable value to use for the performance of the Rio-Tinto-Alcan W1100N-series material used to fabricate the NETCO SNAP-IN® rack inserts.

In the case of a 60 percent reduction in retention force, the inserts would still maintain a minimum 100 lbf of retention force within the cell (i.e., 60 percent reduction of the 250 lbf minimum retention force) required to remove an insert. The 100 lbf retention force is adequate to maintain the inserts in their required position under SSE conditions with margin (see Section 3.5 below).

Using data for pure AA1100-H1112 aluminum alloy provides a reasonable estimate for relaxation for the boron carbide-reinforced Rio-Tinto-Alcan W1100N-series material. Stress relaxation in boron carbide reinforced W1100N-series aluminum is expected to be less than for the AA1100-series pure alloy because of the presence of the reinforcing boron carbide. In addition, the impact of stress relaxation on retention force will be monitored as part of the program described in Section 3.8.

3.5 Seismic/Structural

As described in UFSAR Section 9.1.2.2.2, the spent fuel storage racks are designed to comply with Seismic Category I requirements in accordance with the following NRC Regulatory Guides (RG): RG 1.29, “Seismic Design Classification,” Revision 3, September 1978; RG 1.61, “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 0, October 1973; and RG 1.92, “Combining Modal Responses and Spatial Components in Seismic Response Analysis,” Revision 1, February 1976. The design of the spent fuel storage racks is in accordance with Standard Review Plan (SRP) Section 9.1.2, “New and Spent Fuel Storage,” Revision 2, March 1979 (as applicable to spent fuel racks). As a result, the rack inserts are also classified as Seismic Category I.

An evaluation of the existing design basis seismic/structural analysis for the Joseph Oat (i.e. Boraflex) SFP storage racks was performed to determine the impact of the installation of inserts in all cell locations. The evaluation determined that the existing racks can accommodate the inserts without significant impact on the racks themselves based on the following:

- The inserts are installed in the space between the fuel assembly and the cell well. The existing seismic/structural analysis use a BWR fuel assembly weight of approximately 700 lbs (dry). As the rack inserts weight less than 20 lbs each, they represent only a small increase in weight per cell location (i.e. less than 3%).
- The maximum calculated stress factor for any of the installed Joseph Oat racks is 0.257 compared to the maximum allowable limit of 1.0. Therefore, the racks have a minimum safety factor of approximately 4 against ASME Section III, Subsection NF stress limits.
- The existing analyses for maximum seismic impact load between a fuel assembly and the surrounding cell shows that the predicted results are a factor of 2 less than the limits for the rack walls, connecting welds, and Boraflex panels. As described previously, the installation of inserts results in only a small weight increase. In addition, the installed inserts reduce the free space between the fuel assembly and the surrounding cell walls, which would tend to reduce seismic impact forces.
- The strength evaluation of the reinforced concrete SFP for Fermi 2 includes evaluation of the final configuration following implementation of the third campaign associated with License Amendment No. 141 (see Section 3.10). The final configuration following campaign three represents the highest density storage configuration and therefore places the most load on the SFP floor from a design analysis. Since the current capacity from implementing only the first two campaigns of Amendment No. 141 is much less than that for the third campaign, the reduction in total fuel assembly weight substantially offsets the relatively small weight increase due to the inserts. Therefore the existing SFP structural evaluation remains bounding of the current configuration even once inserts are installed.

The existing SFP design basis also includes an analysis of the thermal effects of gamma heating (from the spent fuel) on the Fermi 2 SFP concrete walls. The NETCO SNAP-IN® rack inserts would tend to absorb some amount of gamma energy, thereby reducing the amount of energy deposited in the pool walls. Neglecting the inserts and the associated gamma energy absorption conservatively maximizes the energy deposition in the pool walls and the resulting temperature gradient. Therefore, there is no adverse impact on the average or maximum SFP concrete temperatures due to the addition of NETCO SNAP-IN® rack inserts to the SFP.

The existing SFP design basis further includes an analysis for the potential buckling of the SFP liner due to the differential thermal expansion between the liner and the underlying concrete. The results of the analysis are used to determine the safety margin against failure of the liner plate and the liner welds. The analysis considers the combined effects of maximum thermal load and hydrostatic pressure. Since the values for both temperature and pressure loads are conservatively assumed as bounding values, there is no adverse impact on the SFP liner due to the addition of NETCO SNAP-IN® rack inserts to the SFP.

In addition to the evaluations described above for the SFP racks, an evaluation was performed to verify that the inserts would be retained within the cell during seismic events. The evaluation shows a retention force of 81 lbf is required to prevent upward movement of the insert during seismic events. The retention force due to the insert design is required to be at least 63 lbs, since the weight of the insert itself (less than 20 lbs) provides the remainder of the 81 lbf of retention force. Given the initial retention force at the time of installation of at least 250 lbf, the evaluation determines that a stress relaxation of over 70% can be accommodated. This result provides margin to accommodate stress relaxation larger than the expected stress relaxation of 60% discussed in Section 3.4.4 above. The test results from the demonstration activities (see Section 3.1.4) and the corresponding initial retention force criteria (i.e., 250 lbf) will ensure that the inserts remain in the installed location during fuel moves and during a design basis seismic event. The monitoring program described in Section 3.8.4 will ensure that stress relaxation over time does not reduce the retention force below the minimum required during seismic events. DTE may perform future refinement of the seismic evaluation to reduce the minimum required retention force to provide additional margin for stress relaxation if needed based on the results of the monitoring program described in Section 3.8.4.

As described in Section 4.2, NETCO SNAP-IN® rack inserts have been installed in several plants. Structural analyses of the inserts themselves have been previously performed as part of these applications to ensure there is no potential for operational failure of the rack insert during design basis conditions. An operational failure in this context is the inability of the rack insert to perform its intended function as a neutron absorber or to maintain the critical characteristics to which it was manufactured. These analyses have also demonstrated that the stresses on the inserts during installation (and in the installed configuration) will not result in operational failure of the inserts. The results of these analyses have been confirmed based on the successful installation and continued use of inserts in the SFPs at these plants. These previous analyses and subsequent operational experience are applicable to the Fermi 2 NETCO SNAP-IN® rack inserts due to the similarity in design (see Section 3.3.3). However, additional confirmatory analyses of the inserts will be performed for Fermi 2 using the final design specifications based on the sizing tests described in Section 3.1.4. These analyses will demonstrate the adequacy of the inserts from a seismic/structural perspective.

3.6 Thermal-Hydraulic

Installation of the NETCO SNAP-IN® rack inserts does not alter the allowed maximum number of fuel assemblies, maximum heat loads, or methods of determining decay heat loads in the SFP. The rack inserts displace a small amount of water inventory in the SFP. The volume of water displaced by the rack inserts is negligible compared to the total SFP water volume. Thus, there is also a negligible impact on the SFP maximum bulk temperatures time-to-boil, and boil-off rate for the SFP. The rack inserts may reduce natural circulation flow in the region within the SFP storage rack cell but outside of the fuel channel/assembly. Fuel assembly heat removal via natural circulation through the fuel assembly itself is not affected. This has an insignificant impact on the heat transferred to the SFP and the heat removal capability of the SFP cooling system. Based on these considerations, there is an insignificant overall effect on the thermal-hydraulic design of the SFP due to installation of the rack inserts.

3.7 Accident Conditions

3.7.1 Accident Considerations Related to Criticality

The SFP storage rack configuration was analyzed for credible accident scenarios. The scenarios considered are presented in the bulleted list that follows and are discussed in Section 5.5 of Enclosure 4.

- No inserts on rack periphery
- Missing insert
- Dropped/damaged fuel
- Abnormal positioning of a fuel assembly outside the fuel storage rack
- Dropped bundle on rack
- Rack sliding
- Loss of spent fuel cooling

As discussed in Section 3.2 and demonstrated in Enclosure 4, the criticality safety analysis performed showed a storage rack maximum k-effective of less than 0.95, at a 95% probability, 95% confidence level.

Note that misorientation of an insert is not analyzed as a credible accident scenario. Insert installation procedures will require verification of the correct insert orientation, consistent with the criticality safety analysis assumptions. If an insert is identified as misoriented, the condition would be corrected. Any interim period where an insert was misoriented would be bounded by the case of a missing insert, which is explicitly addressed in the criticality safety analysis.

3.7.2 Fuel Handling Accident

Use of the NETCO SNAP-IN® rack inserts does not affect the radiological consequences of the fuel handling accident (FHA). The design basis FHA described in UFSAR Section 15.7.4 assumes that during a refueling operation, a fuel assembly and refueling mast are dropped on top of irradiated fuel in the core. The UFSAR describes this scenario as bounding an FHA over the SFP. The source term of the longer-cooled fuel in the SFP available for release as a result of a postulated FHA is less than that for the fuel in the core immediately following shutdown. The potential drop height over the SFP is also less than the potential drop height above the core. The rack insert itself weighs 20 lbs or less such that a dropped insert by itself would be unlikely to have any substantial impact on fuel in the SFP below. However, the rack insert would typically be moved with one of its associated tools (installation tool or removal tool). An insert coupled with one of these tools would be of similar geometry but lesser combined weight to a fuel assembly and refueling mast. In addition, since the UFSAR Section 15.7.4 analysis assumes failure of all the fuel rods in the dropped assembly in addition to failure of the fuel that is impacted by the dropped assembly, a dropped rack insert and associated tool would result in fewer fuel failures for the same drop height and weight. For all of these reasons, the radiological

consequences of a potential drop of a rack insert and removal/installation tool above fuel in the SFP is bounded by the UFSAR Section 15.7.4 design basis FHA.

3.8 Rack Insert Monitoring Program

3.8.1 Monitoring Program Overview

Rio-Tinto-Alcan provides an aluminum boron carbide composite (i.e., BORALCAN™) from which the NETCO SNAP-IN® rack inserts are fabricated. Rio-Tinto-Alcan material has been previously approved for use in SFP racks in other plants as indicated in Section 4.2. Initial corrosion testing in simulated SFP conditions has been described in Section 3.3.2 above. DTE will implement the monitoring activities described in the subsections below that consist of monitoring the physical properties of the absorber material, performing periodic neutron attenuation testing to confirm the physical properties, and observing the inserts for wear. If an abnormal condition is identified and confirmed, the abnormal condition would be entered into the Fermi 2 Corrective Action Program for disposition.

3.8.2 Fast Start Coupon Surveillance Program (LaSalle)

The fast start coupon surveillance program was a one-time program implemented at LaSalle (see Section 4.2) before the first deployment of NETCO SNAP-IN® rack inserts. This program consisted of a series of 24 coupons cut from extra Rio-Tinto-Alcan composite produced for the LaSalle demonstration program. This coupon string was installed in the LaSalle SFP. The coupons cut from the demonstration program Rio-Tinto-Alcan material were 2x4 inches and had two 0.25 inch diameter holes along the top and bottom edge. The purpose of the fast start program was to provide early performance data on the Rio-Tinto-Alcan composite in a SFP environment in support of prototype fabrication activities for the NETCO SNAP-IN® rack inserts product line.

Following each LaSalle refueling outage, the fast start coupons were placed in a spent fuel storage rack cell surrounded by eight cells with freshly discharged fuel which remained there until the next refueling outage. In this manner the gamma energy deposition and temperatures of the coupons were maximized. Two coupons were removed from the string approximately every six months and sent to a qualified laboratory for testing and inspection. The coupons were subjected to pre-installation characterization and were post-test characterized.

The fast-start surveillance program at LaSalle was initiated as part of the product development and demonstration effort undertaken by CWND, NETCO after Exelon decided to employ NETCO SNAP-IN® rack inserts made from Rio-Tinto-Alcan material at LaSalle. The Rio-Tinto-Alcan material was tested and demonstrated to perform well in the laboratory as part of an 8000-hour accelerated corrosion test in simulated SFP environments.

The fast start testing program was intended to identify unanticipated insert material performance issues during the demonstration of the first-of-a-kind use of NETCO SNAP-IN® inserts in SFPs. The fast start coupon surveillance program at LaSalle was intended to ensure that insert material

performance was satisfactory prior to full scale project implementation for Exelon. Based on the satisfactory results at LaSalle and the similarities of the SFP water chemistry, the program does not need to be duplicated for Fermi 2.

The LaSalle and Fermi 2 SFP chemistries and temperatures vary day-to-day; however, in general, are similar with respect to water chemistry and normal operating temperature. The Fermi 2 maximum fuel pool temperature limit in the UFSAR is 150°F. The normal operating temperature range for the Fermi 2 SFP is between 80°F and 100°F, with the average temperature over the past 2 years being approximately 94°F. These maximum and normal operating temperatures are very similar to those identified for LaSalle. The chemistry program that governs SFP chemistry for both LaSalle and Fermi 2 is in accordance with the requirements of BWRVIP-190, "BWR Water Chemistry Guidelines."

The results of the LaSalle inspections were previously submitted to the NRC with the license amendment request for Quad Cities (Reference 6.14) to use NETCO SNAP-IN® inserts in their SFPs. As described in the Quad Cities submittal, there was essentially no change in the Rio-Tinto-Alcan composite coupons from their pre-use characterization values.

Enclosure 8 provides an overall qualification of the insert material for both Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) SFP environments at a range of B_4C loadings (16 to 25 volume percent) in aluminum which bounds the Fermi 2 inserts (i.e., 23 volume percent).

3.8.3 Long-Term Coupon Monitoring Program

The long-term coupon monitoring program at Fermi 2 will consist of periodic testing of different types of coupons fastened to two specially designed coupon "trees." The coupon trees will be placed within the Fermi 2 SFP as part of the first installation campaign of NETCO SNAP-IN® rack inserts and will reside there as long as the spent fuel storage racks with NETCO SNAP-IN® rack inserts continue to be used. Periodically, as described below, coupons will be removed and sent to a qualified laboratory for testing.

The types and minimum quantities of the long-term monitoring coupons are described in Table 3.8-1 below. All coupons will be manufactured to the same material specification as the Fermi 2 rack inserts. Both coupon trees are designed to be inserted into rack cells. One coupon tree is designed to hold most of the galvanic coupons. The other coupon tree will hold the general and bend coupons and the remaining galvanic coupons. The general and galvanic coupons will be monitored for any changes to their physical properties and especially for any changes to their effective areal density or signs of corrosion, which could indicate neutron absorber material degradation. They will be situated near the center of the active fuel region to maximize exposure from surrounding fuel. The bend coupon tree is designed to hold coupons in capsules at a 90 degree (nominal) bend angle which is, on average, a 5 degree deflection from their as-manufactured dimension. The bend coupons are intended to monitor the performance of the bend region of the inserts, especially crack formation under the in-service strain to which the inserts are subjected. As it is important for the coupons to simulate the most severe environment

expected for the inserts by maximizing dose and temperature exposure, the coupon trees will be placed, to the extent possible, in a location that provides this type of environment. As may be appropriate, the location of the coupon tree assemblies will be periodically moved around the pool in order to maximize the thermal and radiological load upon the coupon trees, yet ensure that the load seen by the coupon tree assemblies remains conservative compared to that seen by the installed inserts. The proposed strategy to maximize radiation exposure of the new coupon trees does not adversely impact B.5.b SFP loading requirements as a similar strategy is already utilized in the Fermi 2 SFP for the current coupon trees associated with both the Boraflex and Boral racks.

Table 3.8-1: Long-Term Monitoring Coupon Types and Minimum Quantities

Coupon Type	Number	Objective
General	16	Various*
Bend	16	Track effects along bend radii
Galvanic (bi-metallic)	80	Trend galvanic corrosions with Stainless Steel, Inconel, NSF, and Zircaloy coupons*

*Includes monitoring of ^{10}B areal density

The initial proposed frequency for coupon inspection under the long-term monitoring program is shown in Table 3.8-2. Based on this frequency, there will be a sufficient number of test coupons installed into the SFP to last 80 years (i.e., well beyond the Fermi 2 PEO). Therefore, coupons will not have to be re-inserted into the fuel pool after removal for inspection. Spare coupons beyond these minimum quantities may be included on the coupon trees. Upon good performance, DTE may extend the coupon inspection frequency but not to exceed the frequencies delineated in UFSAR Section B.1.27 and NEI 16-03-A (see Section 3.8.5).

Table 3.8-2: Frequency for Coupon Inspection

Coupon Type	First 10 Years	After 10 Years with Satisfactory Performance
General	1 coupon every 5 years	2 coupons every 10 years
Bend	1 coupon every 5 years	2 coupons every 10 years
Galvanic Couples:		
Stainless Steel	1 couple every 5 years	
Inconel	1 couple every 5 years	
Zircaloy-2	1 couple every 5 years	
Zircaloy-4	1 couple every 5 years	
NSF	1 couple every 5 years	

Note that Fermi 2 currently has existing coupon programs for the Boral and Boraflex racks. No physical changes are being proposed to the Boral racks as previously discussed and DTE therefore does not plan to modify the existing Boral coupon program based on this LAR. Upon

implementation of this license amendment following approval, Boraflex will no longer be credited to perform any neutron absorption function. As a result, the Boraflex coupon program will no longer be needed. Previous commitments regarding the Boraflex monitoring program will be eliminated as described in Enclosure 9. In addition, the Boraflex coupons and coupon trees may be removed from the Fermi 2 SFP.

3.8.4 Full Rack Insert Inspections/Testing

Rack inserts from the SFP will be subjected to three types of inspections/testing as indicated in Table 3.8-3. Rack inserts will be visually inspected by camera while remaining in the storage racks to visually monitor for physical deformities such as bubbling, corrosion pitting, cracking, or flaking. Special attention shall be paid to development of any edge or corner defects. The rack inserts for in-situ visual inspections will be selected randomly to ensure adequate sampling of the pool population.

Table 3.8-3: Full Insert Inspection/Testing Types

Inspection/Testing Type	**Objective**
In-Situ Inspection	Visually monitor for signs of degradation
Removal Inspection	Test for wear along insert length and adequate retention force
Pull Testing	Monitor retention force

As indicated in Table 3.8-3, rack inserts will also be removed for inspection. Minimal insert material wear is expected within the active fuel region due to adequate clearance between the fuel assembly and rack insert. The nominal dimensions of the spent fuel storage cells and the rack inserts allow sufficient clearance between the fuel assembly and the cell walls or insert surface. The combined effects of adequate clearance and infrequent fuel assembly movement will preclude significant wear of the rack insert. As a verification measure, however, full-length rack inserts in high duty rack cell locations (i.e., those with a relatively high number of fuel assembly insertions and removals) will be inspected for wear.

A region of high duty SFP storage rack cell locations will be identified for this inspection type. These locations will be monitored for fuel insertion and removal events to ensure that their service bounds that of the general population of storage locations. On a periodic basis (see Table 3.8-4), an insert will be removed from this region and will be inspected for thickness along its length at several locations. This collection of measurements will then be compared with the as-built thickness measurements of the removed insert to verify it has sustained uniform wear over its service life. The insert removal force will also be measured and documented. Retention force is also measured and documented during pull testing as discussed further below.

Inserts removed for the removal inspection under this program will not be re-inserted into the SFP. A minimum of 8 spare inserts will be reserved for replacement of the designated full-length

inserts removed for inspection. One of the spare full-length inserts will be used for comparison during the full-length insert inspection, but it is not required to use the same spare insert for each comparison. The spare inserts will be held in controlled environmental conditions such that the inserts remain devoid of visible damage, contamination, corrosion or oxidation with the exception of the compact, adherent, protective film of alumina, which normally forms on aluminum as a result of exposure to air. The spare inserts will be kept in storage containers that protect them from possible unplanned and unwarranted deformation from any other objects or from possible contamination such as leaks, spills, etc. In addition, the containers will be kept in a building that protects the insert from outdoor elements such as wind, rain, etc. that could contribute to surface contamination or corrosion, e.g. a basic warehouse.

The third inspection/testing to be applied to the full insert will be pull testing. As described in Section 3.4.4, stress relaxation over time will reduce the retention force of the insert. Pull testing will be used to confirm that adequate retention force exists to meet the requirements for seismic events. The periodic pull test will be accomplished by applying an upward force (using the specially designed insert removal tool) on the installed insert until the insert begins to move. The break-free force will be recorded for trending, comparison, and determination of retention force acceptability based on the stress relaxation. Each pull test will involve an adequate sample of installed inserts, with the inserts selected to conservatively represent all inserts installed in the pool. The specific sample size will be determined prior to each pull testing campaign. The pull test will not fully remove the insert such that it will be re-inserted following testing, provided relevant acceptance criteria are met. In the event that one or more of the selected insert samples fail to meet the retention force acceptance criterion, the sample size will be suitably increased. Each insert failing to meet the retention force acceptance criteria will be replaced.

The insert pull testing allows for trending of retention force data over time such that the approach to the retention force acceptance criteria can be monitored. It should be noted that the stress relaxation rate is not linear with respect to time. Therefore, a more significant reduction in stress and thus retention force is expected in the first few years of exposure, but the relaxation rate becomes asymptotic over a longer period of time. Pull testing will be performed more frequently during the initial 10 years based on this behavior.

The initial proposed frequency for full insert inspection/testing under the long-term monitoring program is shown in Table 3.8-4. The number of spare inserts, described above, will be adequate to ensure sufficient replacements inserts to last for 80 years (i.e., well beyond the Fermi 2 PEO) when insert removal is performed in accordance with this frequency. Upon good performance, DTE may extend the coupon inspection frequency but not to exceed the frequencies delineated in UFSAR Section B.1.27 and NEI 16-03-A (see Section 3.8.5).

Table 3.8-4: Frequency for Full Insert Inspection/Testing

Inspection/Testing Type	First 10 Years	After 10 Years with Satisfactory Performance
In-Situ Visual Inspection	2 inspections every 2 years	2 inspections every 4 years
Removal Inspection	1 removal every 10 years	
Pull Testing	3 pull tests within 10 years (nominally years 3, 6, & 10)	1 pull test every 5 years

3.8.5 Monitoring Program UFSAR and TS Requirements

Renewed Facility Operating License No. NPF-43 License Renewal License Condition (a) states that:

> The information in the Updated Final Safety Analysis Report (UFSAR) supplement, submitted pursuant to 10 CFR 54.21(d), as revised during the license renewal application review process, and licensee commitments as reiterated in Appendix A to the "Safety Evaluation Report Related to the License Renewal of Fermi 2," are collectively the "License Renewal UFSAR Supplement." This supplement is henceforth part of the UFSAR which will be updated in accordance with 10 CFR 50.71(e). As such, the licensee may make changes to the programs, activities, and commitments described in this Supplement, provided the licensee evaluates such changes pursuant to the criteria set forth in 10 CFR 50.59, "Changes, Tests and Experiments," and otherwise complies with the requirements in that section.

In accordance with this License Renewal License Condition (a), DTE incorporated the "License Renewal UFSAR Supplement" into UFSAR Revision 21 (Reference 6.9) as Appendix B. UFSAR Appendix B contains a "Neutron-Absorbing Material Monitoring Program" in Section B.1.27. The program description indicates that the program applies to neutron-absorbing materials used in the SFP and indicates Boral as an example material. Although the Rio-Tinto-Alcan BORALCAN™ composite is not listed as an example material, this program would apply to the Rio-Tinto-Alcan BORALCAN™ composite material as soon as the inserts are credited as performing a neutron-absorption function (i.e., following full implementation of this license amendment). As part of the implementation of this LAR following approval, UFSAR Section B.1.27 will be updated to specifically include the Rio-Tinto-Alcan BORALCAN™ composite material in the list of example materials to which the program applies. See Enclosure 9 for regulatory commitments associated with this LAR. The program description further states that the program relies on periodic inspection, testing, and other monitoring activities to assure that the required five percent subcriticality margin is maintained (i.e. k-effective less than or equal to 0.95). The program description includes two enhancements which will be implemented prior to the period of extended operation (also shown in Item 20 of UFSAR Table B-1 for License Renewal Commitments).

The Fermi 2 Neutron-Absorbing Material Monitoring Program was reviewed by the NRC staff as documented in Section 3.0.3.2.15 of the SER for the Fermi 2 License Renewal (Reference 6.6). The SER reiterates that the program applies to all neutron-absorbing material other than Boraflex which includes, but is not limited to, Boral (i.e., it would apply to the BORALCAN™ of the new inserts). The SER further states that the Fermi 2 Neutron-Absorbing Material Monitoring Program, with enhancements, is consistent with the requirements of the aging management program XI.M40, "Monitoring of Neutron-Absorbing Materials Other than Boraflex," documented in the Generic Aging Lessons Learned (GALL) Report, NUREG-1801 (Reference 6.18).

The Neutron-Absorbing Material Monitoring Program described in the Fermi 2 UFSAR contains general requirements at a high level. The specific and detailed proposed monitoring activities described in Sections 3.8.3 and 3.8.4 will satisfy the requirements of the Neutron-Absorbing Material Monitoring Program already described in the Fermi 2 UFSAR and therefore will also meet the recommendations of NUREG-1801.

In parallel to the Fermi 2 LRA review and approval, NEI submitted NEI 16-03, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools." NEI 16-03 was reviewed and approved by the NRC in March 2017 and resubmitted as NEI 16-03-A in May 2017 (Reference 6.19). The NRC staff has identified that NEI 16-03-A is acceptable for referencing in licensing applications. NEI 16-03-A provides general guidance for a neutron absorber monitoring program that can that confirm the neutron absorbers continue to provide the criticality control relied upon in the criticality analyses. NEI 16-03-A and its associated NRC SER both reference NUREG-1801. There is significant overlap between the NEI 16-03-A and NUREG-1801 guidance and the NRC SER even indicates that the NEI guidance is consistent with the NUREG-1801 guidance. Therefore, it is expected that the Fermi 2 UFSAR Section B.1.27 program will also be consistent with the NEI 16-03-A guidance. As part of the implementation of this LAR following approval, UFSAR Section B.1.27 will be updated to also specifically state that the program activities for BORALCAN™ will meet the guidance in NEI 16-03-A. See Enclosure 9 for regulatory commitments associated with this LAR. The specific and detailed proposed monitoring activities described in Sections 3.8.3 and 3.8.4 will satisfy the recommendations of NEI 16-03-A.

The Fermi 2 TS currently contain programmatic requirements for monitoring the SFP in Section 5.5.13, "High Density Spent Fuel Racks." As stated in the description, the TS 5.5.13 program only applies to SFP racks containing Boraflex as the neutron absorber. There are no current TS programmatic requirements for the SFP racks containing Boral as the neutron absorber material. As described in Section 2.2, DTE plans to remove the TS 5.5.13 program as part of this LAR. In addition, based on the discussion above, DTE does not propose to create any new TS requirements related to programs to monitor the SFP neutron absorbing materials (either the existing Boral or the new NETCO SNAP-IN® neutron absorbing inserts made from BORALCAN™).

DTE notes that the NRC staff has recently approved TSTF-557, "Spent Fuel Storage Rack Neutron Absorber Monitoring Program" (References 6.21 and 6.22). TSTF-557 would add a

new program to the TS that would reference NEI 16-03-A. TSTF-557 identifies that the program is optional and could be used by licensees that require licensing requirements for a spent fuel pool neutron absorber monitoring program. In the case of Fermi 2, DTE already has incorporated the relevant licensing requirements into the Fermi 2 UFSAR as required by License Renewal License Condition (a). The Fermi 2 UFSAR Section B.1.27 program has already been reviewed and approved by the NRC, is in accordance with NUREG-1801, and contains similar requirements to NEI 16-03-A. DTE also will revise UFSAR Section B.1.27 to require that the BORALCAN™ monitoring activities will be in accordance with the NEI 16-03-A guidance as described above. DTE believes it is not necessary to create a new TS program, like the one proposed in TSTF-557, since the requirements would be duplicative of requirements already included in the Fermi 2 UFSAR.

To summarize, the Fermi 2 UFSAR Section B.1.27 contains programmatic requirements for monitoring SFP neutron-absorbing materials. The UFSAR program will apply to the new NETCO SNAP-IN® neutron absorbing inserts made from BORALCAN™ in addition to the existing Boral material. The UFSAR program is based on NUREG-1801 and has previously been reviewed and approved by the NRC as part of License Renewal. The UFSAR program is also consistent with the guidance in NEI 16-03-A and will be revised to specifically reference the NEI 16-03-A guidance for the BORALCAN™ activities. Regulatory commitments associated with these changes are listed in Enclosure 9. The programmatic requirements will be controlled by the UFSAR and are not required to be duplicated in the Fermi 2 TS. The specific proposed monitoring activities described in Sections 3.8.3 and 3.8.4 meet or exceed the UFSAR requirements, as well as the NUREG-1801 and NEI 16-03-A recommendations. The specific proposed monitoring activities will be incorporated into Fermi 2 procedures.

3.9 Installation and Removal of Rack Inserts

A typical installation tool with a NETCO SNAP-IN® rack insert engaged is shown in Figure 2-3 of Enclosure 8. This tool has been modified from that shown in Enclosure 8 for use at Fermi 2. The design weight of the installation tool with the rack insert is less than 1000 lbs. This weight is within the capacity of the SFP refuel bridge auxiliary hoist and is also bounded by the fuel handling accident and Fermi 2 heavy load restrictions.

An insert setting tool may also be used to aid in the full installation of an insert. This tool is only used if an insert has not been fully lowered into a cell by the installation tool itself. Once an insert has been installed using the installation tool, if the top edge of the insert remains above the top surface of the cell, the setting tool is used to push the insert down until it is flush with the top of the cell. The design weight of the setting tool is also less than 1000 lbs. The setting tool does not hold an insert such that only the weight of the setting tool without an insert would be applied to the hoist.

A separate removal tool has been designed and fabricated for rack insert removal. Any required removal of rack inserts will be performed using the appropriate configuration controls and confirmation of restored configuration. The weight of the removal tool is less than the weight of the installation tool and therefore remains within the load restrictions described above.

3.10 Legacy Rack Descriptions and License Amendment 141

The Fermi 2 SFP formerly contained low density storage racks and a storage rack for defective fuel assemblies (i.e. the defective fuel assembly storage rack). In January 2001, the NRC approved a re-rack of the Fermi 2 SFP via License Amendment No. 141. The SER for the license amendment indicated that the re-rack would be accomplished in three campaigns. The SER further indicated that the second campaign would include removal of the defective fuel storage rack and four low density racks. The TS changes associated with License Amendment No. 141 revised TS 4.3.1.c to provide a bounding list of all the rack types that could be present in the SFP throughout the three campaigns. Thus, the revised TS 4.3.1.c included the defective fuel assembly storage rack and low density storage racks even though full implementation of the approved license amendment would eventually eliminate these racks.

The second campaign of the re-rack was implemented via a Fermi 2 engineering design package (EDP). The EDP scope including the removal of the defective fuel storage rack and low density storage racks was approved in October 2006. The EDP was implemented in 2007 during Cycle 12 and the defective fuel storage rack and low density storage racks were removed at that time. UFSAR Section 9.1.2 and associated drawings were revised to reflect the removal of these racks. These UFSAR changes were submitted to the NRC with UFSAR Revision 15 on May 15, 2008. Section 9.1.2.5 of the current UFSAR revision (Reference 6.9) describes that the low density storage racks were removed during Cycle 12. Section 9.1.2.2.1 of the current UFSAR revision also describes that defective fuel assemblies are stored in cells in the Holtec racks (i.e., not in the defective fuel storage rack that was removed).

The defective fuel storage rack and low density storage racks were removed from the Fermi 2 SFP in 2007, consistent with the NRC approval in 2001. The Fermi 2 UFSAR was updated to reflect the SFP configuration. TS 4.3.1.c has not been updated since License Amendment No. 141 and therefore still lists these racks. Removal of the defective fuel storage rack and low density storage racks from TS 4.3.1.c is an administrative change to the TS to remove obsolete information.

As described previously, License Amendment No. 141 approved a re-rack in three campaigns. The current Fermi 2 SFP storage capacity, based on completion of the first two campaigns, is less than the storage capacity limit of TS 4.3.3, which reflects the maximum capacity that could be obtained upon completion of the third campaign. This LAR requests approval for crediting neutron absorbing inserts in the Boraflex racks in order to eliminate the License Renewal License Condition (c) which requires completion of the third campaign prior to the PEO in order to discontinue reliance on Boraflex to perform a neutron absorption function. Once installation of inserts is complete, completion of the third campaign would not be required as a License Condition. Although no longer required, DTE would still retain the ability to complete the third campaign re-rack in the future in accordance with the original approval of License Amendment No. 141 and the design and licensing basis of the Fermi 2 SFP.

3.11 Summary and Conclusions

The proposed change is an alternative to fulfill the Fermi 2 License Renewal License Condition to replace Boraflex racks with Boral racks. The proposed change to install NETCO SNAP-IN® rack inserts in the SFP storage racks has been evaluated and shown to be a safe and effective alternative to rack replacement. Following installation of the inserts, the criticality safety analysis will no longer credit Boraflex to perform a neutron absorption function while still meeting relevant regulatory requirements (see Section 4.1).

4.0 REGULATORY ANALYSIS

4.1 Applicable Regulatory Requirements/Criteria

The NRC requirements and guidance documents described below are applicable to the review of the proposed changes.

10 CFR 50.68, "Criticality accident requirements," paragraph (b)(4) states that the k-effective of the spent fuel storage racks loaded with fuel of the maximum fuel assembly reactivity and flooded with unborated water must not exceed 0.95, at a 95 percent probability, 95 percent confidence level. This regulatory requirement is consistent with the requirements of Fermi 2 TS 4.3.1.b, which also requires a k-effective of less than or equal to 0.95 when flooded with unborated water and considering uncertainties as described in Section 9.1 of the UFSAR. Fermi 2 UFSAR Section 9.1.2.1 specifies that the criticality safety analyses account for uncertainties with a 95 percent probability with a 95 percent confidence level. The new criticality safety analysis, provided as Enclosure 4 to this submittal, demonstrates that the Fermi 2 TS (and UFSAR) requirement is met for storage of spent fuel in the Boraflex racks by crediting the neutron absorbing inserts rather than Boraflex. Therefore, the new criticality analysis also meets the requirement of 10 CFR 50.68 (b)(4). Additionally, paragraph (b)(7) states that the maximum nominal U-235 enrichment of fresh fuel assemblies is limited to five percent by weight. Although no change is being proposed regarding new fuel procurement in this LAR, all of the fuel assemblies considered in the criticality safety analysis in Enclosure 4 have an enrichment of less than five percent by weight, consistent with the requirement of 10 CFR 50.68(b)(7).

Note the Fermi 2 UFSAR has not previously addressed compliance with 10 CFR 50.68. Instead, as allowed by 10 CFR 50.68(a), the Fermi 2 UFSAR describes compliance with, and exemptions from, 10 CFR 70.24. Fermi 2 compliance with 10 CFR 50.68 was also not addressed in License Amendment No. 141. Fermi 2 generally meets all of the requirements of 10 CFR 50.68, as indicated in part by the discussion above. However, certain Fermi 2 activities, such as the handling of new fuel within shipping containers, do not strictly meet 10 CFR 50.68 or 10 CFR 70.24. The Fermi 2 UFSAR describes the NRC-approved exemptions to 10 CFR 70.24. As stipulated in 10 CFR 70.24(d)(2), exemptions from 10 CFR 70.24 held by a licensee may be ineffective as long as the licensee elects to comply with 10 CFR 50.68. No changes are being proposed in this LAR regarding handling of new fuel. In order to avoid the potential loss of previously approved exemptions to 10 CFR 70.24 for activities unrelated to this LAR, Fermi 2

will maintain 10 CFR 70.24 as the licensing basis rather than electing to comply with 10 CFR 50.68 as part of this LAR. The information above regarding how the criticality safety analysis meets the requirements of 10 CFR 50.68 is provided for information only.

10 CFR 50, Appendix A, General Design Criterion (GDC) 61, "Fuel storage and handling and radioactivity control," requires that fuel storage systems be designed to assure adequate safety under normal and postulated accident conditions. The Fermi 2 UFSAR (Reference 6.9), Section 3.1.2.6.2, describes conformance with GDC 61. Evaluations were performed to demonstrate that the installation of neutron absorbing inserts into the Boraflex racks does not alter conformance with GDC 61.

10 CFR 50, Appendix A, GDC 62, "Prevention of criticality in fuel storage and handling," requires that criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations. The Fermi 2 UFSAR, Section 3.1.2.6.3, describes conformance with GDC 62. This section currently describes Boraflex as a neutron absorbing material which ensures that k-effective is less than 0.95 with a 95 percent probability at a 95 percent confidence level. The new criticality safety analysis, provided as Enclosure 4 to this submittal, demonstrates that this requirement is met by crediting the neutron absorbing inserts rather than Boraflex. As part of the implementation of this LAR following approval, UFSAR Section 3.1.2.6.3 will be revised accordingly. See Enclosure 9 for regulatory commitments associated with this LAR.

10 CFR 50.36, "Technical specifications," details the content and information that must be included in a station's Technical Specifications (TS). In accordance with 10 CFR 50.36, TS are required to include (1) safety limits, limiting safety system settings, and limiting control settings; (2) limiting conditions for operation; (3) surveillance requirements; (4) design features; and (5) administrative controls. The spent fuel storage racks are design features which are included in the Fermi 2 TS in accordance with 10 CFR 50.36. The proposed changes to the Fermi 2 TS are made to ensure that the design features relied upon in the criticality safety analysis (i.e., the neutron absorbing inserts) are adequately described in the TS. The proposed changes also remove an administrative control from the TS as an administrative control program focused on Boraflex as a neutron absorbing material will no longer be required. Administrative controls of the other neutron absorbing materials in the SFP, including the new BORALCAN™ material, is addressed by the relevant aging management program included in UFSAR Appendix B and developed in accordance with 10 CFR 54, "Requirements for renewal of operating licenses for nuclear power plants."

NUREG-1433 Volume 1, Revision 4.0, "Standard Technical Specifications, General Electric BWR/4 Plants," provides the improved Standard Technical Specifications (STS) for General Electric BWR/4 plants. Requirements for fuel storage racks are found in STS 4.3. The Fermi 2 TS 4.3, and changes proposed herein, are consistent with the STS in NUREG-1433 with the exception of the substitution of Fermi 2 plant-specific values for the generic values indicated by brackets in the STS. In addition, the improved STS in NUREG-1433 (Revision 4.0) do not currently contain any administrative controls or programs for neutron absorbers in Section 5. Therefore, the elimination of administrative controls for Boraflex that are no longer applicable

from the Fermi 2 TS is consistent with the improved STS. Although TSTF-557 is now an NRC-approved change to NUREG-1433 that would add administrative controls to the improved STS, it is only an optional change for licensees as discussed in Section 3.8.5.

The proposed changes ensure the safety of fuel storage by continuing to meet these applicable regulations and requirements.

4.2 Precedent

The installation of NETCO SNAP-IN® neutron absorbing inserts has been performed at several nuclear power plants within the last several years. The NRC has previously approved use of NETCO SNAP-IN® neutron absorbing inserts in criticality safety analyses for the following plants:

- LaSalle Units 1 and 2 (References 6.10 and 6.11)
- Peach Bottom Units 2 and 3 (References 6.12 and 6.13)
- Quad Cities Units 1 and 2 (References 6.14 and 6.15)
- Palo Verde Units 1, 2, and 3 (References 6.16 and 6.17)

The design of the Quad Cities Boraflex racks is very similar to the design of the Fermi 2 Boraflex racks. Therefore, the NETCO SNAP-IN® rack inserts to be utilized at Fermi 2 are expected to be most similar to those installed at Quad Cities. The criticality safety analysis for Fermi 2 was performed by the same vendor (GEH/GNF) using the same methodology as for Peach Bottom. Therefore, the criticality safety analysis provided with this LAR is most similar to that provided with and reviewed with the Peach Bottom LAR.

In addition, the NRC is currently reviewing a request by River Bend to credit NETCO SNAP-IN® neutron absorbing inserts (Reference 6.20). The Fermi 2 request is similar to the River Bend request under review.

4.3 No Significant Hazards Consideration

In accordance with 10 CFR 50.90, "Application for amendment of license, construction permit or early site permit," DTE is requesting to amend Renewed Facility Operating License No. NPF-43 for Fermi 2.

DTE proposes to revise the License Renewal License Condition (c), TS Section 4.3, and TS Section 5.5.13 as described in Section 2.0 above.

DTE has evaluated whether a significant hazards consideration is involved with the proposed amendment by focusing on the three standards set forth in 10 CFR 50.92(c), "Issuance of amendment," as discussed below:

1. Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No.

The proposed change revises the Renewed Facility Operating License and Technical Specifications to reflect installation of NETCO SNAP-IN® rack inserts in SFP storage rack cells. The changes are necessary to ensure that, without credit for Boraflex as a neutron absorbing material as required by the License Renewal License Condition, the effective neutron multiplication factor, k-effective, is less than or equal to 0.95, if the spent fuel pool (SFP) is fully flooded with unborated water. Since the proposed changes pertain only to the SFP, only those accidents that are related to movement and storage of fuel assemblies in the SFP could potentially be affected by the proposed changes.

The installation of NETCO SNAP-IN® rack inserts and their credit in the criticality safety analysis does not result in a significant increase in the probability of an accident previously analyzed because there are no changes in the manner in which spent fuel is handled, moved, or stored in the rack cells. The probability that a fuel assembly would be dropped is unchanged by the installation of the NETCO SNAP-IN® rack inserts and their credit in the criticality safety analysis. These events involve failures of administrative controls, human performance, and equipment failures that are unaffected by the type of neutron absorbing material utilized in the SFP racks.

The installation of NETCO SNAP-IN® rack inserts and their credit in the criticality safety analysis does not result in a significant increase in the consequences of an accident previously analyzed because there is no change to the fuel assemblies that provide the source term used in calculating the radiological consequences of a fuel handling accident. In addition, consistent with the current design, only one fuel assembly will be moved at a time. Thus, the consequences of dropping an insert with tooling or a fuel assembly onto any other fuel assembly or other structure remain bounded by the previously analyzed fuel handling accident. The proposed changes do not impact the effectiveness of the other engineered design features, such as isolation systems, that limit the dose consequences of a fuel handling accident.

Therefore, the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed amendment create the possibility of a new or different kind of accident from any accident previously evaluated?

   Response: No.

   Onsite storage of spent fuel assemblies in the Fermi 2 SFP is a normal activity for which Fermi 2 has been designed and licensed. As part of assuring that this normal activity can be performed without endangering the public health and safety, the ability to safely accommodate different possible accidents in the SFP have been previously analyzed. These analyses address accidents such as radiological releases due to dropping a fuel assembly; and

potential inadvertent criticality due to misloading a fuel assembly. The proposed SFP storage configuration utilizing the NETCO SNAP-IN® rack inserts does not change the method of fuel movement or spent fuel storage and does not create the potential for a new accident. The proposed changes also allow for the continued use of SFP storage rack cells with Boraflex within those SFP storage rack cells; however, no credit is taken for Boraflex as a neutron absorbing material.

The rack inserts are passive devices. These devices, when inside a SFP storage rack cell, perform the same function as the previously licensed Boraflex neutron absorber panels in that cell. The NETCO SNAP-IN® rack inserts do not add any limiting structural loads or adversely affect the removal of decay heat from the assemblies. No change in total heat load in the spent fuel pool is being made. The insert devices will be monitored to ensure they maintain their design function over the life of the spent fuel pool. The existing fuel handling accident, which assumes the drop of a fuel assembly and refueling mast, bounds the drop of a rack insert and associated tools. This proposed change does not create the possibility of misloading an assembly into a SFP storage rack cell. Inadvertent removal of an insert, although largely precluded by design and administrative controls, does not challenge subcriticality requirements as explicitly demonstrated by the criticality safety analysis.

Therefore, the proposed change does not create the possibility of a new or different kind of accident from any previously evaluated.

3. Does the proposed amendment involve a significant reduction in a margin of safety?

   Response: No.

   The NETCO SNAP-IN® rack inserts are being installed to maintain the margin of safety in the SFP criticality safety analysis. The NETCO SNAP-IN® rack inserts, once approved and installed, will replace the existing Boraflex as the credited neutron absorber for controlling spent fuel pool reactivity, even though the Boraflex material will remain in place.

   Fermi 2 TS 4.3, "Fuel Storage," Specification 4.3.1.b requires the SFP storage racks to maintain the effective neutron multiplication factor, k-effective, less than or equal to 0.95 when fully flooded with unborated water, which includes an allowance for uncertainties. Therefore, for SFP criticality safety considerations, the required safety margin is 5 percent.

   The proposed changes ensure, as verified by the new criticality safety analysis, that k-effective continues to be less than or equal to 0.95, thus preserving the required safety margin of 5 percent.

   In addition, the radiological consequences of a dropped fuel assembly, considering the installed NETCO SNAP-IN® rack inserts, remain unchanged as the anticipated fuel damage due to a fuel handling accident is unaffected by the addition of the inserts in the SFP storage cells. The proposed changes also do not increase the capacity of the SFP.

Therefore, the proposed change does not involve a significant reduction in a margin of safety.

Based on the above evaluation, DTE concludes that the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of "no significant hazards consideration" is justified.

4.4 Conclusion

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

DTE has evaluated the proposed amendment for environmental considerations. The review has resulted in the determination that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20, or would change an inspection or surveillance requirement. However, the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment is required for the proposed amendment.

6.0 REFERENCES

6.1 "Summary of June 27, 2018, Public Meeting with DTE Electric Company Regarding Upcoming License Amendment Request to Revise a License Condition Related to Boraflex Storage Racks (EPID L-2018-LRM-0031)", dated July 16, 2018 (ML18194A540).

6.2 DTE Letter NRC-16-0061, "DTE Response to NRC Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated October 11, 2016 (ML16286A280).

6.3 NRC Letter, "Fermi 2 – Closeout of Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated August 27, 2018 (ML18030B178).

6.4 NRC Letter, "Issuance of Renewed Facility Operating License No. NPF-43 for Fermi Nuclear Power Plant, Unit 2 (CAC No. MF4222)," dated December 15, 2016 (ML16270A551).

6.5 DTE Letter NRC-15-0081, "Fermi 2 License Renewal Application Update for the Boraflex Monitoring Program," dated September 24, 2015 (ML15268A454).

6.6 NUREG-2210, "Safety Evaluation Report Related to the License Renewal of Fermi 2," dated December 2016 (ML16356A234).

6.7 NRC Letter, "Fermi 2 – Issuance of Amendment Re: Spent Fuel Pool Rerack (TAC No. MA7233)," dated January 25, 2001 (ML010310205).

6.8 NEI 12-16 Revision 2, Draft B, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants," dated January 2017 (ML17009A343).

6.9 Fermi 2 Updated Final Safety Analysis Report, Revision 21, dated October 2017 (ML17298B265).

6.10 Exelon Letter, "License Amendment Regarding the Use of Neutron Absorbing Inserts in Unit 2 Spent Fuel Pool Storage Racks," dated October 5, 2009 (ML092810279).

6.11 NRC Letter, "LaSalle County Station, Units 1 and 2, Issuance of Amendments Concerning Spent Fuel Neutron Absorbers (TAC Nos. ME2376 and ME2377) (RS-09-133)," dated January 28, 2011 (ML110250051).

6.12 Exelon Letter, "License Amendment Request – Use of Neutron Absorbing Inserts in Units 2 and 3 Spent Fuel Pool Storage Racks," dated November 3, 2011 (ML113081441).

6.13 NRC Letter, "Peach Bottom Atomic Power Station, Units 2 and 3 – Issuance of Amendments Re: Use of Neutron Absorbing Inserts in Spent Fuel Pool Storage Racks (TAC Nos. ME7538 and ME7539)," dated May 21, 2013 (ML13114A929).

6.14 Exelon Letter, "License Amendment Request – Use of Neutron Absorbing Inserts in Units 1 and 2 Spent Fuel Storage Racks," dated July 16, 2013 (ML13199A037).

6.15 NRC Letter, "Quad Cities Nuclear Power Station, Units 1 and 2 – Issuance of Amendments Regarding NETCO Inserts (TAC Nos. MF2489 and MF2490) (RS-13-148)," dated December 31, 2014 (ML14346A306).

6.16 APS Letter, "Palo Verde Nuclear Generating Station (PVNGS,) Units 1, 2, and 3, License Amendment Request to Revise Technical Specifications to Incorporate Updated Criticality Safety Analysis," dated November 25, 2015 (ML15336A087).

6.17 NRC Letter, "Palo Verde Nuclear Generating Station, Units 1, 2, and 3 – Issuance of Amendments to Revise Technical Specifications to Incorporate Updated Criticality Safety Analysis (CAC Nos. MF7138, MF7139, and MF7140)," dated July 28, 2017 (ML17188A412).

6.18 NUREG-1801, "Generic Aging Lessons Learned (GALL) Report," Revision 2, dated December 2010 (ML103490041).

6.19 NEI 16-03-A Revision 0, "Guidance for Monitoring of Fixed Neutron Absorbers in Spent Fuel Pools," dated May 2017 (ML17263A133).

6.20 Entergy Letter, "License Amendment Request, Criticality Safety Analysis, Technical Specifications 4.3.1, Criticality, and Technical Specification 5.5, Programs and Manuals," dated October 24, 2018 (ML18297A103).

6.21 TSTF-557 Revision 1, "Spent Fuel Storage Rack Neutron Absorber Monitoring Program," dated December 19, 2017 (ML17353A608).

6.22 NRC Letter, "Final Safety Evaluations of Technical Specifications Task Force Traveler TSTF-557, Revision 1, "Spent Fuel Storage Rack Neutron Absorber Monitoring Program"," dated January 15, 2019 (ML19007A224).

Enclosure 2 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

Marked-up Pages of Existing Fermi 2 OL and TS

activities to be completed before the period of extended operation (PEO), as follows:

1. The applicant shall implement those new programs and enhancements to existing programs no later than 6 months prior to the PEO.

2. The applicant shall complete those activities by the 6-month date before the PEO or the end of the last refueling outage prior to the PEO, whichever occurs later.

The applicant shall notify the NRC in writing within 30 days after having accomplished item (b)1. above and include the status of those activities that have been or remain to be completed in item (b)2. above.

Replace with:
Deleted

(c) ~~DTE Electric Company shall fully implement the Boraflex rack replacement approved in Amendment No. 141 before the PEO (i.e., March 20, 2025), so that the Boraflex material in the spent fuel pool will not be required to perform a neutron absorption function. DTE Electric Company shall submit a letter to the NRC, within 60 days following completion of the removal of the Boraflex material and installation of the Boral material, as described in Amendment No. 141, confirming the removal of the Boraflex material and discontinued reliance on its neutron absorption function.~~

D. Exemptions from certain requirements of Appendices E and J to 10 CFR Part 50, are described in supplements to the SER. These include: (a) an exemption from the requirement of Section IV.F of Appendix E that a full participation emergency planning exercise be conducted within one year before issuance of the first operating license for full power and prior to operation above five percent of rated power (Section 13.3 of SSER #6); and (b) an exemption from the requirement of Paragraph III.C.2(b) of Appendix J, the testing of the main steam isolation valves at the peak calculated containment pressure associated with the design basis accident (Section 6.2.7 of SSER #5). These exemptions are authorized by law and will not endanger life or property or the common defense and security and are otherwise in the public interest. Therefore, these exemptions are hereby granted pursuant to 10 CFR 50.12. With the granting of these exemptions, the facility will operate, to the extent authorized herein, in conformity with the application, as amended, the provisions of the Act, and the rules and regulations of the Commission.

E. The licensee shall fully implement and maintain in effect all provisions of the Commission-approved physical security, training and qualification, and safeguards contingency plans including amendments made pursuant to provisions of the Miscellaneous Amendments and Search Requirements revisions to 10 CFR 73.55 (51 FR 27817 and 27822) and to the authority of 10 CFR 50.90 and 10 CFR 50.54(p). The plans, which contain Safeguards Information protected under 10 CFR 73.21, are entitled: "Fermi 2 Physical Security Plan, Security Training and Qualification Plan, and

4.0 DESIGN FEATURES

4.1 Site Location

The Fermi 2 site is located on the western shore of Lake Erie in Frenchtown Township, Monroe County, Michigan, approximately 8 miles east-northeast of the city of Monroe, Michigan.

4.2 Reactor Core

4.2.1 Fuel Assemblies

The reactor shall contain 764 fuel assemblies. Each assembly shall consist of a matrix of Zircalloy fuel rods with an initial composition of natural or slightly enriched uranium dioxide (UO_2) as fuel material and water rods. Limited substitutions of zirconium alloy or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with NRC staff approved codes and methods and have been shown by tests or analyses to comply with all safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

4.2.2 Control Rod Assemblies

The reactor core shall contain 185 cruciform shaped control rod assemblies. The control material shall be boron carbide and/or hafnium metal as approved by the NRC.

4.3 Fuel Storage

4.3.1 Criticality

Replace with:
1.30

The spent fuel storage racks are designed and shall be maintained with:

a. Fuel assemblies having a maximum k-infinity of ~~1.31~~ in the normal reactor core configuration at cold conditions;

(continued)

4.0 DESIGN FEATURES

4.3 Fuel Storage (continued)

b. $k_{eff} \leq 0.95$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR; and

c. The following nominal center to center distances between fuel assemblies placed in the various storage rack types, as applicable

Replace with: BORALCAN™

Spacing (inches)	Rack Type
6.22	High density storage racks that contain ~~Boraflex~~ as the neutron absorbing material
6.23	High density storage racks that contain Boral as the neutron absorbing material
~~11.9 x 6.6~~	~~Low density storage racks~~
~~10.5~~	~~Defective fuel assembly storage rack~~

Delete text

Delete text

4.3.2 Drainage

The spent fuel storage pool is designed and shall be maintained to prevent inadvertent draining of the pool below elevation 660 ft 11.5 inches.

4.3.3 Capacity

The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 4608 fuel assemblies.

5.5 Programs and Manuals

5.5.12 Primary Containment Leakage Rate Testing Program (continued)

e. The provisions of SR 3.0.2 do not apply to the test frequencies in the Primary Containment Leakage Rate Testing Program.

f. The provisions of SR 3.0.3 are applicable to the Primary Containment Leakage Rate Testing Program.

Replace with:
Not Used

5.5.13 ~~High Density Spent Fuel Racks~~

~~A program shall be provided, for the high density storage racks containing Boraflex as the neutron absorber, which will ensure that any unanticipated degradation of the Boraflex will be detected and will not compromise the integrity of the racks.~~

5.5.14 Control Room Envelope Habitability Program

A Control Room Envelope (CRE) Habitability Program shall be established and implemented to ensure that CRE habitability is maintained such that, with an OPERABLE Control Room Emergency Filtration (CREF) System, CRE occupants can control the reactor safely under normal conditions and maintain it in a safe condition following a radiological event, hazardous chemical release, or a smoke challenge. The program shall ensure that adequate radiation protection is provided to permit access and occupancy of the CRE under design basis accident (DBA) conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent (TEDE) for the duration of the accident. The program shall include the following elements:

a. The definition of the CRE and the CRE boundary.

b. Requirements for maintaining the CRE boundary in its design condition including configuration control and preventive maintenance.

c. Requirements for (i) determining the unfiltered air inleakage past the CRE boundary into the CRE in accordance with the testing methods and at the frequencies specified in Sections C.1 and C.2 of Regulatory Guide 1.197, "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors," Revision 0, May 2003, and (ii) assessing CRE habitability at the Frequencies specified in Sections C.1 and C.2 of Regulatory Guide 1.197, Revision 0.

(continued)

Enclosure 3 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

Clean Pages of Fermi 2 OL and TS with Changes Incorporated

activities to be completed before the period of extended operation (PEO), as follows:

1. The applicant shall implement those new programs and enhancements to existing programs no later than 6 months prior to the PEO.

2. The applicant shall complete those activities by the 6-month date before the PEO or the end of the last refueling outage prior to the PEO, whichever occurs later.

The applicant shall notify the NRC in writing within 30 days after having accomplished item (b)1. above and include the status of those activities that have been or remain to be completed in item (b)2. above.

(c) Deleted

D. Exemptions from certain requirements of Appendices E and J to 10 CFR Part 50, are described in supplements to the SER. These include: (a) an exemption from the requirement of Section IV.F of Appendix E that a full participation emergency planning exercise be conducted within one year before issuance of the first operating license for full power and prior to operation above five percent of rated power (Section 13.3 of SSER #6); and (b) an exemption from the requirement of Paragraph III.C.2(b) of Appendix J, the testing of the main steam isolation valves at the peak calculated containment pressure associated with the design basis accident (Section 6.2.7 of SSER #5). These exemptions are authorized by law and will not endanger life or property or the common defense and security and are otherwise in the public interest. Therefore, these exemptions are hereby granted pursuant to 10 CFR 50.12. With the granting of these exemptions, the facility will operate, to the extent authorized herein, in conformity with the application, as amended, the provisions of the Act, and the rules and regulations of the Commission.

E. The licensee shall fully implement and maintain in effect all provisions of the Commission-approved physical security, training and qualification, and safeguards contingency plans including amendments made pursuant to provisions of the Miscellaneous Amendments and Search Requirements revisions to 10 CFR 73.55 (51 FR 27817 and 27822) and to the authority of 10 CFR 50.90 and 10 CFR 50.54(p). The plans, which contain Safeguards Information protected under 10 CFR 73.21, are entitled: "Fermi 2 Physical Security Plan, Security Training and Qualification Plan, and

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The Fermi 2 site is located on the western shore of Lake Erie in Frenchtown Township, Monroe County, Michigan, approximately 8 miles east-northeast of the city of Monroe, Michigan.

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4.2.1 Fuel Assemblies

The reactor shall contain 764 fuel assemblies. Each assembly shall consist of a matrix of Zircalloy fuel rods with an initial composition of natural or slightly enriched uranium dioxide (UO_2) as fuel material and water rods. Limited substitutions of zirconium alloy or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with NRC staff approved codes and methods and have been shown by tests or analyses to comply with all safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

4.2.2 Control Rod Assemblies

The reactor core shall contain 185 cruciform shaped control rod assemblies. The control material shall be boron carbide and/or hafnium metal as approved by the NRC.

4.3 Fuel Storage

4.3.1 Criticality

The spent fuel storage racks are designed and shall be maintained with:

a. Fuel assemblies having a maximum k-infinity of 1.30 in the normal reactor core configuration at cold conditions;

(continued)

4.0 DESIGN FEATURES

4.3 Fuel Storage (continued)

b. $k_{eff} \leq 0.95$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR; and

c. The following nominal center to center distances between fuel assemblies placed in the various storage rack types, as applicable

Spacing (inches)	Rack Type
6.22	High density storage racks that contain BORALCAN™ as the neutron absorbing material
6.23	High density storage racks that contain Boral as the neutron absorbing material

4.3.2 Drainage

The spent fuel storage pool is designed and shall be maintained to prevent inadvertent draining of the pool below elevation 660 ft 11.5 inches.

4.3.3 Capacity

The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 4608 fuel assemblies.

5.5 Programs and Manuals

5.5.12 Primary Containment Leakage Rate Testing Program (continued)

e. The provisions of SR 3.0.2 do not apply to the test frequencies in the Primary Containment Leakage Rate Testing Program.

f. The provisions of SR 3.0.3 are applicable to the Primary Containment Leakage Rate Testing Program.

5.5.13 Not Used

5.5.14 Control Room Envelope Habitability Program

A Control Room Envelope (CRE) Habitability Program shall be established and implemented to ensure that CRE habitability is maintained such that, with an OPERABLE Control Room Emergency Filtration (CREF) System, CRE occupants can control the reactor safely under normal conditions and maintain it in a safe condition following a radiological event, hazardous chemical release, or a smoke challenge. The program shall ensure that adequate radiation protection is provided to permit access and occupancy of the CRE under design basis accident (DBA) conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent (TEDE) for the duration of the accident. The program shall include the following elements:

a. The definition of the CRE and the CRE boundary.

b. Requirements for maintaining the CRE boundary in its design condition including configuration control and preventive maintenance.

c. Requirements for (i) determining the unfiltered air inleakage past the CRE boundary into the CRE in accordance with the testing methods and at the frequencies specified in Sections C.1 and C.2 of Regulatory Guide 1.197, "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors," Revision 0, May 2003, and (ii) assessing CRE habitability at the Frequencies specified in Sections C.1 and C.2 of Regulatory Guide 1.197, Revision 0.

(continued)

Enclosure 5 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

NEDO-33889 – SFP Criticality Safety Analysis with Inserts (Non-Proprietary Version)

Global Nuclear Fuel

NEDO-33889P
Revision 0
October 2018

Non-Proprietary Information

Fermi Nuclear Generating Station Unit 2: Fuel Storage Criticality Safety Analysis of Spent Fuel Storage Racks with Rack Inserts

INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-33889P, Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

Revision Status

Revision Number	Date	Description of Change
0	October 2018	Initial issue

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List of Figures

ACRONYMS

Term	Definition
2D	Two-Dimensional
AOA	Area of Applicability
BAF	Bottom of Active Fuel
BOL	Beginning-of-Life
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
DOM	Dominant Lattice
EALF	Energy of the Average Lethargy Causing Fission
[[	]]
GEH	GE-Hitachi Nuclear Energy Americas LLC
GNF	Global Nuclear Fuel - Americas, LLC
HTC	Haut Taux de Combustion
H/X	Hydrogen-to-Fissile Ratio
MOX	Mixed Uranium-Plutonium Oxide
NCA	Nuclear Critical Assembly
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
SCCG	Standard Cold Core Geometry
SS	Stainless Steel
VAN	Vanished Lattice
WREC	Westinghouse Reactor Evaluation Center
UO_2	Uranium Dioxide

1.0 INTRODUCTION

This report describes the criticality analysis and results for the Fermi Boraflex spent fuel racks with credit for NETCO-SNAP-IN® neutron absorbing inserts. No credit for the Boraflex neutron absorber is taken in this analysis. The methodology and analytical models utilized in this criticality analysis confirm that the storage rack systems have been accurately and conservatively represented. This analysis covers the current GE14 and future GNF3 fuel product lines and all legacy fuel stored in Fermi's spent fuel pool.

The racks are analyzed using the MCNP-05P Monte Carlo neutron transport program and ENDF/B-VII.0 cross-section library. The methodology used in this analysis is the peak Standard Cold Core Geometry (SCCG) in-core eigenvalue (k_∞) criterion methodology. A maximum SCCG, uncontrolled peak in-core k_∞ of 1.30 as defined by the lattice physics code TGBLA06 (Reference 1) is set as the limit for this analysis. As demonstrated in Table 1, the analysis resulted in a storage rack maximum k-effective (k_{max}(95/95)) less than 0.95 for normal and credible abnormal operation with tolerances and uncertainties taken into account.

Table 1 – Summary k_{max}(95/95) Result

Region	k_{max}(95/95)
Boraflex Spent Fuel Rack with NETCO-SNAP-IN® Inserts	[[ ]]

2.0 REQUIREMENTS

Title 10 of the Code of Federal Regulations (CFR) Part 50 defines the requirements for the prevention of criticality in fuel storage and handling at nuclear power plants. 10 CFR 50.68 details specifically that the storage rack k_{max}(95/95) for spent fuel storage racks must be demonstrated to be ≤ 0.95 for normal and credible abnormal operation with tolerances and computational uncertainties taken into account. Reference 2 outlines the standards that must be met for these analyses. All necessary requirements are met in this analysis. Nuclear Energy Institute (NEI) 12-16 (Reference 3) is used as the guidance document for this analysis.

3.0 METHOD OF ANALYSIS

In this evaluation, in-core k_∞ values and exposure dependent, pin-by-pin isotopic specifications are generated using the GE-Hitachi Nuclear Energy Americas LLC (GEH)/GNF lattice physics production code TGBLA06. TGBLA06 solves Two-Dimensional (2D) diffusion equations with diffusion parameters corrected by transport theory to provide system multiplication factors and perform burnup calculations.

The fuel storage criticality calculations are then performed using MCNP-05P, the GEH/GNF proprietary version of MCNP5 (Reference 4). MCNP-05P is a Monte Carlo program for solving the linear neutron transport equation for a fixed source or an eigenvalue problem. The code implements the Monte Carlo process for neutron, photon, electron, or coupled transport involving all these particles, and computes the eigenvalue for neutron-multiplying systems. For the present application, only neutron transport is considered.

3.1 Cross-Sections

TGBLA06 uses ENDF/B-V cross-section data to perform coarse-mesh, broad-group, diffusion theory calculations. It includes thermal neutron scattering with hydrogen using an S(α,β) light water thermal scattering kernel.

MCNP-05P uses point-wise (i.e., continuous) cross-section data, and all reactions in a given cross-section evaluation (e.g., ENDF/B-VII.0) are considered. For the present work, thermal neutron scattering with hydrogen was described using an S(α,β) light water thermal scattering kernel. The cross-section tables include all details of the ENDF representations for neutron data. The code requires that all the cross-sections be given on a single union energy grid suitable for linear interpolation; however, the cross-section energy grid varies from isotope to isotope. The libraries include very little data thinning and utilize resonance integral reconstruction error tolerances of 0.001%.

3.2 Geometry Treatment

TGBLA06 is a 2D lattice design computer program for Boiling Water Reactor (BWR) fuel bundle analysis. It assumes that a lattice is uniform and infinite along the axial direction and that the lattice geometry and material are reflecting with respect to the lattice boundary along the transverse directions.

MCNP-05P implements a robust geometry representation that can correctly model complex components in three dimensions. An arbitrary three-dimensional configuration is treated as geometric cells bounded by first and second-degree surfaces and some special fourth-degree elliptical tori. The cells are described in a cartesian coordinate system and are defined by the intersections, unions and complements of the regions bounded by the surfaces. Surfaces are defined by supplying coefficients to the analytic surface equations or, for certain types of surfaces, known points on the surfaces. Rather than combining several pre-defined geometrical bodies in a combinatorial geometry scheme, MCNP-05P has the flexibility of defining geometrical shapes from all the first and second-degree surfaces of analytical geometry and elliptical tori and then combining them with Boolean operators. The code performs extensive checking for geometry errors and provides a plotting feature for examining the geometry and material assignments.

3.3 Convergence Checks

The use of TGBLA06 as a depletion code in this criticality analysis is consistent with its use for BWR fuel design and its associated user's manual. Convergence checks are encoded in the standard error routines and the absence of error messages was confirmed in all code output.

In this analysis, the following criticality code parameters were specified. At a minimum, all MCNP-05P cases were run with [[ ]] neutrons per generation, [[ ]] cycles skipped and [[ ]] total cycles run. Some cases were run for more cycles skipped and more total cycles in order to meet all the converge checks. For this analysis, the following MCNP-05P convergence checks were reviewed and confirmed passed for each case:

- [[

]]

3.4 Validation and Computational Basis

[[

]]

Table 2 – Summary of the Critical Benchmark Experiments

Experiment		Experiments	Year	Where
[[				
				]]

Table 3 – Area of Applicability Covered by Code Validation

Parameters	Validation Area of Applicability	Spent Fuel Rack Characteristics
[[		
		]]

[[

]]

3.5 In-Core k_∞ Methodology

The design of the fuel storage racks provides for a subcritical multiplication factor for both normal and credible abnormal storage conditions. In all cases, the storage rack eigenvalue must be ≤ 0.95. To demonstrate compliance with this limit, the peak in-core k_∞ method is utilized.

The peak in-core k_∞ criterion method relies on a well-characterized relationship between infinite lattice k_∞ (in-core) for a given fuel design and a specific fuel storage rack k_∞ (in-rack) containing that fuel. The use of an infinite lattice k_∞ criterion for demonstrating compliance to fuel storage criticality criteria has been used for all General Electric-supplied storage racks and is currently used for re-rack designs at a number of plants. This report demonstrates that the methodology is also appropriate for use at Fermi by presenting the following:

- A well-characterized, linear relationship between infinite lattice k_∞ (in-core) and fuel storage rack k_∞ (in-rack)
- The use of a design basis lattice with a conservative rack efficiency and in-core k_∞ for all criticality analyses

The analysis performed to calculate the lattice k_∞ to confirm compliance with the above criterion uses the Nuclear Regulatory Commission (NRC)-approved lattice physics methods encoded into the TGBLA06 engineering computer program. One of the outputs of the TGBLA06 solution is the lattice k_∞ of a specific nuclear design for a given set of input state parameters (e.g., void fraction, control state, fuel temperature).

Compliance of fuel with specified k_∞ limits will be confirmed for each new lattice as part of the bundle design process. Documentation that this has been met will be contained in the fuel design information report, which defines the maximum lattice k_∞ for each assembly nuclear design. The process for validating that specific assembly designs are acceptable for storage in the Fermi fuel storage racks is provided below.

1. [[

]]

Documentation that all legacy fuel types at Fermi currently comply with this in-core limit is documented in Appendix B.

3.6 Definitions

Fuel Assembly – is a complete fuel unit consisting of a basic fuel rod structure that may include large central water rods. Several shorter rods may be included in the assembly. These are called "part-length rods". A fuel assembly includes the fuel channel.

Gadolinia – The compound Gd_2O_3. The gadolinium content in integral burnable absorber fuel rods is usually expressed in weight percentage gadolinia.

Lattice – An axial zone of a fuel assembly within which the nuclear characteristics of the individual rods are unchanged.

Dominant Lattice – An axial zone of a fuel assembly typically located in the bottom half of the bundle within which all possible fuel rod locations for a given fuel design are occupied.

Mid Lattice – [[

]]

Vanished Lattice – An axial zone of a fuel assembly typically in the upper half of the bundle within which a number of possible fuel rod locations are unoccupied.

Rack Efficiency – the ratio of a particular lattice statepoint in-rack eigenvalue (k_∞) to its associated lattice nominal in-core eigenvalue (k_∞). This value allows for a straightforward comparison of a rack's criticality response to varying lattice designs within a particular fuel product line. A lower

rack efficiency implies increased reactivity suppression capability relative to an alternate design with a higher rack efficiency.

Design Basis Lattice – The lattice geometry, exposure history, and corresponding fuel isotopics for a fuel product line that result in the highest rack efficiency in a sensitivity study of reasonable fuel parameters at the desired in-core reactivity. This lattice is used for all normal, abnormal, and tolerance evaluations in the fuel rack analysis.

3.7 Assumptions and Conservatisms

The fuel storage rack criticality calculations are performed with the following assumptions to ensure the true system reactivity is always less than the calculated reactivity:

1. [[

]]

5. For conservatism, only positive reactivity differences from nominal conditions determined from depletion sensitivity and abnormal configuration, analyses are added as biases to the final storage rack k_{max}(95/95).
6. Neutron absorption in spacer grids, concrete, activated corrosion and wear products (CRUD) and axial blankets is ignored to limit parasitic losses in non-fuel materials.
7. TGBLA06 defined “lumped fission products” and Xe-135 are both conservatively ignored for MCNP-05P in-rack k_{∞} calculations.
8. [[

]]

9. Only ^{10}B is modeled in the rack inserts. Each insert is assumed to contain the minimum areal density of 0.0157 g $^{10}B/cm^2$. All other insert material is ignored. Ignoring the other materials conservatively limits neutron absorption in the insert.

10. No credit is taken for the Boraflex in the storage racks in the analysis, and all material between the inner cell wall and outer wrapper of the fuel rack is modeled as water. Modeling this material as water is reasonable, as the outer wrapper does not provide a water tight seal between the Boraflex and pool environment, and therefore any significant gap formations within the poison material will be filled with water.

11. Each Boraflex rack cell will contain one chevron-shaped insert, and the inserts will be oriented uniformly in all the Boraflex racks. This analysis assumes the two neutron absorber panels in each chevron-shaped insert in the rack cells will be oriented such that one panel will be on the north side and the other panel will be on the west side. This configuration ensures that insert absorber material will be present between the Boraflex racks and the Boral racks to the north, and between the Boraflex rack adjacent to the dry cask storage pad. Therefore, the Boraflex racks are isolated from neutron interactions from the Boral racks and dry cask storage pad. In this orientation there will be no insert absorber material between the outer edges of the Boraflex racks and the south and east pool walls.

4.0 FUEL DESIGN BASIS

This rack criticality analysis covers all legacy fuel in Fermi, the current fuel product line in Fermi, GE14, and planned future fuel, GNF3. The disposition for all legacy fuel is in Appendix B. The description of current and future fuel product lines, GE14 and GNF3, are found in Sections 4.1 and 4.2. Both these product lines are used to determine the design basis bundle in Section 5.3.

All fuel is UO_2 with some fuel rods containing gadolinia, Gd_2O_3.

This criticality analysis covers reconstituted fuel where a rod containing fuel is replaced with another fueled or non-fueled rod. This analysis does not cover reconstituted fuel where there are missing fuel rods locations that are not part of the normal fuel product line design.

This criticality analysis also covers the storage of non-fuel items such as channels in spent fuel rack locations because this analysis covers peak reactivity fuel in every rack cell location.

4.1 GE14 Fuel Description

The GE14 fuel lattice configuration is a 10x10 fuel rod array minus eight fuel rods that have been replaced with two large water rods, as shown in Figure 1 with corresponding dimensions in Table 4. Figure 1 also demonstrates the part-length rod locations, which cannot be changed for this fuel design. Fuel channel dimensions are provided in Figure 2 and Table 5. Pellet stack density is in Table 6. [[

]]

[[

]]

Figure 1 – GE14 Fuel Lattice Configuration

Table 4 – Nominal Dimensions for GE14 Fuel Lattice

Item			Dimension	
			mm	in
[[				
				]]

[[

]]

Figure 2 – GE14 Channel Dimensions

Table 5 – Nominal Channel Dimensions for GE14 Lattice

Dimension (Variable)	mm	inches
[[		
		]]

Table 6 – GE14 Fuel Stack Density as a Function of Gadolinia Concentration

[[								
								]]

[[

]]

4.2 GNF3 Fuel Description

The GNF3 fuel lattice configuration is a 10x10 fuel rod array [[ ]], as shown in Figure 3 with corresponding dimensions in Table 7. Figure 3 also demonstrates the part-length rod locations. Fuel channel dimensions are provided in Figure 4 and Table 8. Pellet stack density is in Table 9. [[

]]

[[

]]

Figure 3 - GNF3 Lattice Configuration

Table 7 - Nominal Dimensions for GNF3 Fuel Lattice

Item			Dimension	
			mm	in
[[				
				]]

[[

]]

Figure 4 – GNF3 Channel Dimensions

Table 8 - Nominal Channel Dimensions for GNF3 Lattice

Channel Name		83AV				93AV			
Bundle Number		4424				4350			
Channel Section		Zone 1		Zone 2		Zone 1		Zone 2	
Dimension		mm	in	mm	in	mm	in	mm	in
[[									
									]]

Table 9 – GNF3 Fuel Stack Density as a Function of Gadolinia Concentration

[[								
								]]

4.3 Fuel Model Description

The fuel models considered include 2D geometric modeling of all fuel material, cladding, water rods, and channels. [[

]] An example of a GNF3 mid lattice model in MCNP-05P is depicted in Figure 5.

[[

]]

Figure 5 – GNF3 Lattice in MCNP-05P

[[

]] The lattice type and exposure history that results in the worst-case rack efficiency for an in-core k_∞ greater than the proposed limit is then used to define the design basis lattice. This lattice is assumed to be stored in every location in the rack being analyzed. Details on the determination of the design basis lattice using the process outlined above are presented in Section 5.3.

5.0 CRITICALITY ANALYSIS OF SPENT FUEL STORAGE RACKS

5.1 Description of Spent Fuel Storage Racks

The Fermi Boraflex storage racks manufactured by Joseph Oat Corporation consist of a 304 SS structure composed of a series of square vertical tubes (cells). These tubes contain 0.070-inch thick Boraflex panels sandwiched between a 0.075-inch SS inner cell wall and a 0.075-inch SS outer wrapper. The Boraflex containing cells are arranged in a checkerboard pattern with the space between a 4-cell group forming a fifth bundle storage location with a center-to-center cell pitch of 6.22 inches. Rack array are placed adjacent to one another in the spent fuel pool. A schematic of a Boraflex storage rack array without inserts installed is shown in Figure 6.

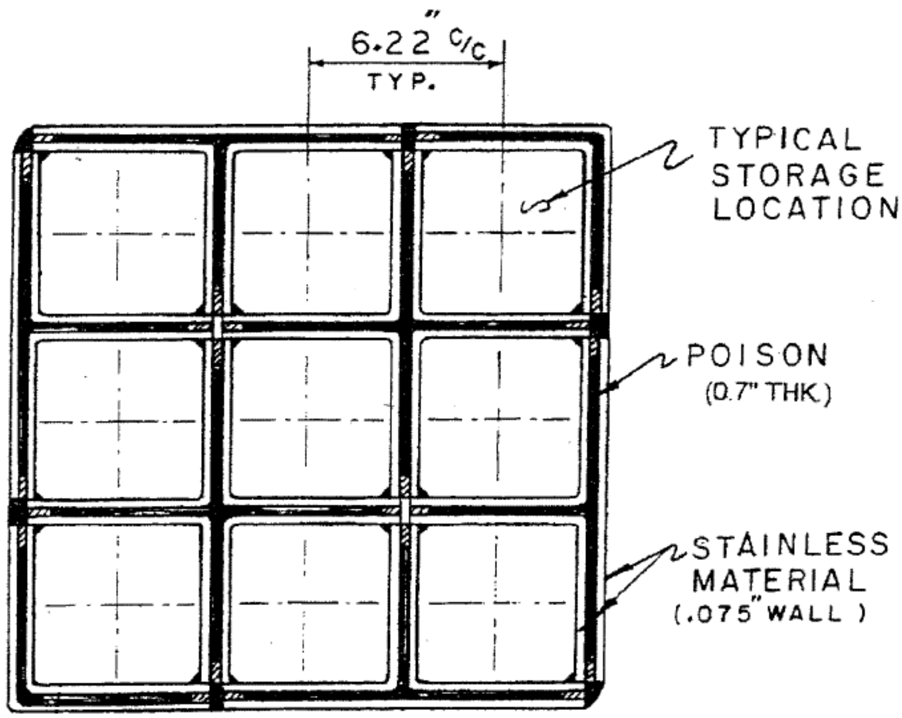

Figure 6 –Spent Rack Array Without Inserts

Originally, the racks employed thermal neutron absorption in the ^{10}B of the Boraflex as the primary mechanism of reactivity control; however, the Boraflex has been demonstrated to be degrading over time. Therefore, no credit is taken for the Boraflex in this analysis, and all material between the inner cell wall and outer wrapper is modeled as water. Modeling this material as water is reasonable, as the outer wrapper does not provide a water tight seal between the Boraflex and pool environment. Therefore, any significant gap formations within the poison material will be filled with water.

To supplement the reactivity suppression capability of the rack, chevron shaped neutron absorbing inserts (NETCO-SNAP-IN®) are installed in each of the storage cells in a storage rack module. These inserts extend over the full-length of the active fuel region of the storage assemblies. The inserts are manufactured from a Rio Tinto Alcan aluminum boron carbide metal matrix composite with a minimum certified areal density of 0.0157 g $^{10}B/cm^2$. The minimum designed wing length of the inserts is [[ ]] inches, and the nominal thickness is [[ ]] inches. Each insert is installed with the same orientation. In this way, one leg of an insert exists between each bundle in the storage rack assembly. A general schematic demonstrating this layout is provided in Figure 7.

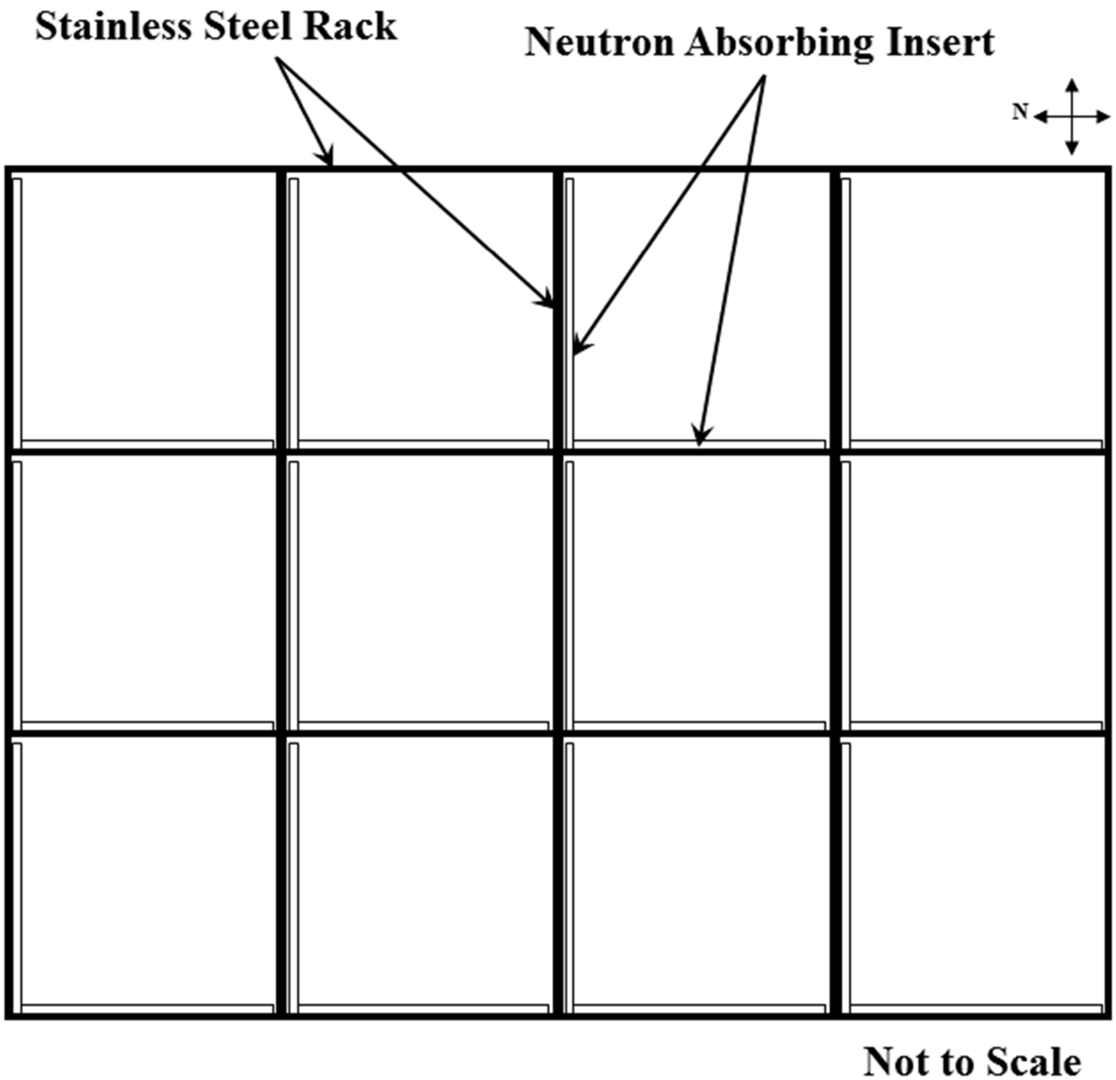

Figure 7 – Storage Rack Array with Inserts

Based on the insert configuration, peripheral storage cells on the south and east sides of the storage pools will not be surrounded by four wings of the absorbing insert. The reactivity effect of this storage limitation is assessed in Section 5.5.

5.2 Spent Fuel Storage Rack Models

This analysis covers a single bounding storage configuration of maximum reactivity fuel in every storage location with a NETCO-SNAP-IN® insert in every storage location.

A 2D infinite storage array with periodic boundary conditions is modeled to conservatively represent the nominal spent fuel pool configuration. An image of a single element of the model is provided in Figure 8 and a zoomed in view of Figure 9, with dimensions and tolerances presented in Table 10. This single element is used to define a 10x10 rack array with periodic boundary conditions. This array is used in the design basis bundle selection process in Section 5.3.

MCNP-05P initial source distribution is defined as [[
]]

[[
]]

Figure 8 – Storage Rack Model Schematic

[[
]]

Figure 9 – Zoomed Storage Rack Model Schematic

Table 10 – Storage Rack Model Dimensions

		Tolerances	
Rack Model Parameter	**Nominal**	**Plus**	**Minus**
	(inches)	***(inches)***	***(inches)***
Rack Pitch	6.220	0.1250	None
Inner Cell Wall Thickness	0.075	0.0040	0.0040
Outer Wrapper Thickness	0.075	0.0040	0.0040
Boraflex Thickness	0.070	0.0070	0.0070
Boraflex Width	5.910	0.0625	0.0625
[[			
			]]

[[

]]

5.3 Design Basis Lattice Selection

Table 11 defines the lattice designs and exposure histories that were explicitly studied in the spent fuel storage rack to determine the geometric configuration and isotopic composition that results in the worst rack efficiency. Note that void state is not a relevant parameter for zero exposure peak reactivity cases, and, therefore, only a single result is presented for these fuel loadings. Figure 10 presents a graph that demonstrates the linear nature of the in-core to in-rack results over all rack efficiency cases studied in the rack system. [[

]] The highest rack efficiency with an in-core k_∞ greater than the proposed limit of 1.30 is found to result from the parameters defined in Table 11 Case 7. The geometry and isotopics defined for this case are used to define all bundles in the remaining spent fuel rack analyses.

Table 11 – Fuel Parameter Ranges Studied in Spent Fuel Rack

Case	Bundle	Lattice Type	Void	Average Lattice Enrichment (^{235}U wt.%)	Number of Gadolinia Rods	Gadolinia Concentration (Gd wt. %)	Peak-Reactivity Exposure (GWD/ST)	TGBLA06 Defined In-Core k_∞	MCNP-05P Defined In-Rack k_∞	Rack Efficiency
[[										

Table 11 – Fuel Parameter Ranges Studied in Spent Fuel Rack

Case	Bundle	Lattice Type	Void	Average Lattice Enrichment (^{235}U wt.%)	Number of Gadolinia Rods	Gadolinia Concentration (Gd wt. %)	Peak-Reactivity Exposure (GWD/ST)	TGBLA06 Defined In-Core k_∞	MCNP-05P Defined In-Rack k_∞	Rack Efficiency
										]]

[[

]]

Figure 10 – Spent Fuel In-Core versus In-Rack Eigenvalues

5.4 Normal Configuration Analysis

5.4.1 Analytical Models

The most reactive normal configuration was determined by studying the reactivity effect of the following credible normal scenarios:

- [[

]]

5.4.2 Results

The results of the study are provided in Table 12. [[

]] The in-rack k_∞ associated with this nominal combination of conditions is [[ ]], and is hereafter referred to as k_{Normal}. This configuration will be used for all abnormal and tolerance studies that are performed on an infinite basis. Any small, positive reactivity differences from this nominal condition are included in the calculation of the system bias in Section 5.5.2.

Table 12 – Spent Fuel Storage Rack In-Rack k_∞ Results – Normal Configurations

Term	Configuration	In-Rack k_∞	MCNP-05P Uncertainty (1σ)
[[			
			]]

[[
]]

5.5 Bias Cases

5.5.1 Depletion Bias Cases

The following configurations related to the depletion conditions of the stored bundles were explicitly considered, where each description defines a condition all bundles in storage experience over their entire exposure histories. These bound the conditions the bundles actually experience.

- [[
]]

The following potential reactivity effect of changes that occur during depletion are considered:

a. Fuel rod changes (clad creep, fuel densification/swelling)

[[
]]

b. Material dependent grid growth

[[
]]

5.5.2 Normal Bias Cases

The following bias cases are included for normal conditions. As seen in Table 12, [[
]] and are therefore included in Table 16.

- No inserts on rack periphery

[[

]]

Table 13 – Rack Periphery Study Results

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk
[[			
			]]

- Missing rack insert

  A missing insert from the 10x10 infinite array was analyzed to cover the periodic removal of an insert for inspection or an insert being accidently removed during fuel movement. The relative reactivity increase from this condition is included in the bias table in Table 16.

5.5.3 Abnormal/Accident Bias Cases

Additionally, perturbations of the normal spent fuel rack configuration were considered for credible accident scenarios. The scenarios considered are presented in the bulleted lists that follow, with explanations of the abnormal condition provided below each listing of similar configurations. The most limiting of these abnormal conditions is included in the final Δk_{Bias} term in Table 16.

- Dropped/damaged fuel

  [[

  ]]

- Abnormal positioning of a fuel assembly outside the fuel storage rack

  [[

]]

[[

]]

Figure 11 – Finite Misplaced Bundle Model Example

Table 14 – Results for a Misplaced Bundle

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk
[[			
			]]

The following abnormal configurations are also considered bounded, with the justification provided:

- Dropped bundle on rack

  Justification – For a drop on the rack, the fuel assembly will come to rest horizontally on top of the rack with a minimum separation distance from the fuel in the rack of more than 12 inches. At this separation distance, the fissile material will be separated by enough neutron mean free paths to preclude neutron interactions that increase k_{eff}, and the overall effect on reactivity will be insignificant.

- Rack sliding due to seismic event which causes water gap between racks to close

  Justification – The racks modeled in this analysis are infinite in extent with no inter-module water gaps. This essentially assumes all racks are close-fitting and bounds possible reactivity effects of rack sliding.

- Loss of spent fuel pool cooling

  Justification – [[

  ]]

Table 15 – Spent Fuel Storage Rack Abnormal Bias Summary

Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk	Δk Uncertainty (2σ)
[[				
				]]

[[
]]

5.5.4 Results

The results of the abnormal studies are provided in Table 16. [[

]] The total contribution from these independent conditions to the k_{max}(95/95) of the spent fuel rack is calculated using Equation 1. In this equation, a Δk_{Bi} value must be both positive and the largest for its respective term to be considered.

$$\Delta k_{Bias} = \sum_{i=1}^{n} \Delta k_{Bi} \tag{1}$$

Table 16 – Spent Fuel Storage Rack Bias Summary

Term	Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk	Δk Uncertainty (2σ)
[[					
					]]

[[

]]

5.6 Tolerance Analysis

5.6.1 Analytic Models

The following tolerance study configurations were explicitly considered for the spent fuel rack:

- [[

]]

- [[

]]

All the tolerances used in these analyses are at least 2σ design limits. The models developed for these studies were all based on the normal configuration presented in Section 5.4.

There is no manufacturing tolerance for a decrease in rack pitch; therefore, no tolerance case was performed for rack pitch increase. [[

]]

Because the Boraflex is modeled as water in this analysis, no tolerance cases are performed on the Boraflex thickness or width.

5.6.2 Results

The results of the tolerance studies are provided in Table 17. The Δk term in this table represents the difference between the system reactivity with the specified tolerance perturbation and k_{Normal}. The total contribution from these independent tolerances to the k_{max}(95/95) of the spent fuel rack is calculated using Equation 2. In this equation, a Δk_{Ti} value must be both positive and the largest for its respective term to be considered.

$$\Delta k_{Tolerances} = \sqrt{\sum_{i=1}^{n} \Delta k_{Ti}^{2}} \qquad (2)$$

Table 17 – Spent Fuel Storage Rack Tolerance Configuration Δk Results

Term	Description	k_{eff}	MCNP-05P Uncertainty (1σ)	Δk*	Δk Uncertainty (2σ)+
[[					
					]]

[[

]]

5.7 Uncertainty Values

The total contribution to the k_{max}(95/95) of the spent fuel rack from the problem and code specific uncertainties is calculated using Equation 3 and the values in Table 18.

$$\Delta k_{Uncertainty} = \sqrt{\sum_{i=1}^{n} \Delta k_{Ui}^{2}} \quad (3)$$

Table 18 – Spent Fuel Storage Rack Uncertainty Δk Values

Term	Description	Value
[[		
		]]

5.8 Maximum Reactivity

The maximum reactivity of the spent fuel rack without crediting Boraflex and with rack inserts installed, considering all biases, tolerances, and uncertainties, is calculated using Equation 4. The final values are presented in Table 19.

$$k_{max(95/95)} = k_{Normal} + \Delta k_{Bias} + \Delta k_{Tolerance} + \Delta k_{Uncertainty} \quad (4)$$

Table 19 – Spent Fuel Storage Rack Results Summary

Term	Value
[[	
	]]

[[

]]

6.0 INTERFACES BETWEEN AREAS WITH DIFFERENT STORAGE CONDITIONS

The Fermi spent fuel pool contains Boral racks and a dry cask storage pad; thus, there are interfaces between these areas and the Boraflex racks. However, application of Assumption 11 dictates that there will be insert absorber material along all of these interface locations. Thus, these interfaces are bounded by the misloaded bundle case including the abnormal/accident bias cases. Therefore, there are no interface restrictions.

It is recognized that there are two fuel-preparation machines adjacent to the north facing edge of the Fermi spent fuel pool. The function of these fuel-preparation machines is to remove and replace fuel bundle channels, perform fuel inspections, and new fuel receipt/transfer activities. The Boraflex racks are separated from these fuel-preparation machines by another set of Boral spent fuel racks. Because this minimum separation distance from the fuel in the Boraflex racks to the fuel-preparation machines is more than 12 inches, they are neutronically decoupled. At this separation distance, the fissile material will be separated by enough neutron mean free paths to preclude neutron interactions that increase k_{eff}.

7.0 CONCLUSIONS

The Fermi spent fuel racks have been analyzed for the storage of GE14 and GNF3 fuel using the MCNP-05P Monte Carlo neutron transport program and the k_∞ criterion methodology. A maximum SCCG, uncontrolled peak in-core eigenvalue (k_∞) of 1.30 as defined by TGBLA06 is specified as the rack design limit for GE14 and GNF3 fuel in the spent fuel racks with NETCO-SNAP-IN® rack inserts installed. The analyses resulted in a storage rack maximum k-effective (k_{max}(95/95)) less than the 10 CFR 50.68 limit of 0.95 for normal and credible abnormal operation with tolerances and computational uncertainties taken into account. Documentation that all legacy Fermi fuel types meet the k_{max}(95/95) limit is found in Appendix B.

8.0 REFERENCES

1. General Electric Company, "Steady-State Nuclear Methods," NEDE-30130-P-A, April 1985.
2. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Section 9.1.1, "Criticality Safety of Fresh and Spent Fuel Storage and Handling," US NRC, Revision 3, March 2007. (NRC ADAMS Accession Number ML070570006).
3. NEI 12-16 Revision 3, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants," March 2018. (NRC ADAMS Accession Number ML18088B400).
4. LA-UR-03-1987, "MCNP – A General Monte Carlo N-Particle Transport Code, Version 5," April 2003.
5. NUREG/CR-6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology," US NRC, January 2001. (NRC ADAMS Accession Number ML050250061).
6. Global Nuclear Fuel, "GE14 – Boraflex Spent Fuel Storage Rack Criticality Analysis for Fermi Unit 2," 0000-0026-1913-SFP, Revision 5, August 2016.
7. J.R. Taylor, "An Introduction to Error Analysis," page 268-271, 2nd Edition, University Science Books, 1997.

APPENDIX A - MCNP-05P CODE VALIDATION

Table 20 presents the results of the benchmark calculations described in Section 3.4. Note that it is necessary to make an adjustment to the calculated k_{eff} value if the critical experiment being modeled was not at a critical state. This adjustment is done by normalizing the k_{calc} values to the experimental values, which is valid for small differences in k_{eff}. This normalization is reported as k_{norm} and is determined using Equation A-1. The combined uncertainty from the measurement and the calculation (σ_t) is also determined using Equation A-2.

$$k_{norm} = k_{calc}/k_{exp} \qquad \text{(A-1)}$$

$$\sigma_t = \sqrt{\sigma_{calc}^2 + \sigma_{exp}^2} \qquad \text{(A-2)}$$

Table 20 – MCNP-05P Results for the Benchmark Calculations

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)
[[								

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)

#	Experiment	Expt. #	Benchmark Eigenvalue (k_{exp})	Experimental Uncertainty (σ_{exp})	MCNP-05P Result (k_{calc})	MCNP-05P Uncertainty (σ_{calc})	Norm. Result (k_{norm})	Combined Uncertainty (σ_t)
								]]

A.1 - Trend Analysis

To determine if any trend is evident in this pool of experiments, the parameters listed in Table 21 were considered as independent variables.

Table 21 – Trending Parameters

Energy of the Average Lethargy causing Fission (EALF)
Uranium Enrichment (wt.% ^{235}U)
Plutonium Content (wt.% ^{239}Pu)
Atom ratio of hydrogen to fissile material (H/X)

Each parameter was plotted against the k_{norm} results independently for each case that was analyzed. These plots are provided in Figure 12 through Figure 15. This scatter plot of data was first analyzed by visual inspection to determine if any trends were readily apparent in the data. During this inspection, the axes of the graphs were modified to different scales to allow for a more thorough review. No clear evidence of a trend, linear or otherwise, was observed from this inspection.

[[

]]

Figure 12 – Scatterplot of k_{norm} versus EALF

[[

]]

Figure 13 – Scatterplot of k_{norm} versus ^{235}U wt.%

[[

]]

Figure 14 – Scatterplot of k_{norm} versus ^{239}Pu wt.%

[[

]]

Figure 15 – Scatterplot of k_{norm} versus H/X

To further check for trends in the data, a linear regression was performed. The linear regression fitted equation is in the form y(x)= a +bx, where y is the dependent variable (k_{norm}) and x is any of the predictor variables from Table 21. Unweighted k_{norm} values were used in this evaluation, although it is noted that, due to the very similar σ values reported in Table 20, using weighted values would produce very similar results. This regression was performed using the built-in regression analysis tool in Excel. The fitted lines are included in Figure 12 through Figure 15. Again, it is noted through visual inspection that the trends do not appear to exhibit a strong correlation to the data. A useful tool to validate this claim is the linear correlation coefficient. This is a quantitative measure of the degree to which a linear relation exists between two variables. It is often expressed as the square term, r^2, and can be calculated directly using built in functions in Excel. The closer r^2 gets to the value of 1, the better the fit of data is expected to be to the linear equation. Results from this linear regression evaluation are summarized in Table 22.

A final method to test for goodness of fit is the chi squared test (χ^2). This method is explained in detail in Reference 7. In general, it can be stated that χ^2 is an indicator of the agreement between the observed (calculated) and expected (fitted) values for some variable. For linear goodness of fit testing using this method, Equation A-3 is utilized, where the expected value of $f(x_i)$ corresponds to the linear fitted equation for the trending parameter, x_i.

$$\chi^2 = \sum_1^N \left(\frac{k_{calc^i} - f(x_i)}{\sigma_{calc^i}}\right)^2 \qquad \text{(A-3)}$$

A more convenient way to report this result is the reduced chi squared value, which is denoted as $\tilde{\chi}^2$ and is defined by Equation A-4, where d is the degrees of freedom for the evaluation.

$$\tilde{\chi}^2 = \chi^2/d \qquad \text{(A-4)}$$

If a value of one or less is obtained for this equation, then there is no reason to doubt the expected (fitted) distribution is reasonable; however, if the value is much larger than one, the expected distribution is unlikely to be a good fit. Results for each trending parameter are summarized in Table 22.

Table 22 – Trending Results Summary

Trend Parameter	Intercept	Slope	r^2	$\tilde{\chi}^2$	Valid Trend
EALF	[[				No
^{235}U wt.%					No
^{239}Pu wt.%					No
H/X				]]	No

The results in Table 22 clearly demonstrate that there are no statistically significant or valid trends of k_{norm} with any of the trending parameters.

A.2 - Bias and Bias Uncertainty Calculation – Single Sided Tolerance Limit

As no trends are apparent in the critical experiment results, a weighted single-sided tolerance limit methodology is utilized to establish the bias and bias uncertainty for this AOA and code package combination. Use of this method requires the critical experiment results to have a normal statistical distribution. This was verified using the Anderson-Darling normality test. A graphical image of the results for this normality test, including the p-value for the distribution, is provided in Figure 16. Because the reported p-value is greater than 0.05, it is confirmed that the data fits a normal distribution, and the single sided tolerance limit methodology is confirmed to be applicable.

[[

]]

Figure 16 – Normality Test of k_{norm} Results

When using this method, the weighted bias and bias uncertainty are calculated using the following equations:

$$Bias = \bar{k}_{norm} - 1 \quad \text{(A-5)}$$

$$Bias\ Uncertainty = U \cdot S_p \quad \text{(A-6)}$$

$$\bar{k}_{norm} = \frac{\sum_{i=1}^{n} \frac{k_{norm_i}}{\sigma_t^2}}{\sum_{i=1}^{n} \frac{1}{\sigma_t^2}} \quad \text{(A-7)}$$

(A-8)

$$S_P = \sqrt{s^2 + \bar{\sigma}^2}$$

$$\bar{\sigma}^2 = \frac{n}{\sum_{i=1}^{n} \frac{1}{\sigma_t^2}} \quad \text{(A-9)}$$

$$s^2 = \frac{\left(\frac{1}{n-1}\right)\sum_{i=1}^{n}\frac{1}{\sigma_t^2}\left(k_{norm\,i} - \bar{k}_{norm}\right)^2}{\frac{1}{n}\sum_{i=1}^{n}\frac{1}{\sigma_t^2}} \tag{A-10}$$

where:

$\bar{k}_{norm}$ = Average weighted k_{norm}

S_P = Pooled standard deviation

s^2 = Variance about the mean

$\bar{\sigma}^2$ = Average total variance

U = one-sided tolerance factor for n data points at (95/95 confidence/probability level)

n = number of data points (= [[ ]])

Table 23 summarizes the results of these calculations.

Table 23 - Bias and Bias Uncertainty for MCNP-05P with ENDF/B-VII

Bias (weighted)	[[
Bias Uncertainty (95/95 level)	
Variance About the Mean	
Average Total Variance	
Pooled Standard Deviation (1σ)	
One-Sided Tolerance Factor	]]

Using the average weighted bias and pooled standard deviation; the upper one-sided 95/95-tolerance limit (bias uncertainty) was calculated for use in criticality calculations, in accordance with NUREG/CR-6698 (Reference 5) guidance. [[

]] Table 24 summarizes the recommended bias and bias uncertainty to be used in criticality calculations.

Table 24 – Recommended Bias and Bias Uncertainty in Criticality Analyses for MCNP-05P with ENDF/B-VII

Bias	[[
Bias Uncertainty (95/95)	]]

APPENDIX B - LEGACY FUEL STORAGE JUSTIFICATION

Exposure dependent, maximum, uncontrolled in-core k_∞ results for each fuel assembly in the Fermi spent fuel pool are confirmed to be less than 1.30. The in-core k_∞ values have been calculated using the process for validating that specific assembly designs are acceptable for storage in the Fermi fuel storage racks, as outlined in Section 3.5. The margin to safety was also confirmed to exist in the storage rack by analyzing the peak reactivity legacy fuel lattice of each product line under normal conditions of storage, as outlined in Section 5.4 and the in-core reactivity values are presented in Table 25. This information demonstrates that all fuel assemblies currently in the Fermi spent fuel pool have considerable margin to the reactivity of the GNF3 design basis bundle used in this analysis. Any GE14 and GNF3 bundles in Fermi's core or spent fuel pool are covered by the design basis bundle study in Section 5.3.

The GNF3 design basis bundle with an in-core k_∞ value of 1.30 was shown to be below the 10 CFR 50.68 0.95 in-rack k-effective limit when analyzed in the storage racks. As represented in Table 25, the legacy fuel types have a significantly lower in-core k_∞ value than the GNF3 design basis bundle (i.e., less reactive than the design basis bundle). Therefore, it is confirmed that all legacy fuel bundles are safe for storage in the Fermi spent fuel storage racks with rack inserts installed.

Values in Table 25 represent the in-core k_∞ of the most reactive lattice at the most reactive exposure and void history.

Table 25 – Limiting Cold As-Designed Eigenvalue of Bundles Inserted Into Fermi 2

Bundle	Bundle Name	In-Core k_∞
[[		

Table 25 – Limiting Cold As-Designed Eigenvalue of Bundles Inserted Into Fermi 2

Bundle	Bundle Name	In-Core k_∞

]]

Enclosure 6 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

Global Nuclear Fuel and Curtiss-Wright Affidavits for Enclosure 4

Global Nuclear Fuel – Americas

AFFIDAVIT

I, Lisa Schichlein, state as follows:

(1) I am a Senior Project Manager, NPP/Services Licensing, Regulatory Affairs, GE-Hitachi Nuclear Energy Americas LLC (GEH), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in GNF-A proprietary report, NEDC-33889P, "Fermi Nuclear Generating Station Unit 2: Fuel Storage Criticality Safety Analysis of Spent Fuel Storage Racks with Rack Inserts," Revision 0, October 2018. GNF-A proprietary information within the text and tables is identified by a dotted underline inside double square brackets. [[This sentence is an example.{3}]] Figures and large objects containing GNF-A proprietary information are identified with double square brackets before and after the object. In all cases, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GNF-A relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975 F2d 871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704 F2d 1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GNF-A's competitors without license from GNF-A constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future GNF-A customer-funded development plans and programs, resulting in potential products to GNF-A;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. above.

(5) To address 10 CFR 2.390 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GNF-A, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GNF-A, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GNF-A.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GNF-A are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains details of GNF-A's fuel design and licensing methodology. The development of this methodology, along with the testing, development and approval was achieved at a significant cost to GNF-A or its licensor.

The development of the fuel design and licensing methodology along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GNF-A asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GNF-A's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GNF-A's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical, and NRC review costs comprise a substantial investment of time and money by GNF-A.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GNF-A's competitive advantage will be lost if its competitors are able to use the results of the GNF-A experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GNF-A would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GNF-A of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on this 8th day of October 2018.

Lisa Schichlein
Senior Project Manager
NPP/Services Licensing
Regulatory Affairs
GE-Hitachi Nuclear Energy Americas LLC
3901 Castle Hayne Road
Wilmington, NC 28401
lisa.schichlein@ge.com

CURTISS-WRIGHT AFFIDAVIT PURSUANT TO 10 CFR 2.390

I, Karl Scot Leuenroth, depose and say that I am the Division Manager of Curtiss-Wright's Scientech Division, duly authorized to make this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below.

I am submitting this affidavit in conformance with the provisions of 10 CFR 2.390 of the Commission's regulations for withholding Curtiss-Wright's information for which proprietary treatment is sought as contained in NEDC-33889P, "Fermi Nuclear Station Unit 2: Fuel Storage Criticality Safety Analysis of Spent Fuel Storage Racks with Rack Inserts," Revision 0, October 2018.

I have personal knowledge of the criteria and procedures utilized by Curtiss-Wright in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1) The information sought to be withheld from public disclosure is technical information related to the Snap-In Insert technology, which involves considerable research and development of intellectual property by Curtiss-Wright. Curtiss-Wright Flow Control and Services LLC. (CW) information is identified by a solid underline inside double square brackets. [[This sentence is an example.{C}]] CW proprietary information in figures and large objects is identified by double square brackets before and after the object.

2) The information is of a type customarily held in confidence by Curtiss-Wright, and not customarily disclosed to the public. Curtiss-Wright has a rational basis for determining the types of information customarily held in confidence by it.

3) The information is being transmitted to the Commission in confidence under the provisions of 10 CFR 2.390 with the understanding that it is to be received in confidence by the Commission.

4) The information, to the best of my knowledge and belief, is not available in public sources, and any disclosure to third parties has been made pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence.

5) Public disclosure of the information is likely to cause substantial harm to the competitive position of Curtiss-Wright because:

a) A similar product is manufactured and sold by competitors of Curtiss-Wright.

b) Development of this information by Curtiss-Wright required expenditure of considerable resources. To the best of my knowledge and belief, a competitor would have to undergo similar expense in generating equivalent information.

c) In order to acquire such information, a competitor would also require considerable time and inconvenience related to the development of a design and analysis of a similar neutron attenuation technology for use in a spent fuel pool.

d) The availability of such information to competitors would enable them to modify their product to better compete with Curtiss-Wright, take marketing or other actions to improve their product's position or impair the position of Curtiss-Wright's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

Karl Scot Leuenroth

Enclosure 7 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

Completed NEI 12-16 Checklist for NEDC-33889P

APPENDIX C: CRITICALITY ANALYSIS CHECKLIST

The criticality analysis checklist is completed by the applicant prior to submittal to the NRC. It provides a useful guide to the applicant to ensure that all the applicable subject areas are addressed in the application, or to provide justification/identification of alternative approaches.

The checklist also assists the NRC reviewer in identifying areas of the analysis that conform or do not conform to the guidance in NEI 12-16. Subsequently, the NRC review can then be more efficiently focused on those areas that deviate from NEI 12-16 and the justification for those deviations.

**Unless otherwise noted, section numbers refer to sections in NEDC-33889P (Enclosure 4 to NRC-19-0004). References to the "license amendment" refer to Enclosure 1 to NRC-19-0004.*

Subject	Included	Notes* / Explanation
1.0 Introduction and Overview		
Purpose of submittal	YES	
Changes requested	YES	
Summary of physical changes	YES	
Summary of Tech Spec changes	YES	Not included in the criticality analysis, included in separate part of license amendment.
Summary of analytical scope	YES	
2.0 Acceptance Criteria and Regulatory Guidance		
Summary of requirements and guidance	YES	
Requirements documents referenced	YES	
Guidance documents referenced	YES	
Acceptance criteria described	YES	
3.0 Reactor and Fuel Design Description		
Describe reactor operating parameters	NO	See Section 5.5.1 for discussion.
Describe all fuel in pool	YES	Section 4.1 and Appendix B
Geometric dimensions (Nominal and Tolerances)	YES	Section 4.1
Schematic of guide tube patterns	YES	Water rods shown in Section 4.1. Guide tube patterns not applicable for BWR fuel.
Material compositions	YES	Section 4.0
Describe future fuel to be covered	YES	Section 4.2
Geometric dimensions (Nominal and Tolerances)	YES	Section 4.2
Schematic of guide tube patterns	YES	Water rods shown in Section 4.2. Guide tube patterns not applicable for BWR fuel.
Material compositions	YES	Section 4.0

Describe all fuel inserts	NO	There are no fuel inserts in this analysis
Geometric Dimensions (Nominal and Tolerances)		
Schematic (axial/cross-section)		
Material compositions		
Describe non-standard fuel	YES	Section 4.0
Geometric dimensions		
Describe non-fuel items in fuel cells	YES	Section 4.0
Nominal and tolerance dimensions	NO	Not applicable
4.0 Spent Fuel Pool/Storage Rack Description		
New fuel vault & Storage rack description	NO	No new fuel vault analysis in this report
Nominal and tolerance dimensions		
Schematic (axial/cross-section)		
Material compositions		
Spent fuel pool, Storage rack description	YES	Section 5.1-5.2
Nominal and tolerance dimensions		
Schematic (axial/cross-section)		
Material compositions		
Other Reactivity Control Devices (Inserts)	YES	Section 5.1-5.2
Nominal and tolerance dimensions		
Schematic (axial/cross-section)		
Material compositions		
5.0 Overview of the Method of Analysis		
New fuel rack analysis description	NO	There is no new fuel rack analysis in this report
Storage geometries		
Bounding assembly design(s)		
Integral absorber credit		
Accident analysis		
Spent fuel storage rack analysis description	YES	Section 5.0 and Section 3.5-3.7
Storage geometries	YES	Section 5.2
Bounding assembly design(s)	YES	Section 5.3
Soluble boron credit	NO	Not applicable - No soluble boron credit in this BWR criticality analysis
Boron dilution analysis		
Burnup credit	NO	No burnup credit in BWR peak reactivity analysis – fuel is evaluated at peak reactivity
Decay/Cooling time credit	NO	No decay/cooling time credit
Integral absorber credit	YES	Section 5.3, Table 10
Other credit	NO	No other credit
Fixed neutron absorbers	YES	Credit for NETCO SNAP-IN® Neutron Absorbing inserts.

Aging management program	YES	Described by licensee in separate part of license amendment
Accident analysis	YES	Section 5.5.3
Temperature increase	YES	Section 5.5.3/Section 5.4.1
Assembly drop	YES	Section 5.5.3
Single assembly misload	NO	Uniform pool with peak reactivity fuel, no opportunity for misload
Multiple misload	NO	
Boron dilution	NO	Not applicable - No soluble boron credit in this BWR criticality analysis
Other	YES	Section 5.5.3
Fuel out of rack analysis	NO	Not applicable, see Section 6.0
Handling		
Movement		
Inspection		
6.0 Computer Codes, Cross Sections and Validation Overview		
Code/Modules Used for Calculation of k_{eff}	YES	Described in Section 3.0
Cross section library	YES	Section 3.1
Description of nuclides used	YES	Section 4.3
Convergence checks	YES	Section 3.3
Code/Module Used for Depletion Calculation	YES	Described in Section 3.0
Cross section library	YES	Section 3.1
Description of nuclides used	YES	Section 4.3
Convergence checks	YES	Section 3.3
Validation of Code and Library	YES	Section 3.4/Appendix A
Major Actinides and Structural Materials	YES	Section 3.4
Minor Actinides and Fission Products	YES	Section 3.4
Absorbers Credited	YES	Section 3.4
7.0 Criticality Safety Analysis of the New Fuel Rack		
Rack model	NO	There is no new fuel rack analysis in this report.
Boundary conditions		
Source distribution		
Geometry restrictions		
Limiting fuel design		
Fuel density		
Burnable Poisons		
Fuel dimensions		
Axial blankets		

Limiting rack model		
Storage vault dimensions and materials		
Temperature		
Multiple regions/configurations		
Flooded		
Low density moderator		
Eccentric fuel placement		
Tolerances		
Fuel geometry		
Fuel pin pitch		
Fuel pellet OD		
Fuel clad OD		
Fuel content		
Enrichment		
Density		
Integral absorber		
Rack geometry		
Rack pitch		
Cell wall thickness		
Storage vault dimensions/materials		
Code uncertainty		
Biases		
Temperature		
Code bias		
Moderator Conditions		
Fully flooded and optimum density moderator		
8.0 Depletion Analysis for Spent Fuel		
Depletion Model Considerations	YES	Described in Section 3.3, Section 3.7, and 4.3
Time step verification		
Convergence verification		
Simplifications		
Non-uniform enrichments		
Post Depletion Nuclide Adjustment		
Cooling Time		
Depletion Parameters		
Burnable Absorbers		
Integral Absorbers		
Soluble Boron		
Fuel and Moderator Temperature		
Power		
Control rod insertion		
Atypical Cycle Operating History		

9.0 Criticality Safety Analysis of Spent Fuel Pool Storage Racks		
Rack model	YES	Section 5.2
Boundary conditions		
Source distribution		
Geometry restrictions		
Design Basis Fuel Description	YES	Section 5.3
Fuel density	YES	Sections 4.1 and 4.2
Burnable Poisons	YES	Section 5.3
Fuel assembly inserts	NO	No fuel assembly inserts in this analysis
Fuel dimensions	YES	Section 4.1 and 4.2
Axial blankets	NO	Section 3.7
Configurations considered	YES	Single configuration, uniform pool, Section 6.0
Borated	NO	Not applicable for this analysis
Unborated	YES	
Multiple rack designs	NO	Not applicable for this analysis
Alternate storage geometry	NO	Not applicable for this analysis
Reactivity Control Devices	YES	
Fuel Assembly Inserts	NO	No fuel assembly inserts in this analysis
Storage Cell Inserts	YES	NETCO SNAP-IN® inserts – Section 5.1
Storage Cell Blocking Devices	NO	No blocking devices in this analysis
Axial burnup shapes	NO	Section 3.7
Uniform/Distributed	YES	Section 3.7
Nodalization	NO	Section 3.7
Blankets modeled	NO	Section 3.7
Tolerances/Uncertainties	YES	Section 5.6
Fuel geometry		
Fuel rod pin pitch		
Fuel pellet OD		
Cladding OD		
Axial fuel position	NO	Section 3.7
Fuel content	YES	Section 5.6
Enrichment		
Density		
Assembly insert dimensions and materials	NO	No fuel assembly inserts in this analysis

Rack geometry	YES	Section 5.6
Flux-trap size (width)	NO	Not applicable to non flux-trap racks
Rack cell pitch	NO	Not applicable, See Section 5.6.1
Rack wall thickness	YES	Section 5.6.1
Neutron Absorber Dimensions	NO	Not applicable, See Section 5.6.1
Rack insert dimensions and materials	YES	Section 5.6
Code validation uncertainty	YES	Described in Section 3.4/Section 5.7
Criticality case uncertainty	YES	Section 5.7
Depletion Uncertainty	YES	Described in Section 3.4 and Section 5.7
Burnup Uncertainty	NO	Not applicable for BWR peak reactivity analysis
Biases	YES	Section 5.0
Design Basis Fuel design	YES	Section 5.3
Code bias	YES	Section 3.4/Section 5.5.4
Temperature	YES	Section 5.4/Section 5.5.4
Eccentric fuel placement	YES	Section 5.4.1
Incore thimble depletion effect	NO	Not applicable for this analysis
NRC administrative margin	NO	Not applicable for this analysis
Modeling simplifications	YES	Section 3.7 and 4.3
Identified and described		
10.0 Interface Analysis		
Interface configurations analyzed	NO	Not applicable, See Section 6.0
Between dissimilar racks	NO	Not applicable, See Section 6.0
Between storage configurations within a rack	NO	Not applicable, See Section 6.0
Interface restrictions	NO	None
11.0 Normal Conditions		
Fuel handling equipment	NO	Not applicable for this analysis
Administrative controls	YES	Not included in the criticality analysis, included in separate part of license amendment.
Fuel inspection equipment or processes	NO	Not applicable for this analysis
Fuel reconstitution	YES	Section 4.0

12.0 Accident Analysis		
Boron dilution	NO	Not applicable - No soluble boron credit in this BWR criticality analysis
Normal conditions		
Accident conditions		
Single assembly misload	NO	Uniform pool with maximum reactivity fuel therefore no single assembly misload
Fuel assembly misplacement	YES	Section 5.5.3
Neutron Absorber Insert Misload	YES	Section 5.5.2
Multiple fuel misload	NO	Uniform pool, single storage configuration, no opportunity for multiple misloads
Dropped assembly	YES	Section 5.5.3
Temperature	YES	Section 5.5.3
Seismic event/other natural phenomena	YES	Section 5.5.3, also included in separate part of license amendment.
13.0 Analysis Results and Conclusions		
Summary of results	YES	Section 5.8/7.0
Burnup curve(s)	NO	Not applicable for BWR peak reactivity analyses
Intermediate Decay time treatment	NO	Not applicable for BWR peak reactivity analyses. See Section 4.3.
New administrative controls	YES	Not included in the criticality analysis, included in separate part of license amendment.
Technical Specification markups	YES	Not included in the criticality analysis, included in separate part of license amendment.
14.0 References	YES	**Section 8.0**
Appendix A: Computer Code Validation:		**Appendix A**
Code validation methodology and bases	YES	Appendix A
New Fuel		
Depleted Fuel		
MOX		
HTC		
Convergence		
Trends		
Bias and uncertainty		
Range of applicability	YES	Described in Section 3.4
Analysis of Area of Applicability coverage	YES	Described in Section 3.4

Enclosure 8 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

Material Qualification of NETCO SNAP-IN® Rack Inserts

NET-259-03

MATERIAL QUALIFICATION OF ALCAN COMPOSITE FOR SPENT FUEL STORAGE

Prepared by:

Northeast Technology Corp.
108 N. Front Street
Kingston, NY 12401

August 2008

Rev.	Date	Prepared by:	Reviewed by:	Approved (QA):
5	7/30/09	K. [signature]	[signature]	L. P. Mariani

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1.0 Introduction and Summary

The purpose of this topical report is to demonstrate that aluminum/B_4C sheet produced
from DC (direct chill) cast rolling billets supplied by Rio Tinto Alcan Inc. is a suitable 3
material for use as a neutron absorber in spent nuclear fuel storage applications and in
particular it is a suitable material from which to fabricate NETCO-SNAP-IN® neutron
absorber inserts. The NETCO-SNAP-IN® neutron absorber insert is installed in existing
spent fuel storage racks to restore the reactivity hold-down capability of racks with
degraded Boraflex. Once installed, these neutron absorber inserts become
permanently affixed to the storage racks.

The suitability of Rio Tinto Alcan Inc. material as demonstrated herein is based upon:

- detailed comparison with highly similar material with a successful record of industry-wide, in-service performance
- accelerated corrosion testing in simulated BWR and PWR spent fuel pool environments 4
- evaluating and testing of mechanical properties to verify acceptability of installed insert retention force
- measurement of B_{10} areal density to confirm satisfactory neutron absorption capability
- short term and long term in-situ coupon surveillance programs.

These evaluations are detailed in the various sections of this report.

The Alcan material is supplied as 6x6 inch rectangular DC cast rolling billets that are hot rolled to final gage. The material is designated as aluminum boron carbide composite W1100N.XYB where XY is the boron carbide content which can range from 16 to 30

volume percent. The reinforcing phase of the composite is boron carbide powder containing at least 76 w/o boron and with an average particle size of 7.5 ± 2 μm (D_{50}).

As stated above, one particular application of the W1100N.XYB composite in spent fuel 4
pools is the NETCO-SNAP-IN® neutron absorber insert. The NETCO-SNAP-IN® is proprietary to NETCO and is protected by U.S. Patent No. 6,741,669 B2.[1-1] The first use of NETCO-SNAP-IN® absorber inserts will be at Exelon's LaSalle Unit 2 Station. Other applications of the W1100N.XYB composite include newly fabricated spent fuel storage racks and dry spent fuel storage and transportation casks. With respect to the latter use, this material has been used in dry storage/transportation in the U.S. and extensively in Europe.

Recent guidance has been published for the qualification and acceptance of new boron based metallic neutron absorbers for storage and transportation casks. [1-2] Using this document as a guide, the qualification process described in this report consists of the following elements:

- Review of the composition and manufacturing process of the W1100N.XYB composite and a detailed comparison with the composition and manufacturing process for BORAL™, a neutron absorber material that has been successfully used extensively worldwide for spent nuclear fuel storage racks for the last 40 years.
- An accelerated corrosion program has been completed in both demineralized
water and boric acid (2500 ppm as boron). The program ran for one year in 5
duration. Interim and final results are reported.
- A fast start surveillance coupon program has been initiated (March 08) at LaSalle Unit 2 to provide in-service performance data on the W1100N.16B composite in the actual proposed service environment. This will provide performance data that will always lead the installed NETCO-SNAP-IN® inserts in both time of exposure and absorbed gamma dose. The fast start coupon program consists of a string of 24 coupons connected by stainless links. The coupons have been precharacterized with respect to dimensions, dry weight, density and boron-10

areal density. Periodically coupons will be removed from the string and sent to a qualified laboratory for post exposure testing and inspection.

- A long term surveillance assembly will be placed in the LaSalle pool prior to the installation of the first NETCO-SNAP-IN® inserts. These coupons will differ from the "Fast-Start" and, in particular, will be composed of 17 vol-% B_4C instead of 16 vol-% B_4C material. This modification is due to a manufacturing revision of the 5
NETCO-SNAP-IN® inserts intended to ensure compliance with minimum areal density requirements. The tree will hold the following types of coupons:
  - unclad Alcan W1100N.17B composite coupons
  - W1100N.17B composite coupons with 304L stainless steel, In-718 and Zircaloy samples
  - W1100N.17B composite bend coupons

  Periodically coupons will be removed from the assembly and sent to a qualified laboratory for testing and inspection.

The following sections of this report describe:

- NETCO-SNAP-IN® and Installation Tooling
- Manufacturing process and quality control used for NETCO-SNAP-IN® inserts
- Composition and physical properties of the W1100N.XYB composite
- Description of accelerated corrosion testing and interim results
- Comparative evaluation of W1100N.XYB composite and BORAL™
- Anticipated performance of W1100N.XYB in spent fuel pools
- Detailed description of the "fast start" coupon surveillance program
- Detailed description of long term coupon surveillance program
- Conclusions

References Section 1

1-1. Lindquist, K. O., U.S. Patent No. 6,741,669 B2, "Neutron Absorber Systems and Method for Absorbing Neutrons," May 25, 2004.

1-2. ASTM C 1671-07, "Standard Practice for Qualification and Acceptance of Boron Based Metallic Neutron Absorbers for Nuclear Criticality Control for Dry Cask Storage Systems and Transportation Packaging."

2.0 Description of the NETCO-SNAP-IN® and Installation Tooling

Neutron absorber materials are incorporated in spent fuel storage racks to permit the safe storage of LWR fuel assemblies in close proximity to each other. One or two panels of a neutron absorber material are placed between each face of every fuel assembly in order to maintain the stored fuel in a sufficiently sub-critical condition.

One neutron absorber material used for this purpose, Boraflex, has been observed to experience in service degradation well in advance of its design service life. As degradation proceeds, the matrix intended to retain the neutron absorber (boron carbide) dissolves and the boron carbide slumps to the bottom of the pool. As this occurs, less and less of the neutron absorber is in place to maintain the fuel in a sub-critical condition.

The NETCO-SNAP-IN® insert mitigates the boron carbide loss from Boraflex by inserting a thin chevron-shaped metallic sleeve into the fuel storage cell of the rack. The sleeve is fabricated from an aluminum/boron carbide composite. When installed, this sleeve, or insert, abuts two adjacent faces of the rack wall. It is intended that an insert be installed in all the storage cells of a given module as shown in Figure 2-1. With each insert installed in the same configuration, every face of all fuel assemblies will have neutron absorber material between it and one face of the adjacent fuel assemblies. Since the inserts are fabricated of a neutron absorbing material, replacement of the initial reactivity hold-down system is effectively achieved.

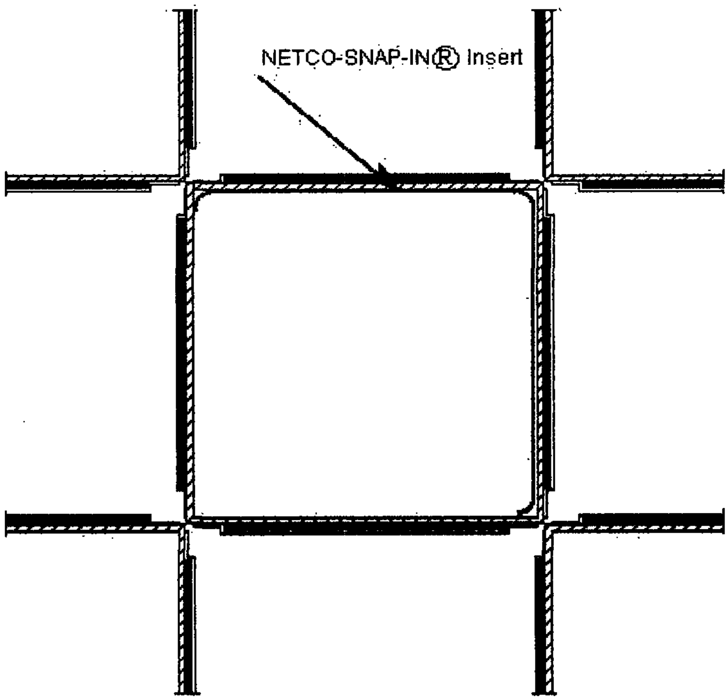

Figure 2-1 NETCO-SNAP-IN® Insert Installed in a Spent Fuel Storage Rack

Figure 2-2 shows a typical NETCO-SNAP-IN®. The insert has a length equivalent to the length of the fuel storage cell and the lower end is tapered to facilitate insertion into the fuel storage cell. The chevron is formed with a central bend angle along its length greater than 90°. The width of each wing of the chevron is slightly less than the minimum inside dimension of the fuel storage cell. Each edge of the wing is roll formed and it is this feature that accommodates cell to cell variations in inside dimensions. Near the top of the NETCO-SNAP-IN® is a hole in each wing that engages the installation tool.

It is noted that the chevrons are formed with a greater than 90° bend angle and this causes compression of the insert as it is "pushed" into the rack cell and assumes the

90° angle between adjacent rack cell walls. The insert is designed to become an integral part of the fuel rack once it has been installed. This is achieved through the elastic deformation of the insert bearing against the rack cell wall and the associated friction force. The force exerted due to this deformation is predicted by the effective spring constant of the insert, which is described in detail elsewhere. The force between the insert wings and the rack cell walls in conjunction with the static friction between these surfaces serves to retain the NETCO-SNAP-IN® and make it a permanent part of the rack once it is installed.

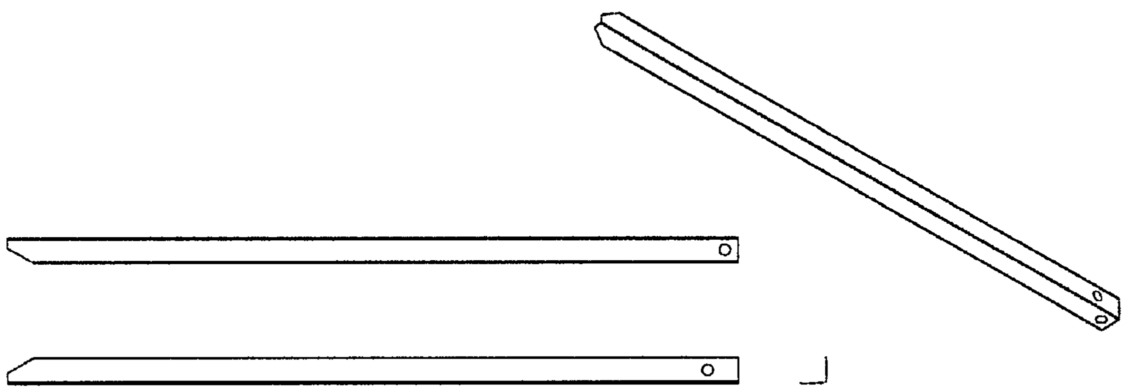
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Figure 2-2 NETCO-SNAP-IN® Insert

The installation tool with a NETCO-SNAP-IN® engaged is shown in Figure 2-3. At the top of the tool is a bail that replicates the bail on a BWR fuel assembly. As such the installation tool can be engaged with a fuel grapple or with the refueling mast. The bail is attached to an anvil assembly that provides a bearing surface on the top edge of the insert. Immediately below the anvil assembly is the head assembly. The head assembly contains two spring loaded cylinders, that engage the insert while it is being moved to the storage cell into which it is destined for installation. When, during installation, the cylinders come into contact with the rack cell wall they retract, thus allowing full insertion of the insert. The curvature of the upper edge of each cylinder is so configured that when the insert is fully installed, upward movement of the tool allows the cylinder to clear the engagement holes in the insert, leaving the insert fully seated in the rack cell.

Again referring to Figure 2-3, a counterweight is suspended from three rods below the head assembly. In addition to partially providing downward insertion force, the counterweight, which contributes to insert stability during installation, lowers the center of gravity of the tool. The insertion tool is constructed entirely of stainless steel and weighs less than 1290 lbs. 3

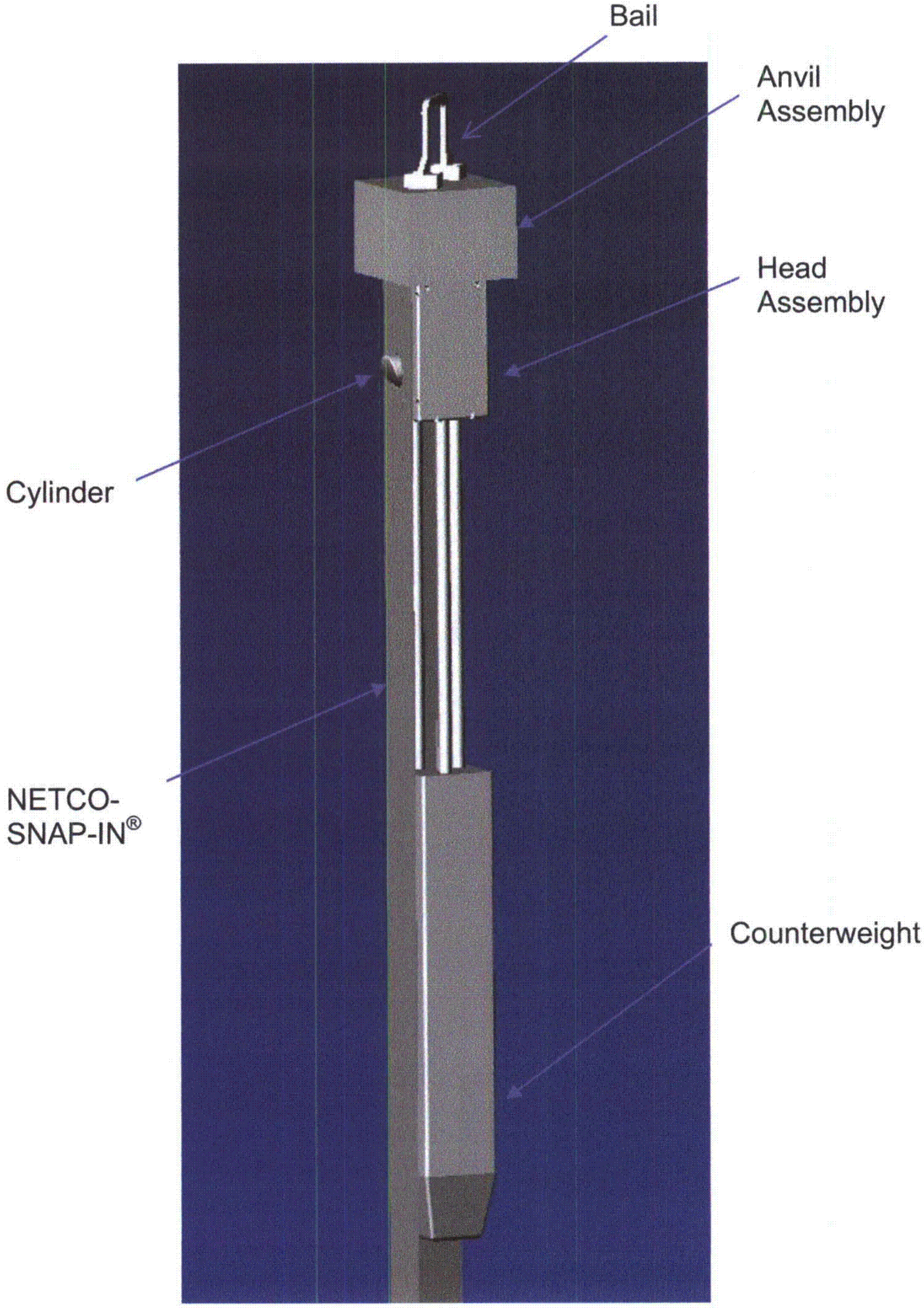

Figure 2-3 Installation Tool

3.0 Manufacturing the NETCO-SNAP-IN® Neutron Absorber Insert

3.1 Billet Production

There are two basic methods for producing aluminum/boron carbide metal matrix composites: powder metallurgy and liquid metal mixing. In the case of powdered metallurgy, atomized metal powder is blended with boron carbide particles, compacted and sintered to form a billet for further processing. The billet is generally extruded to produce rectangular preforms for rolling to final gage. This method has proved to be expensive due to the high cost of atomized metal powders and time consuming processing steps. In addition, wear products from the extrusion die on the surface of the preform need to be removed by cleaning or machining so as not to result in galvanic corrosion in wet storage applications.[3-1] Furthermore, and depending on the process used to produce the billets, the final rolled sheet may have limited ductility making the sheet difficult to form by bending. [3-2]

Alcan has developed a liquid mixing process for producing aluminum/boron carbide composites that use mechanical stirring to mix the powdered B_4C in the molten aluminum. As this mixing process is conducted at temperatures well over the melting point of aluminum, significant aluminum and boron carbide interactions can occur that can result in degraded mechanical and physical properties. [3-3] A significant physical property effect can be the agglomeration of B_4C particles resulting in a non-uniform boron distribution in the composite. Alcan has found that by adding small amounts of Ti (< 2.5%) to the molten aluminum, the B_4C particles become stable in the molten aluminum, eliminating particle clusters, and a uniform blend is achieved. It is thought that a Ti rich zone forms around each boron carbide particle, preventing Al/B_4C interactions.

The molten aluminum/boron carbide blend is direct chill cast into 6"x6" rectangular billets. The length of the billets is determined by the size and gage of the final rolled

product. The rectangular billets can be rolled directly without an intermediate extrusion step and the potential problems and cost associated with extrusion.

3.2 NETCO-SNAP-IN® Production

The Alcan billets are heated to ~ 950°F and hot rolled to final gage. After one transverse rolling the billet is rotated 90° and reduced to final gage in 33 passes in the rolling mill. The rolled sheet is trimmed on a shear to final blank size.

Once the blanks have been produced, the final fabrication steps required to produce the finished NETCO-SNAP-IN® inserts are as follow. The two long edges are trimmed on a shear to provide a tapered lead-in at the bottom of the inserts to facilitate installation. The inserts are then formed on a press brake to an angle somewhat larger than 90° and the two remaining long edges roll formed. The holes that engage the installation tool can be formed by stamping or water jet cutting.

3.3 Applicable Codes, Standards and Regulatory Guidance

The following codes, standards and practices are used as applicable for the design and manufacture of the NETCO-SNAP-IN® inserts.

- ANSI.ANS 8.1 - Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors.
- ANSI/ANS 8.12 - Nuclear Criticality Control and Safety of Plutonium - Uranium Fuel Mixtures Outside Reactor.
- ANSI/ANS 8.17 - Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors.
- ANSI/ANS 57.2 - Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Plants.
- ANSI N45.2.1 - Cleaning of Fluid Systems and Associated Components during Construction Phase of Nuclear Power Plants - 1973 (R.G. 1.37).
- ANSI N45.2.2 - Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants - 1972 (R.G. 1.38).

- American Society for Nondestructive Testing SNT-TC-1A, June 1980, Recommended Practice for Personnel Qualifications and Certification in Nondestructive Testing.
- ASTM C750 - Standard Specification for Nuclear-Grade Boron Carbide Powder.
- ASTM C992 - Standard Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks.
- ASME NQA-1 - Quality Assurance Program Requirements for Nuclear Facilities.
- ASME NQA-2 - Quality Assurance Requirements for Nuclear Power Plants.
- General Design Criterion 62, Prevention of Criticality in Fuel Storage and Handling.
- Memorandum from L. Kopp, SRE, to Timothy Collins, Chief, Reactor Systems Branch, Division of Systems Safety and Analysis, "Guidance on the Regulatory Requirements for Criticality Safety Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1988.
- "OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications," dated April 14, 1978, and the modifications to this document of January 18, 1979.
- 10CFR21 - Reporting of Defects and Non-compliance.
- 10CFR50 Appendix B - Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.
- 10CFR50.68 - Criticality Accident Requirements.
- USNRC Standard Review Plan, NUREG-0800, Section 9.1.1, New Fuel Storage and Section 9.1.2, Spent Fuel Storage.
- USNRC Regulatory Guide 1.13, Spent Fuel Storage Facility Design Basis, Rev. 2, December 1981.

3.4 Quality Assurance

The NETCO-SNAP-INs® are designed and fabricated under control and surveillance of NETCO's Quality Assurance Program[3-4] that conforms to the requirements of 10CFR50 Appendix B. Since the NETCO-SNAP-INs® are used for reactivity control of fuel assemblies stored in close proximity, they are classified as nuclear Safety Related (SR).

As such, and as required by NETCO's Quality Assurance Program[3-4], they are designed and fabricated to preclude the use of any material or manufacturing process that deviates from a rigorous set of specifications established by the NETCO design team. Process controls for materials and fabrication are established to preclude the incidence of errors and inspection steps are implemented to ensure that all critical attributes, as identified by the design team, for the feed material and rolled sheet are met in the final product.

The raw materials including AA1100, B_4C and Ti used to make the cast billets are obtained by Rio Tinto Alcan from qualified suppliers. The material certifications supplied with the feed material are independently confirmed. An independent mass spectroscopic measurement of boron-10 fraction is performed on each lot of boron carbide powder used. Each cast of B_4C and aluminum is chemically analyzed to assure that the composition conforms to the design specification for weight fraction of boron, Al and Ti. Permanent records of these analyses are retained in NETCO's quality assurance files. Each completed NETCO-SNAP-IN® has a unique identifying number etched along the inside upper surface and this number is fully traceable to the billet, cast and feed material lots.

For these purposes, coupons are cut from each rolled insert blank, which is of sufficient size to manufacture two NETCO-SNAP-INs®. Samples from the coupons are subjected to neutron attenuation testing to verify as-manufactured boron-10 areal density and mechanical testing to assure sufficient ductility to permit forming.

Quality Assurance procedures are enforced on the fabrication shop floor that provide all controls necessary to comply with all quality assurance requirements. One hundred percent final inspection at the shop includes dimensions, formed angle, bend, twist, cleanliness, identifying markings and freedom from imperfections.

A summary table of critical characteristics and qualification tests performed in support of those characteristics is listed below: 5

Table 3-1 Insert Quality Assurance Testing Summary

Critical Characteristic	Qualification Testing Performed	Acceptance Criteria	
Minimum B-10 Areal Density	Neutron Attenuation Testing	> 0.0087 g B10/cm^2	
Material Composition	ICP Analysis	Boron, Carbon, Titanium and Aluminum within specification limits	5
Mechanical Properties	Tensile and Bend Testing	Tensile Strength >10 ksi Elongation > 3% Bend Test to support design specification for insert retention force.	

References Section 3

3-1. "Qualification of METAMIC for Spent-Fuel Storage Application," EPRI Report No. 1003137, Prepared for EPRI by Northeast Technology Corp., Kingston, NY, 10/2001.

3-2. "Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications, 2006 Edition," EPRI Report No. 1003721, Prepared by Northeast Technology Corp., Kingston, NY, 10/2006.

3-3. Z. Zhazy, A. Charlette, R. Ghomusheki, X.-G Chen, "Effect of Titanium on Solidification Microstructure of A-16% B_4C Composites," *Light Metals*, 2005, Calgary, Alberta, Canada.

3-4. Quality Assurance Manual, Rev. 1, Northeast Technology Corp., 2007.

4.0 Engineering Evaluation of the Alcan Composite

The Alcan composite is very similar in composition to another neutron absorber material, BORAL™, that has been used extensively for more than 40 years for both wet and dry storage applications. The in-service performance of BORAL™ has been good. In this section the composition, physical properties and mechanical properties of both materials are compared and the industry experience with the BORAL™ neutron absorber reviewed.

4.1 Comparison of the Alcan Composite with BORAL™

<u>Composition</u>

Both of these neutron absorber materials utilize AA1100 as the base alloy for the metal 5
matrix that retains the boron carbide. The compositions of the alloy matrices are compared in Table 4-1. With the exception of the addition of Ti to the Alcan composite, as noted previously, the compositions are almost identical. In fact, the Alcan requirement for other elements is somewhat more stringent than the BORAL™ requirement.

Table 4-1

Comparison of Aluminum Alloy Matrices

Property	AA1100 UNS A91100 Temper O	BORAL Metal Matrix Material Spec	ALCAN Composite Metal Matrix Material Spec	ALCAN Composite Vol 16% B_4C Typical Properties	ALCAN Composite Vol 17% B_4C Typical Properties
Al	99.00% min	99.00% min	99.00% min	82.7%	82.0%
Si & Fe	0.95% max	1.00% max	0.45% max	0.38%	0.39%
Cu	0.05-0.20%	0.05-0.20%	0.05-0.20%	0.11%	0.11%
Mn	0.05% max	0.05% max	0.05% max	< 0.01%	< 0.01%
Zn	0.10% max	0.10% max	0.10% max	<0.01%	0.01%
Mg	---	---	0.05% max	< 0.01%	<0.01%
Ti	---	---	1.00% - 2.50%*	1.85%	2%
B_4C	---	---	---	15.3%	15.9%
Other Elements	0.15% total 0.05% max each	0.15% max each	0.15% total 0.05% max each	0.08%	0.08%
Tensile	11 ksi to 15.5 ksi	10 ksi	Not Specified	17 ksi	17 ksi
Yield	3.5 ksi min	---	Not Specified	10 ksi	10 ksi
Elongation	30% min	0.1	Not Specified	5% - 8%	5% - 8%

5

*Titanium is added during mixing of the B_4C and not part of the matrix material specification.

The boron carbide specifications are compared in Table 4-2. The Alcan specification is somewhat tighter in terms of allowable impurities and requires a much smaller particle size. With respect to the latter, the smaller particle size results in a more homogeneous absorber, less potential for neutron streaming and a more effective neutron absorber material.

Table 4-2
Comparison of Boron Carbide

BORAL™	Constituent	Alcan Composite
70.0 min	Total Boron	76 w/o min
3.0 max	Boric Oxide	0.03 % Typ.
2.0 max	Iron	0.075% Typ.
94.0 min	Total Boron & Carbon	99.6% Typ.
75 - 250 μm	Particle Size	17.5 ± 2 μm

5

Manufacturing Process Physical Form

The manufacturing processes for BORAL™ and the Alcan composite are compared in Figure 4-1. The manufacture of BORAL™ starts with the complete blending of atomized AA1100 powder and boron carbide. An AA1100 rectangular box ~ 12 to 15 inches on a side and a few inches high depending on the thickness of the finished product is filled with the blended powder. The walls of the box are ~ 1 inch thick. After a top is welded on the box, the billet is ready for hot rolling to final gage.

The production process for the Alcan material differs from the BORAL™ process in that the boron carbide powder is blended into molten aluminum and a rectangular billet formed by direct chill casting. Hot rolling is used to produce the final sheet.

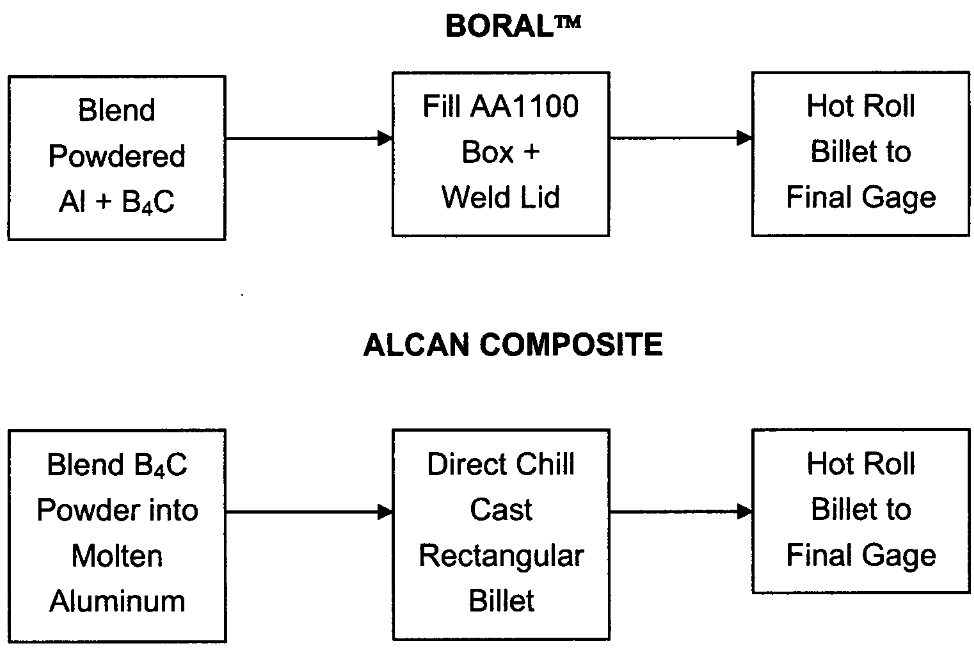

Figure 4-1: Comparison of Manufacturing Processes

In its finished form, BORAL™ consists of 1) a core of uniformly mixed and distributed boron carbide and alloy AA1100 aluminum particles; and 2) an AA1100 surface cladding on both sides of the core, serving as a solid barrier. Figure 4-2 is a micro photograph of the edge of a BORAL™ sample showing the core and clad region. BORAL™ has been produced with the core containing anywhere between 35 w% and 65 w% boron carbide. For most cores produced recently, the core contains about 50 w% boron carbide. In addition, the core is not fully dense and contains as much as 5% open and interconnected porosity.

The Alcan composite, on the other hand, in its final form is a fully dense homogeneous mixture of fine boron carbide particles embedded in the matrix aluminum alloy. As such 5
it contains no porosity that can allow water intrusion and potential problems associated with internal moisture.

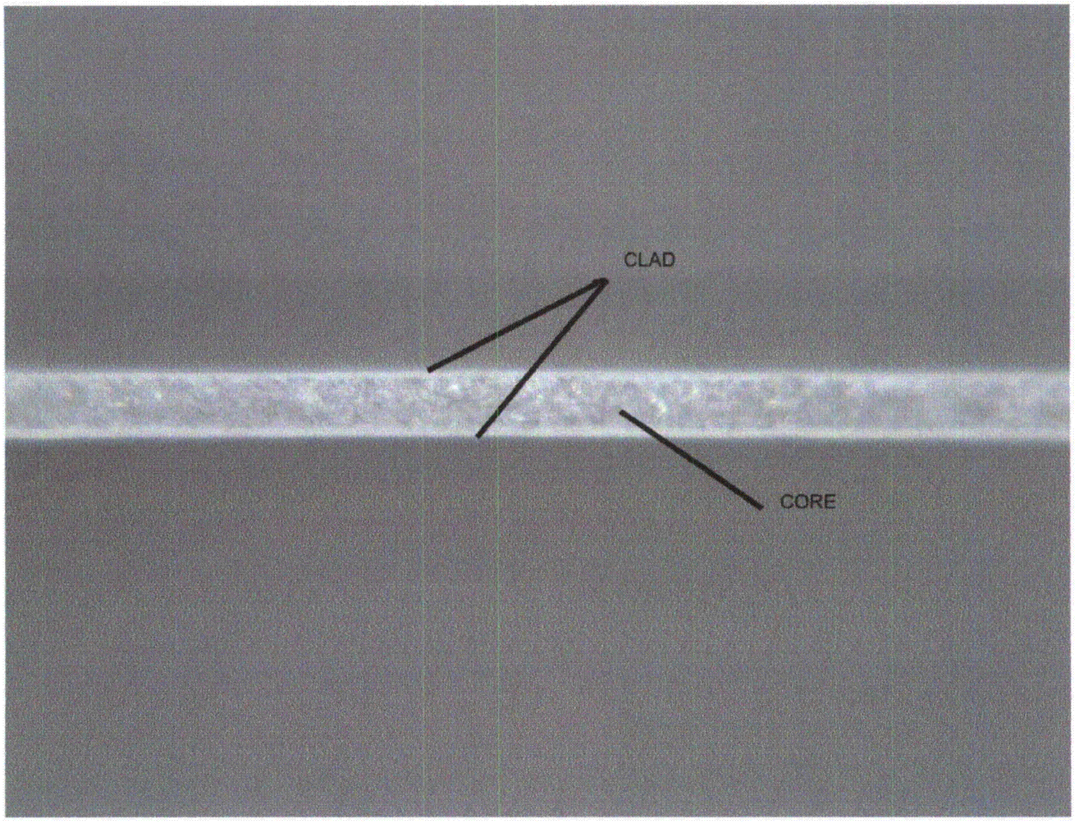

Figure 4-2: Micro Photograph of BORAL™

Mechanical Properties

The mechanical properties of BORAL™ and the Alcan composite are compared in Table 4-3.

Table 4-3

Room Temperature Mechanical Properties of BORAL™ and the Alcan Composite

BORAL™		**Alcan Composite**
10	Tensile Strength, ksi	10
	Ultimate Strength, ksi	17
0.1	Elongation, %	7.0

This comparison shows that the tensile properties of the two materials are similar but the Alcan composite has improved ductility.

Stress Relaxation

During installation, the absorber inserts are compressed from an initial bend angle greater than 90° to the square dimensions of the rack cell interior. Once installed, the inserts maintain a fixed strain within the rack storage cell that may be susceptible to relaxation over time. An analysis of stress relaxation in aluminum alloys has been performed to establish the expected performance of the inserts in this regard.

As shown above, the Rio Tinto Alcan W1100N.16 B alloy had similar mechanical characteristics to 6061 aluminum alloy based Boral material. Reference 4-1 details stress relaxation performance of 6060-T6 alloy after 1000 hours at various temperatures. The data shows approximately 15% stress relaxation after 1000 hours at 100° C.[4-1]

Average bulk pool temperatures within the LaSalle spent fuel pool are approximately 85° F. Stress relaxation at this temperature is expected to be significantly lower than 15% over 1000 hours. As an upper limit, however, data for AA1100-H112 series aluminum[4-2] was analyzed to estimate total stress relaxation after 20 years of service. The results of that analysis showed that the AA1100 series aluminum was, based upon extrapolated data, expected to have experienced an approximate stress reduction of 50% over 20 years. Given the reduced elongation of the Rio-Tinto Alcan composite in comparison with AA1100 series aluminum, this stress relaxation is likely an upper limit for the performance of the W1100N series material.

Typical breakaway withdrawal forces were measured and are typically several hundred pounds. At the 15% relaxation predicted for the 6061-T6 alloy, a reduction in retention force between 45 and 90 lbf after 1000 hours at 100° C would be expected. At the limiting case of a 50% reduction in retention force over 20 years, the inserts would still maintain greater than 150 lbf of retention within the cell if there were no other mitigating factors. These values are adequate to maintain the inserts in their configuration during fuel movement operations provided the fuel bundles are qualified for use in those

locations (i.e. they fit within the specified dimensions). However, the following factors would tend to mitigate the stress relaxation effects:

1. Stress relaxation in boron carbide reinforced aluminum will be less than for the pure alloy; 4
2. The formation of an oxide film on the surface of the inserts will increase the stress (by increasing the spacing between the rack wall and the insert) as well as the coefficient of friction between the insert and the cell wall.

<u>Neutronic Properties</u>

It has been previously noted that the average particle size of boron carbide in BORAL™ is 85 microns and individual particles can range up to 250 microns. Particles of these dimensions introduce self shielding effects that can diminish the neutron absorption effectiveness. NETCO has measured the neutron attenuation characteristics of BORAL™ and the Alcan composite, the latter material with average boron carbide particle size of 17.5 microns.

Figure 4-3 compares the neutron attenuation characteristics of BORAL™ and the Alcan composite. The neutron attenuation characteristics are measured using a collimated thermal energy neutron beam. A sample of a neutron absorber is placed in this neutron beam and the intensity of the beam incident on the absorber, I_i, is measured. The intensity of the beam transmitted through the material, I_t, is also measured and the neutron attenuation characteristic, NA, is calculated as:

$$NA = 1 - I_t/I_i$$

Figure 4-3 shows that for the same areal density BORAL™ absorbs fewer neutrons than the Alcan absorber. This illustrates the importance of neutron channeling effects in absorbers with relatively large particles when a normal mono-directional neutron beam is incident on the absorber.

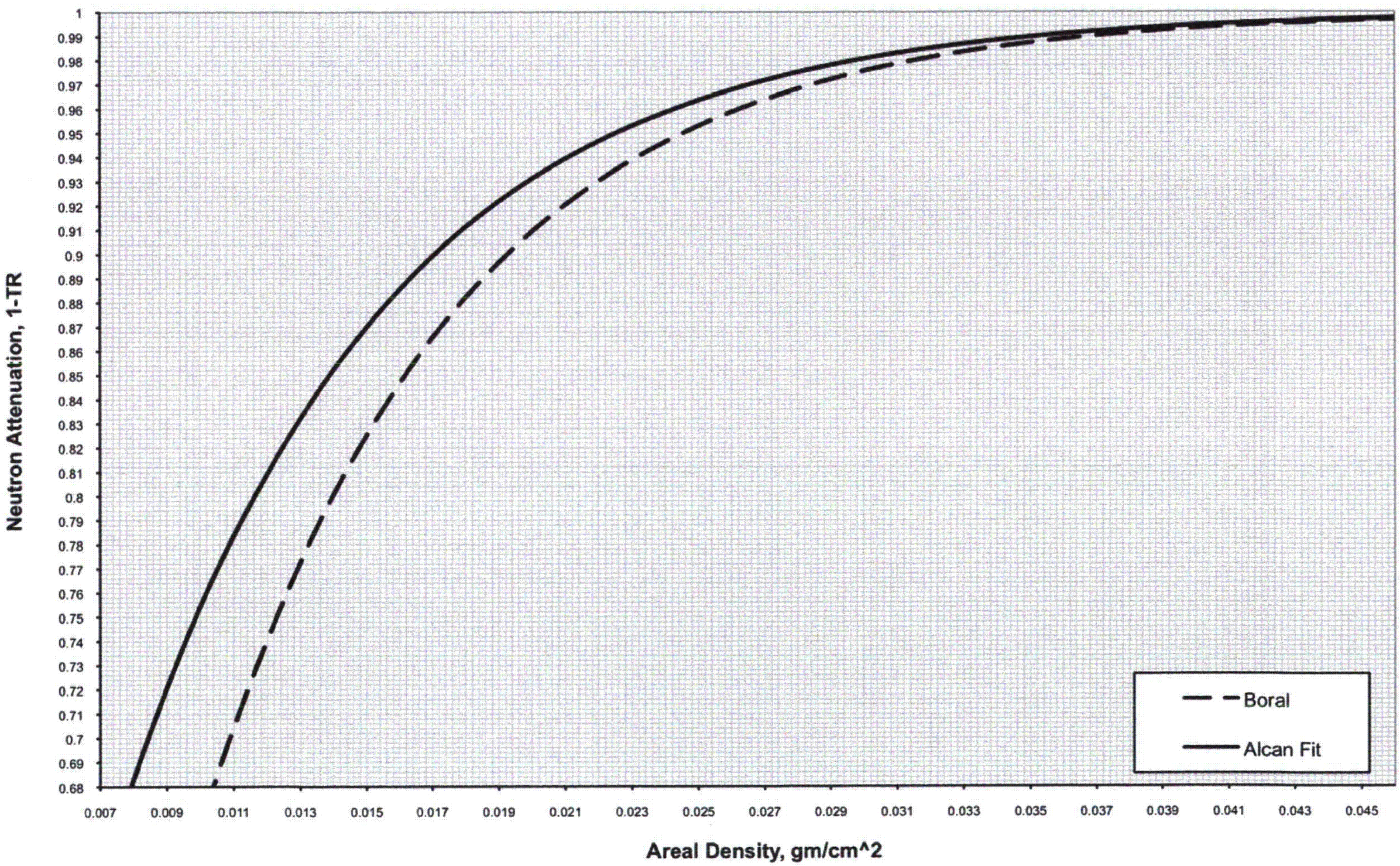

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Figure 4-3: Neutron Attenuation Comparison: BORAL™ vs. Alcan Aluminum Matrix Absorber

4.2 In-Service Performance of Aluminum Matrix Neutron Absorber Material

BORAL™ has been used for nuclear applications for almost 45 years starting in 1964 when it was used for reactivity control in the Yankee Rowe spent fuel racks. Nuclear applications include control elements for test reactors, fuel storage racks for spent nuclear fuel and in dry fuel storage and transportation casks. Table 4-4 contains a partial listing of research reactors where BORAL™ has been used. Table 4-5 contains a partial list of LWR plants where BORAL™ has been used in spent fuel storage racks. It is noted that LaSalle Unit 2 sister unit currently has some 43,000 lbs of BORAL™ in its racks. Table 4-6 is a partial list of plants where BORAL™ has been used for reactivity control in dry storage casks.

For dry storage applications, it is noted that the Alcan composite is now approved for use in the NUHOMS dry storage system as well as the Transnuclear metal cask storage system. The Alcan composite is being used at Peach Bottom, Limerick and St. Lucie as well as in Europe.

Table 4-4

Partial Listing of Research and Test Reactors Where BORAL™ Has Been Used

Research and Test Reactors
AE-6 (USAEC)
BORAX-5 (USAEC)
Brookhaven Medical Research Reactor
JEN-1 (Spain)
Philippine Research-1
Rhode Island Reactor
Triga Mark II (Italy, Austria, etc.)
University of Kansas Reactor
University of Wisconsin Reactor
Venezuela-1
Washington State University Reactor

Table 4-5

Partial List of LWRs Where BORAL™ Has Been Used in Spent Fuel Storage Racks

Pool	Plant Type	Manufacturer	Storage Locations	Country
BEAVER VALLEY 1	PWR	Holtec	1621	USA
BELLEFONTE 1	PWR	Westinghouse	1058	USA
BRAIDWOOD 1&2	PWR	Holtec	2984	USA
BROWNS FERRY 1	BWR	GE	3471	USA
BROWNS FERRY 2	BWR	GE	3471	USA
BROWNS FERRY 3	BWR	GE	3471	USA
BRUNSWICK 1	BWR	Holtec	1839	USA
BYRON 1&2	PWR	Holtec	2984	USA
CALLAWAY	PWR	Holtec	1302	USA
COMANCHE PEAK 1	PWR	Holtec	222	USA
COMANCHE PEAK 2	PWR	Holtec	219	USA
CONN YANKEE	PWR	Holtec		USA
COOK 1&2	PWR	Holtec	3613	USA
COOPER	BWR	NES		USA
CRYSTAL RIVER 3	PWR	Westinghouse	932	USA
DAVIS BESSE 1	PWR	Holtec	1624	USA
DRESDEN 1	BWR	CECO	3537	USA
DRESDEN 2	BWR	CECO	3537	USA
DRESDEN 3	BWR	CECO	3537	USA
DUANE ARNOLD	BWR	PAR	1898	USA
DUANE ARNOLD	BWR	Holtec	1254	USA
FERMI 2	BWR	Holtec	559	USA
FITZPATRICK	BWR	PAR	2797	USA
FITZPATRICK	BWR	Holtec		USA
FT. CALHOUN	PWR	Holtec	160	USA
HARRIS 1	PWR	Holtec	484	USA
HATCH 1	BWR	GE	5830	USA
HATCH 2	BWR	GE	2765	USA
HOPE CREEK	BWR	Holtec	3998	USA
HUMBOLDT BAY 3	BWR	Unknown		USA
INDIAN POINT 3	PWR	UST&D	1340	USA

Table 4-5 (con't.)

Partial List of LWRs Where BORAL™ Has Been Used in Spent Fuel Storage Racks

KEWAUNEE	PWR	Holtec	215	USA
KOEBERG 1	PWR	Holtec		South Africa
KOEBERG 2	PWR	Holtec		South Africa
KORI-4	PWR	Holtec		South Korea
KUOSHENG 1	BWR	ENSA	1578	Taiwan
KUOSHENG 2	BWR	ENSA	1578	Taiwan
LAGUNA VERDE 1	BWR	Holtec		Mexico
LAGUNA VERDE 2	BWR	Holtec		Mexico
LASALLE 1	BWR	UST&D	4029	USA
LIMERICK 1	BWR	Holtec	2500	USA
LIMERICK 2	BWR	Holtec	2766	USA
MAINE YANKEE	PWR	PAR	1464	USA
MCGUIRE 1	PWR	Holtec	286	USA
MCGUIRE 2	PWR	Holtec	286	USA
MILLSTONE 3	PWR	Holtec	1104	USA
MONTICELLO	BWR	GE	2229	USA
NINE MILE POINT 1	BWR	Holtec	3496	USA
OYSTER CREEK	BWR	Holtec	390	USA
PERRY 1	BWR	PAR	2400	USA
PERRY 2	BWR	PAR	1620	USA
PILGRIM	BWR	Holtec	1539	USA
SALEM 1	PWR	ENC	1117	USA
SALEM 1	PWR	Holtec	1117	USA
SALEM 2	PWR	ENC	1139	USA
SALEM 2	PWR	Holtec	1139	USA
SEABROOK 1	PWR	Westinghouse	576	USA
SEQUOYAH 1	PWR	Westinghouse	2091	USA
SEQUOYAH 2	PWR	Holtec		USA
SEQUOYAH 2	PWR	PAR	2091	USA
SIZEWELL B	PWR	Holtec	1901	United Kingdom
SUMMER 1	PWR	Holtec	1712	USA
SUSQUEHANNA 1	BWR	PAR	2840	USA
SUSQUEHANNA 2	BWR	PAR	2840	USA

Table 4-5 (con't.)

Partial List of LWRs Where BORAL™ Has Been Used in Spent Fuel Storage Racks

THREE MILE ISLAND 1	PWR	Holtec	1284	USA
TURKEY POINT 3	PWR	Holtec	131	USA
TURKEY POINT 4	PWR	Holtec	131	USA
ULCHIN 1	PWR	Holtec	1000	South Korea
VERMONT YANKEE	BWR	UST&D	2860	USA
VOGTLE 1	PWR	Unknown	1476	USA
WATERFORD 3	PWR	Holtec	2232	USA
WATTS BAR 1	PWR	Holtec	1610	USA
WATTS BAR 2	PWR	Holtec	1610	USA
YANKEE ROWE	PWR	PAR	721	USA
YONGGWANG 1	PWR	Holtec	1152	South Korea
YONGGWANG 2	PWR	Holtec	1152	South Korea
ZION 1	PWR	Holtec	3012	USA
ZION 2	PWR	Holtec	3012	USA
ANGRA 1	PWR	Holtec	1252	Brazil
CATTENOM-1	PWR	Framatome	2520	France
CATTENOM-2	PWR	Framatome	2520	France
CATTENOM-3	PWR	Framatome	2520	France
CATTENOM-4	PWR	Framatome	2520	France
BELLEVILLE-1	PWR	Framatome	1260	France
BELLEVILLE-2	PWR	Framatome	1260	France
NOGENT-1	PWR	Framatome	1260	France
NOGENT-2	PWR	Framatome	1260	France
PENLY-1	PWR	Framatome	1260	France
PENLY-2	PWR	Framatome	1260	France
GOLFECH-1	PWR	Framatome	1260	France
GOLFECH-2	PWR	Framatome	1260	France

Table 4-6

Partial Listing of LWRs Where BORAL™ Has Been Used in Dry Storage Casks

Plant	Type	Supplier	Current Inventory	Module Capacity	Absorber Type
ARKANSAS 2	Hi-Storm 100(MPC-32)	Holtec	416	32	BORAL
CATAWBA 1	UMS-24	NAC		24	BORAL
DIABLO CANYON 1	Hi-Storm 100(MPC-32)	Holtec			BORAL
DIABLO CANYON 2	Hi-Storm 100(MPC-24)	Holtec			BORAL
DRESDEN 2	Hi-Storm 100(MPC-68)	Holtec	1632	68	BORAL
DUANE ARNOLD	NUHOMS-61BT	Transnuclear	610	61	BORAL
FITZPATRICK	Hi-Storm 100(MPC-68)	Holtec	204	68	BORAL
HADDAM NECK	MPC-24	NAC	651	24	BORAL
HATCH 2	Hi-Storm 100(MPC-68)	Holtec	1496	68	BORAL
MAINE YANKEE	UMS-24	NAC	1440	24	BORAL
PALO VERDE 1	UMS-24	NAC	624	24	BORAL
PEACH BOTTOM 2	TN-68	Transnuclear	1632	68	BORAL
PRAIRIE ISLAND 1	TN-40	Transnuclear	680	40	BORAL
SEQUOYAH 2	Hi-Storm 100(MPC-32)	Holtec	96	32	BORAL
TROJAN	MPC(24)-Only	Holtec	816	24	BORAL
SUSQUEHANNA 1	NUHOMS-61BT	Transnuclear	183	61	BORAL
* as of mid 2005					

In-Service Experience

BORAL™ Plate and Sheet in Wet Storage

It has been noted that in conventional storage racks, once BORAL™ is installed in fuel racks, it is not accessible for inspection to determine its in-service performance. Accordingly, the NRC has, in the past, required utilities to initiate a coupon surveillance program when new racks were installed. A coupon surveillance program consists of a series of small coupons either in a shroud (simulating the manner in which the BORAL™ is encapsulated) or bare. The coupons are generally attached to a surveillance assembly, which is placed in a spent fuel rack storage cell.

The surveillance assembly is generally surrounded by recently discharged fuel assemblies to accelerate the rate at which the coupons accumulate gamma exposure. Prior to placing the assembly in service, the coupons are generally characterized with respect to:

- visual appearance
- dry weight
- dimensions
- specific gravity and density
- boron-10 areal density

Periodically, coupons are removed from the surveillance assembly and sent to an independent laboratory for testing. The post-irradiation test results generally mirror the pre-irradiation test results. As the surveillance coupons are prepared from BORAL™ coupons cut from panels taken from the same production lot(s) used in the racks, the performance of the coupons should be indicative of the performance of the material in the racks.

NETCO maintains laboratory facilities and offers inspection and testing services of neutron absorber surveillance coupons. In that capacity, NETCO has inspected hundreds of aluminum matrix surveillance coupons, many of them BORAL™, from spent fuel pools around the world. It has been observed during testing that some surveillance coupons can be subject to a generalized corrosion, that includes the development of a uniform oxide film. This film, once it forms, tends to be self passivating and prevents further corrosion. Depending on pool conditions, other coupons can be susceptible to localized pitting corrosion. It should be noted that while these corrosion effects can occur in aluminum matrix neutron absorbers, to date this in-service corrosion has not resulted in any detectable decrease in the boron-10 areal density. It is therefore concluded that the aluminum alloy matrix serves as suitable matrix to retain the boron
carbide in spent fuel storage racks. Additional qualification testing has been performed 5
to further demonstrate the corrosion resistance of the Alcan W1100.XYB material in

BWR and PWR spent fuel pool applications. This testing is described in Section 5.0 of this report.

4.3 NETCO Credentials

NETCO has been evaluating, specifying and qualifying neutron absorber material for storage systems and transportation packaging for more than a quarter of a century. In this capacity, NETCO has become an internationally recognized expert in assessing the in-service performance of this class of materials.

In 1987, the Electric Power Research Institute (EPRI) retained NETCO to evaluate the instances of unanticipated performance of one neutron absorber, Boraflex, at two Midwest plants. NETCO's first report on this phenomenon concluded the observed shrinkage of the sheets of absorber would be expected when cross linking polymer was exposed to gamma radiation. NETCO notified EPRI that the BISCO materials qualification program did not adequately test the synergistic effects of gamma radiation and long term exposure to the pool water.

These projections subsequently proved to be remarkably accurate and formed the bases for NETCO's development of BADGER and RACKLIFE. BADGER (Boron-10 Areal Density Gage for Evaluating Racks) is a non-destructive test method that measures the residual boron-10 in spent fuel racks. BADGER has now been used in some 35 test campaigns to assess the reactivity hold down capability of both Boraflex racks and racks with other neutron absorbers.

RACKLIFE is a comprehensive computer program that tracks the performance of each and every Boraflex panel (as many as 4,000) in a typical rack installation. RACKLIFE is based on first principles and on the mass balance of soluble silica as it dissolves from the degraded Boraflex matrix and gradually migrates to the bulk pool volume. NETCO tested samples of irradiated Boraflex and measured the rate of dissolution as a function of both absorbed dose and temperature in its laboratory. This experimental data serves as the basis for the RACKLIFE dissolution model. This model and the RACKLIFE

software upon which it is based as verified by BADGER measurements, serve to assure that spent fuel pool criticality limits are met.

At the Penn State Breazeale Research Reactor laboratory, NETCO routinely tests neutron absorber surveillance coupons. These tests include Alcan composite material, BORAL™, Boraflex, borated stainless steel, METAMIC, Talbor, Carborundum and ESK borated graphite and nano steel.

NETCO was selected by Reynolds Metals Company to conduct qualification testing of its new neutron absorber material, METAMIC. In this test sequence, NETCO conducted accelerated radiation testing, accelerated corrosion testing and elevated temperature testing to qualify this material for use in spent fuel racks and storage and transportation casks. The resulting test report has been accepted by the NRC for both wet and dry applications. A second qualification test sequence for another new neutron absorber BorTec™ was completed by NETCO for DWA Technologies, the manufacturer of BorTec™. As such NETCO is the only organization to have successfully qualified new neutron absorber materials for wet storage applications since BORAL™ was qualified some 40 years ago.

NETCO was retained by EPRI, ENRESA and AAR (former BORAL™ manufacturer) to evaluate clad blister formation under cask drying conditions. Laboratory testing by NETCO simulating cask drying condition lead to recommended changes in the AAR rolling schedule and lead to an improved BORAL™ product that is largely blister resistant.

References Section 4:

4-1 K. Farrell, "ORNL/TM-13049 Assessment of Aluminum Structural Materials for Service Within the ANS Reflector Vessel," Oak Ridge National Laboratory, August 1995 4

4-2 John Gilbert Kaufman, Properties of Aluminum Alloys, ASM International, 1999

5.0 Accelerated Corrosion Testing

5.1 Test Description

The accelerated corrosion test program has been designed to determine the susceptibility of the Rio Tinto Alcan composite to general (uniform) and localized (pitting) corrosion in PWR and BWR spent fuel pools. Two sets of coupons have been tested at the NETCO laboratory; one set in deionized water, simulating BWR pool conditions and one set in deionized water containing 2500 ppm boron as boric acid, simulating PWR pool conditions. Both tests were conducted at 195°F (90.5°C) to accelerate any corrosion effects, which might occur after the 8000 hour (~ 1 year) test period. The tests are accelerated by testing at elevated temperatures relative to typical temperatures in the actual service environment. Typically, spent fuel pools are operated in the temperature range of 80 to 100°F (27 to 38°C) with short term 4
excursions to 130°F (54°C) during refueling outages.

Coupons from each environment were removed after approximately 2000, 4000, 6000 and 8000 hours and subjected to testing. Prior to testing the coupons were precharacterized with respect to thickness, weight and boron-10 areal density. After testing, the coupons were subjected to post-test characterization of these same attributes. The testing after 2000, 4000, 6000 and 8000 hours has been completed. This document represents the final report for this accelerated corrosion test.

5.2 Test Matrices and Coupon Description

The coupon test matrix for the accelerated corrosion test is shown in Table 5-1. A total of 168 coupons have been tested; 84 in deionized water and 84 in 2500 ppm boron as 4
boric acid. As shown in Table 5-1, coupons with two levels of boron carbide loadings were tested. The coupons with an intermediate loading contain 16 vol% boron carbide. The coupons with the maximum boron carbide loading contain 25 vol% boron carbide.

Table 5-1

Coupon Test Matrix for Accelerated Corrosion Testing

Type of Coupon	Number of Coupons	
	16 vol % B_4C	25 vol % B_4C
General	12	12
Bend	12	12
Galvanic (bi-metallic)*	18	18
Subtotal	42	42
Total	84	

*Note: For the galvanic bi-metallic coupons, there are 3 subtypes. These are SS-304L, Zircaloy and Inconel 718, each separately in combination with the Alcan composite. 4

At each of the scheduled test campaigns specific coupons were removed from the baths and subjected to testing. The number and type of coupons tested at 2000 and 6000 hours is summarized in Table 5-2. The number and type of coupons tested at 4000 and 8000 hours is summarized in Table 5-3. Three types of coupons at two boron carbide loadings have been tested as described in Tables 5-2 and 5-3.

Table 5-2

Number and Type of Coupons per Bath Tested After 2000 and 6000 Hours

Type of Coupon	Boron Carbide Loading	
	16 vol %	25 vol %
General (G)	3	3
Bend (B)	3	3
Total	12	

Table 5-3

Number and Type of Coupons per Bath Tested After 4000 and 8000 Hours

Type of Coupon	**Boron Carbide Loading**	
	16 vol %	**25 vol %**
General (G)	3	3
Bend (B)	3	3
Bi-Metallic (BSS)	3	3
Bi-Metallic (BZ)	3	3
Bi-Metallic (BI)	3	3
Total	30	

Since the NETCO-SNAP-INs® are to be used with a mill finish absorber material, that is the finish of the coupons tested. For each coupon type the corrosion rates are determined. The three coupon types are described below.

General 4

General coupons are rectangular (nominally 4 in. x 2 in. in length and width). A test objective of the general coupons is to determine the rate at which a uniform oxide film forms. The rate of oxide build-up is determined by changes in the coupon weight and thickness. Post test exposure, the coupons are subject to precision weighing prior to testing and after a sequence of nitric acid washes and drying after testing.

Bend

Coupons with press brake formed bends are included in the test matrix. These coupons have been deformed to the same bend angle and bend radius used for the NETCO-SNAP-IN®. The test objective of the bend coupons is to determine whether or not bend deformation and stress adversely affect the corrosion susceptibility of the Alcan material. These will be subject to the same pre and post testing as the general coupons. In addition the inner and outer bend radius will be subject to microscopy before and after acid cleaning.

Galvanic (Bi-Metallic) Coupons

In conventional spent fuel racks the neutron absorber material is enclosed in 304L stainless steel wrapper plate, thus the potential for aluminum/stainless steel galvanic corrosion exists. In the NETCO-SNAP-IN® application this material is used unsheathed so that is could be in contact with LWR fuel assemblies. Of the materials in LWR fuel assemblies supplied by U.S. fuel manufacturers, only stainless steel, Inconel and Zircaloy could contact the surface of fuel racks. Accordingly bi-metallic coupons have been prepared with Alcan composite and: 4

304L stainless steel
Inconel 718
Zircaloy

The test objective of the galvanic coupon is to evaluate the potential for galvanic corrosion. The above alloy coupons are nominally 2 in. x 4 in. x 0.065 in. thick. A piece of 2 in. x 4 in. Alcan composite forms the other piece of each couple. The two metals comprising each couple are fastened to each other mechanically with AA1100 wire. Inspection of the galvanic coupons is via optical microscopy, thickness and dry weight measurements. Post test acid cleaning is used depending on the depth of any oxide films.

5.3 Water Chemistry

The laboratory tap water was processed by first passing it through two universal ion
exchange columns and then through two research grade ion exchange columns. The 4
typical quality of the deionized water used for both the BWR and PWR corrosion baths
and make up water is shown in Table 5-4.

Table 5-4

Water Specification for Corrosion Baths

pH	5.75 @ 20°C
Conductivity, :µs/cm	0.5
Resistivity, : Ω/cm	2.0
Aluminum	< 0.010 ppm
SiO_2	< 0.100 ppm
Cl	< 0.010 ppm
Na	< 0.030 ppm

To the PWR bath, sufficient reagent grade boric acid was added to bring the boron 4
concentration to ~ 2500 ppm. This increased the initial conductivity from < 1.0 µs/cm to ~ 40 µs/cm @ 20.0°C and decreased the initial pH from 5.75 @ 20.0°C to ~ 4.76 at 20.0°C.

The conductivity and pH of each of the baths was measured at an approximate frequency of once per week. Figures 5-1 and 5-2 are plots of the measured pH and conductivity of the BWR bath versus time. The plots of the measured pH and conductivity versus time of the PWR bath are shown in Figures 5-3 and 5-4, respectively.

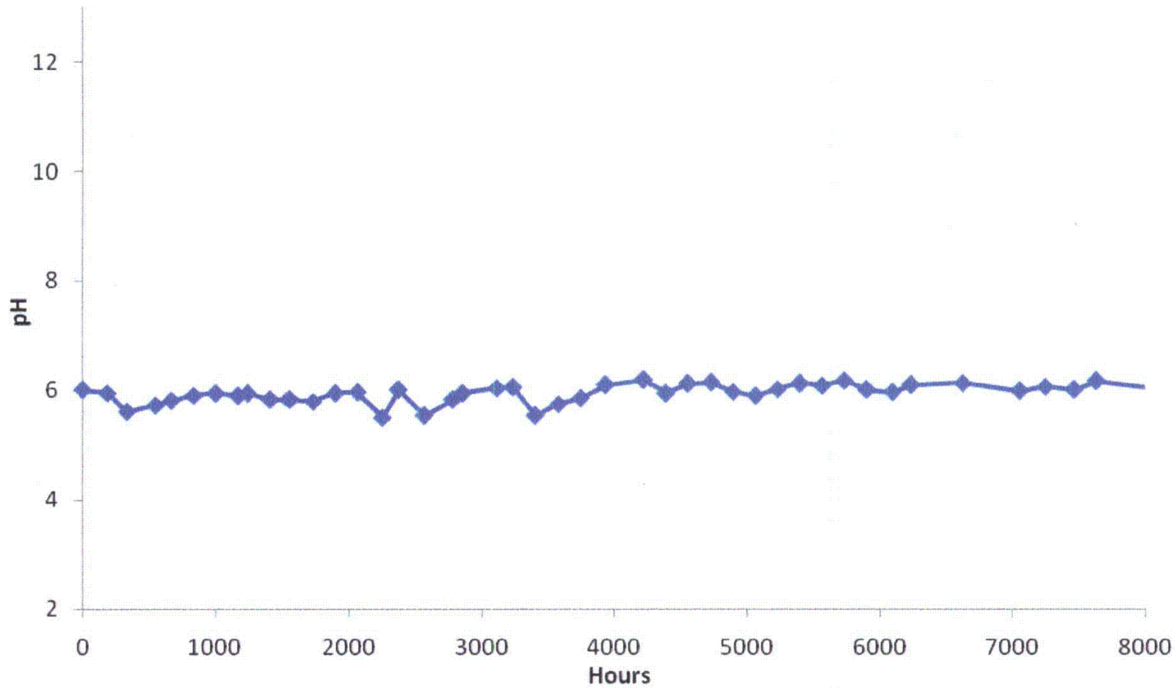

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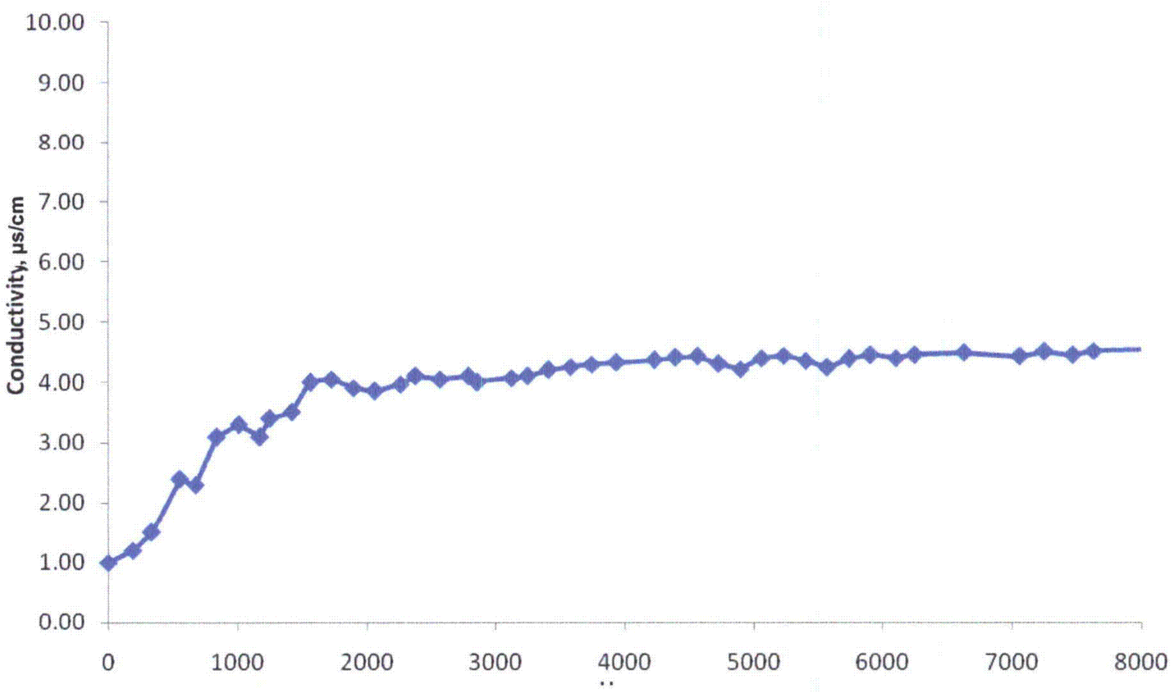
Figure 5-1: pH versus Time: BWR Accelerated Corrosion Test



1 4

Figure 5-2: Water Conductivity versus Time: BWR Accelerated Corrosion Test

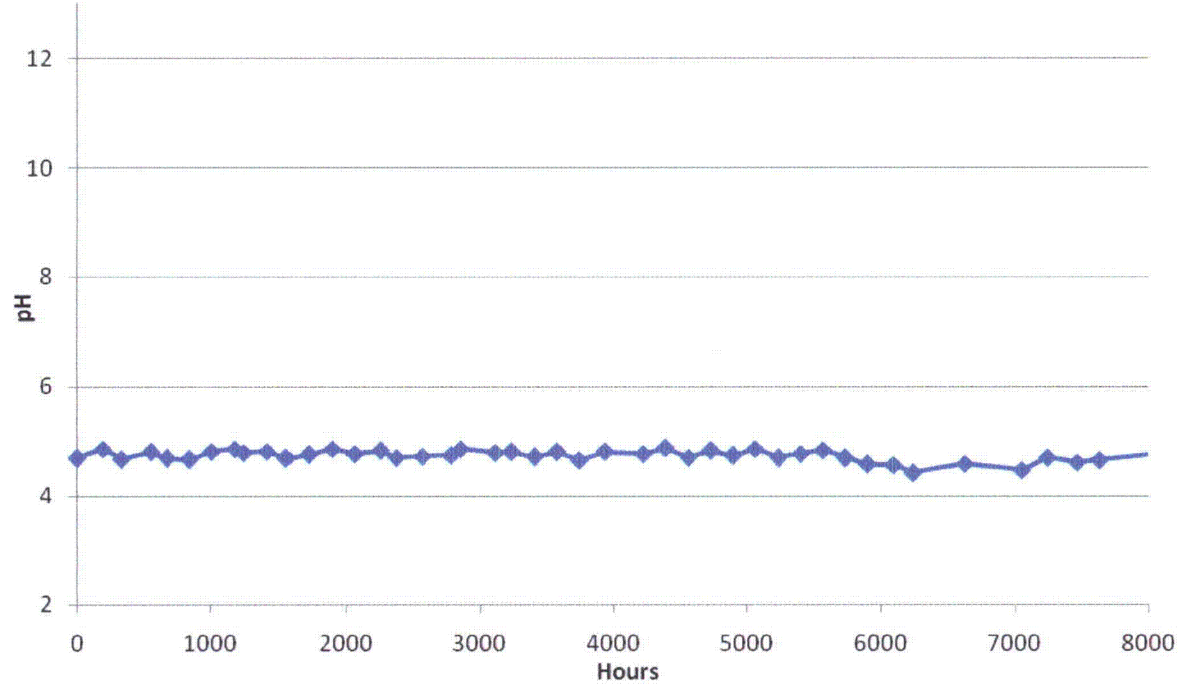


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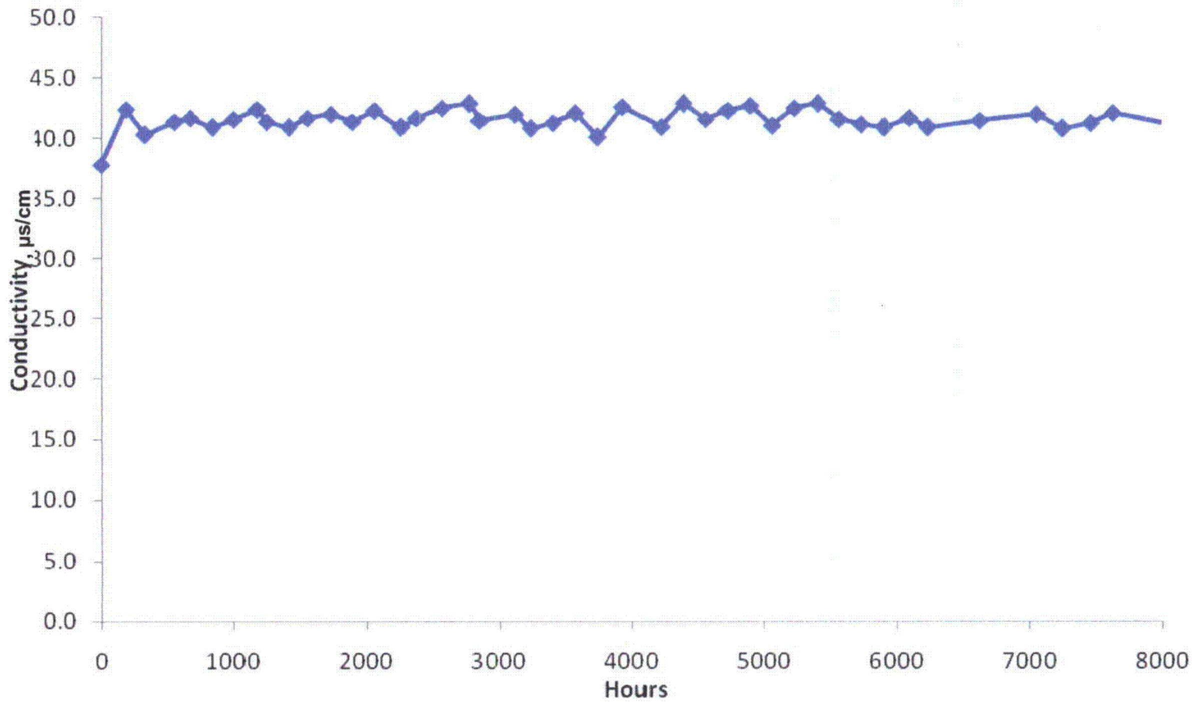
Figure 5-3: pH versus Time: PWR Accelerated Corrosion Test



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4

Figure 5-4: Water Conductivity versus Time: PWR Accelerated Corrosion Test

5.4 *Corrosion Test Results*

Visual Inspection and Microscopy

All coupons removed from the BWR and PWR accelerated corrosion tests after 2000, 4000, 6000 and 8000 hours were subjected to visual inspection. Some of the coupons were subjected to optional microscopy. In addition, high resolution macro photographs were taken both upon removal from the test solutions and after air drying. Optical microscopy was also performed to verify that the oxide films were substantially removed prior to determining coupon weight loss and prior to inspecting for any anomalies along the outer bend radii of the bend coupons. The coupons and the digital data files of all macro photographs, microphotographs and photo micrographs are in permanent storage.

A sampling of photographs and photomicrographs are included in this report to illustrate the pre and post test appearance of the coupons. Photographs and photomicrographs from the 4000 hour and 8000 hour inspections are compared to illustrate little change in coupon surface appearance once an initial oxide film forms. This suggests that the initial oxide film is largely self-passivating, limiting the rate of subsequent oxidation of the base metal. 4

Figure 5-5 is a macrophotograph that compares the appearance of the 16 vol % coupons exposed to the BWR and PWR test conditions for 4000 hours with an as-fabricated archive coupon. The archive coupon is a somewhat darker grey color than pure AA1100 aluminum. This appearance is characteristic of mill finish aluminum that is darkened somewhat by numerous small black boron carbide particles embedded in its surface. Figure 5-6 contains a similar macrophotograph for coupons inspected after 8000 hours.

The coupons exposed to the BWR environment have a more or less uniform white oxide coating with some larger black areas where the boron carbide areas have been exposed. The areas of exposed boron carbide are larger than on the archive material. This may be due to boron carbide that was near the surface but covered by a thin layer

of aluminum in the as-produced material. Once oxidized, the thin oxide layer has insufficient strength to adhere to the underlying boron carbide and is loosened by the circulating bath water.

The coupons exposed to the PWR environment appear somewhat different. The background color is a light grey with smaller areas of exposed boron carbide on the surface. Examination of the surface under a microscope revealed the surface is covered with a uniform translucent film showing some of the color of aluminum through the film. Randomly interspersed are smaller dark areas of exposed boron carbide particles. The surface appearance is similar after 4000 hours and 8000 hours.

Figures 5-7 and 5-8 compare the post test coupons with archive material for the composite with 25 vol % boron carbide loading after 4000 and 8000 hours, respectively. It is noted that the archive material has a darker appearance than the archive material with 16 vol % due to the higher B_4C loading. Similarly, the post test coupons are somewhat darker for the same reason. The oxidized surfaces of these post test 4
coupons are similar to the surfaces of the 16 vol % post test coupons and the appearances maintain their similarity after 4000 and 8000 hours exposure.

Figures 5-9 and 5-10 are microphotographs that compare the appearance of the 16 vol % post test coupons after 4000 and 8000 hours, respectively, with archive material at 8X magnification. Figures 5-11 and 5-12 are microphotographs of 25 vol % coupons exposed to demineralized water and boric acid after 4000 hours and 8000 hours, respectively.

Figures 5-13 and 5-14 are photomicrographs of the surfaces of 16 vol % and 25 vol % boron carbide composite, respectively, in the as-fabricated condition. These can serve as a reference when evaluating the surface condition of the composites after 8000 hours exposure to demineralized water and boric acid.

Figures 5-15 and 5-16 are photomicrographs of the 16 vol % B_4C composite after 8000 hours in demineralized water and boric acid, respectively. The surface appearance in Figure 5-15 is characteristic of areas of between locally heavy surface boron carbide (see e.g. Figure 5-10).

Figures 5-17 and 5-18 are photomicrographs of the 25 vol % B_4C composite after 8000 hours in demineralized water and boric acid, respectively.

The photograph and microphotographs contained in Figures 5-5 through 5-18 serve to illustrate that all coupons develop a more or less uniform oxide film on all surfaces. The appearance of the coupons after 4000 hours exposure compared to their appearance after 8000 hours exposure show that they are essentially identical. This suggests that the oxide film, once formed, is self-passivating and retards subsequent corrosion of the 4
base metal. This conclusion is further supported by the quantitative corrosion rate measurements described subsequently.

The difference in appearance of the coupons exposed to demineralized water and boric acid suggests the different pHs of the baths result in different forms of the oxide. Subsequent acid cleaning of the oxide to measure weight loss further supports this hypothesis. For the coupons exposed to demineralized water, the oxided layer is readily removed by one short soak in nitric acid. For the coupons exposed to the boric acid solution, it required several longer soak periods in order for oxide removal and the coupons to achieve constant weight. It is postulated that at lower pH in the boric acid condition, $\propto$ -alumina (Al_2O_3) forms, which is less soluble in nitric acid than the oxide formed at a higher pH in demineralized water. The latter form of the oxide formed at the higher pH in demineralized water is thought to be a hydrated form or Gibbsite ($Al_2O_3 \cdot 3H_2O$). Optical microscopy of the inside and outside radius of the bend coupons before and after acid cleaning revealed no cracks or other anomalistic corrosion behavior.

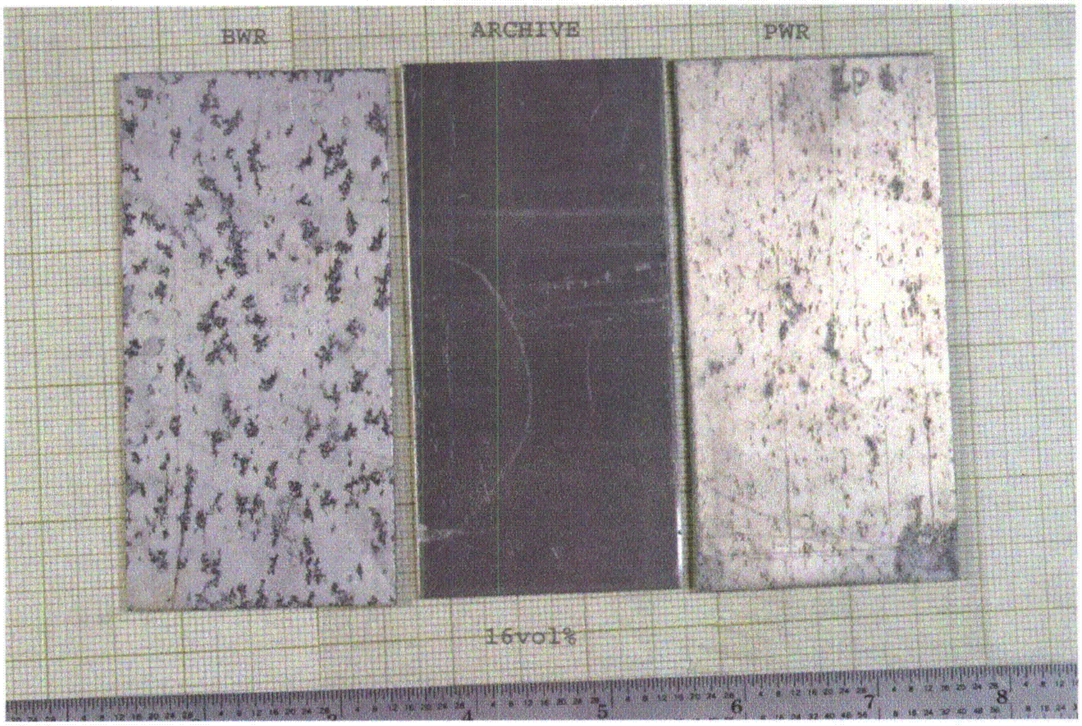

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Figure 5-5: Comparison of Post-Test Coupon Appearance with Archive Material: 16 vol % Boron Carbide Loading after 4000 Hours

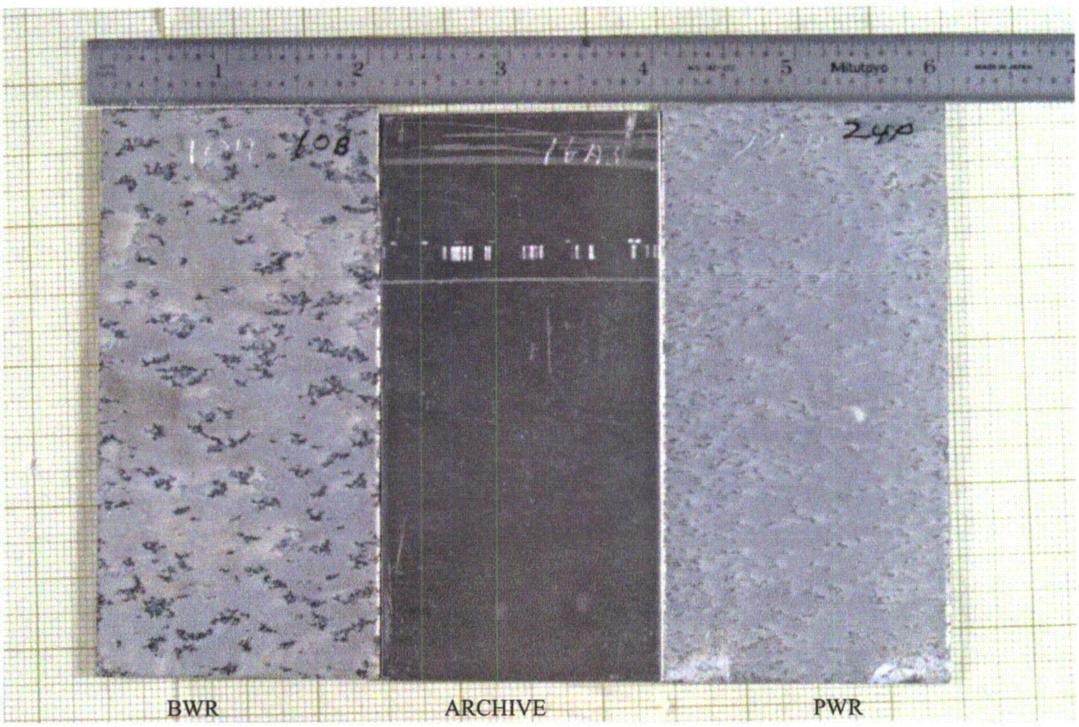

Figure 5-6: Comparison of Post-Test Coupon Appearance with Archive Material: 16 vol % Boron Carbide Loading after 8000 Hours

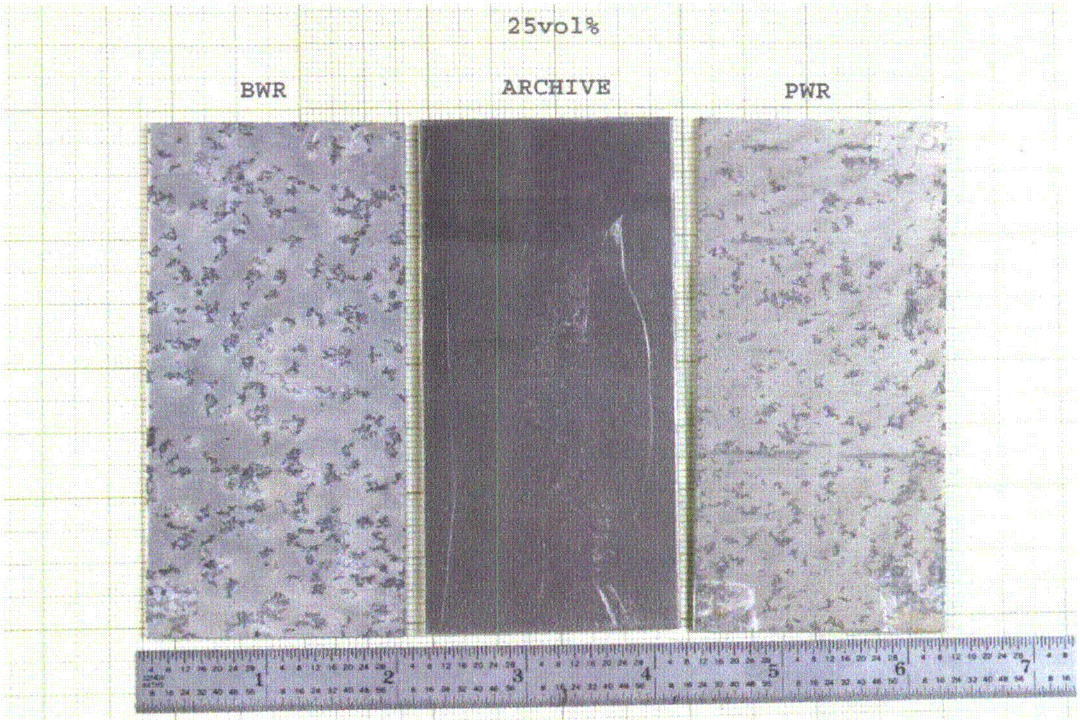

Figure 5-7: Comparison of Post-Test Coupon Appearance with Archive Material: 25 vol % Boron Carbide Loading after 4000 Hours 4

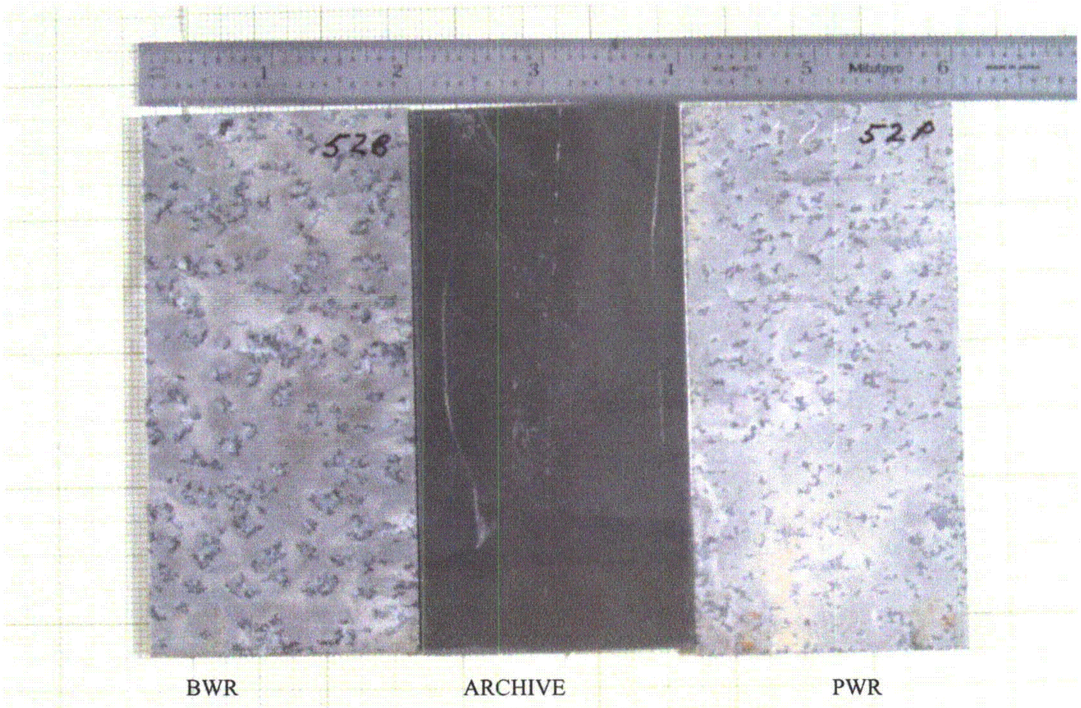

Figure 5-8: Comparison of Post-Test Coupon Appearance with Archive Material: 25 vol % Boron Carbide Loading after 8000 Hours

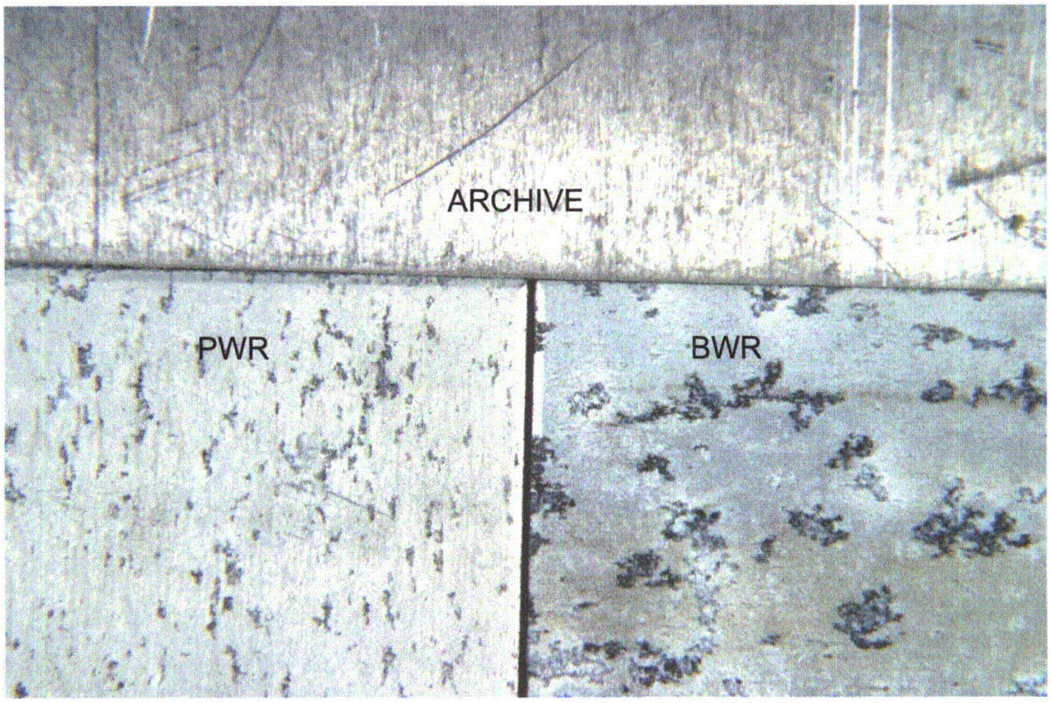

Figure 5-9: Comparison of Post-Test Coupon Appearance with Archive Material: 16 vol % Boron Carbide Loading at 8X Magnification after 4000 Hours 4

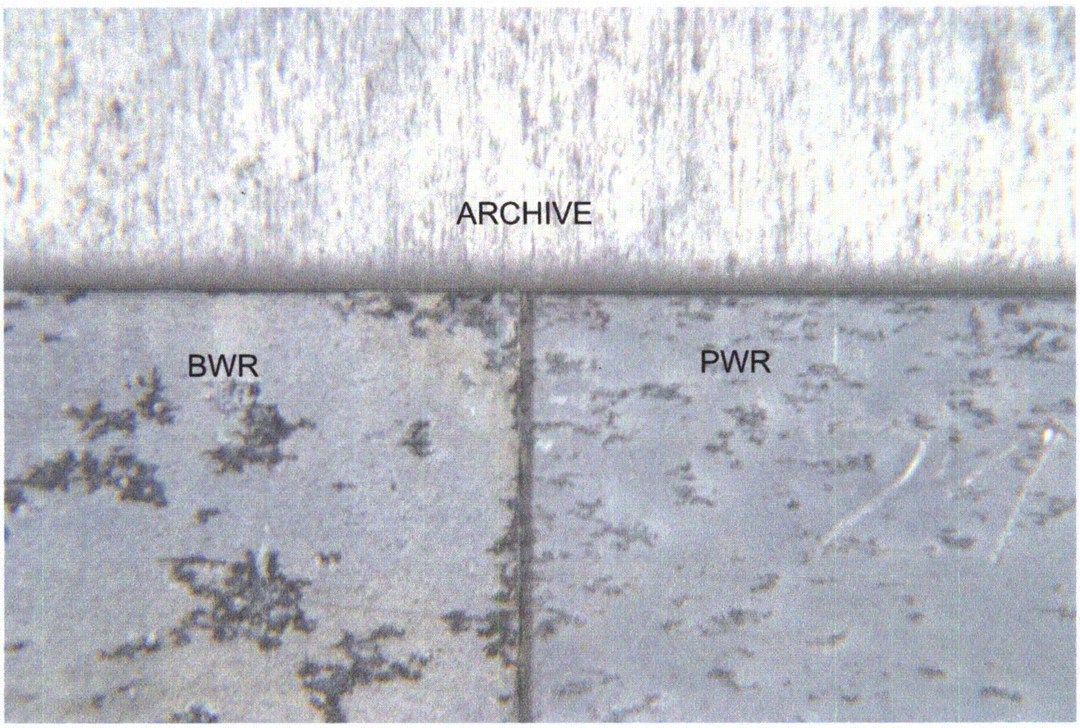

Figure 5-10: Comparison of Post-Test Coupon Appearance with Archive Material: 16 vol % Boron Carbide Loading at 8X Magnification after 8000 Hours

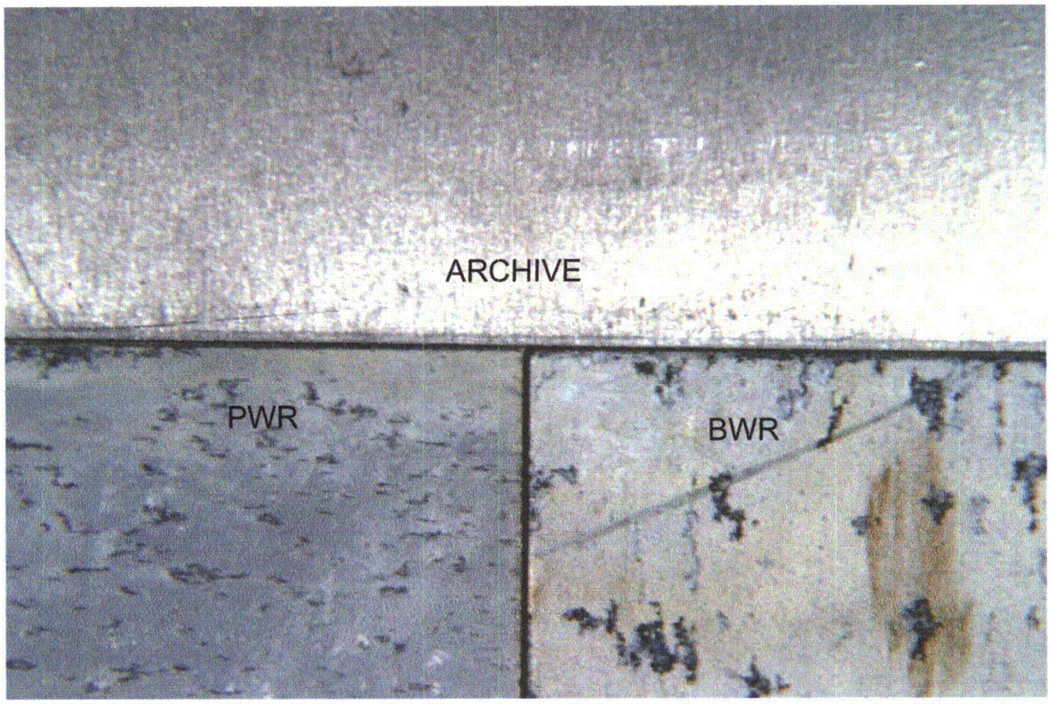

Figure 5-11: Comparison of Post-Test Coupon Appearance with Archive Material: 25 vol % Boron Carbide Loading at 8X Magnification after 4000 Hours 4

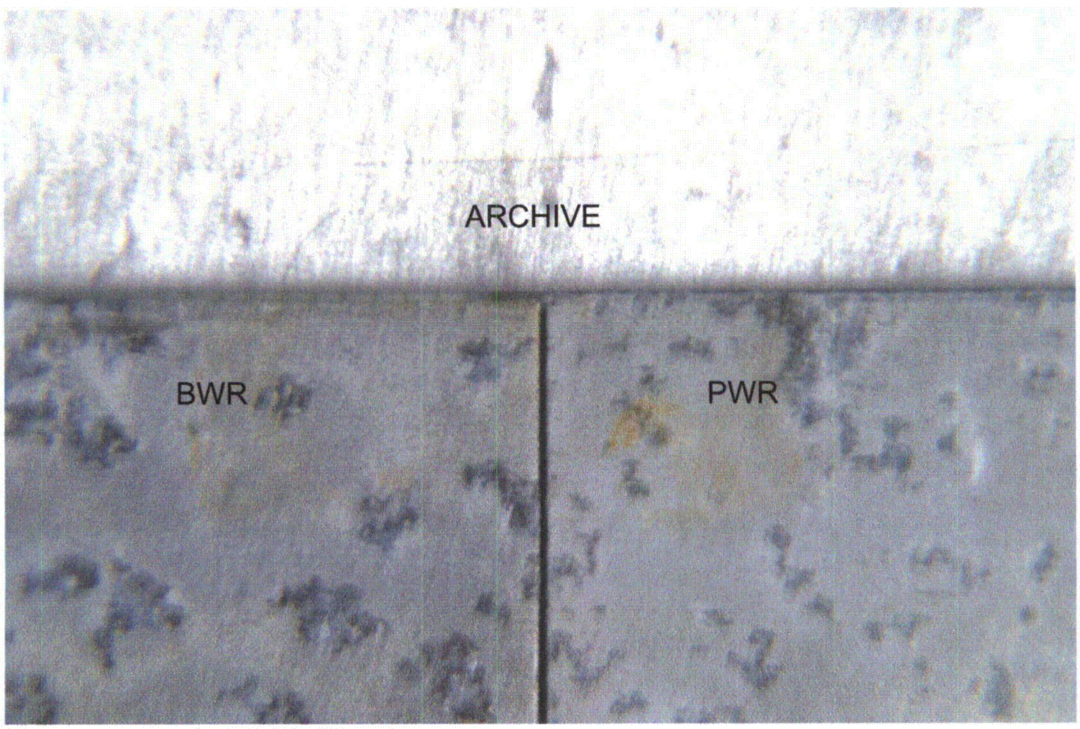

Figure 5-12: Comparison of Post-Test Coupon Appearance with Archive Material: 25 vol % Boron Carbide Loading at 8X Magnification after 8000 Hours

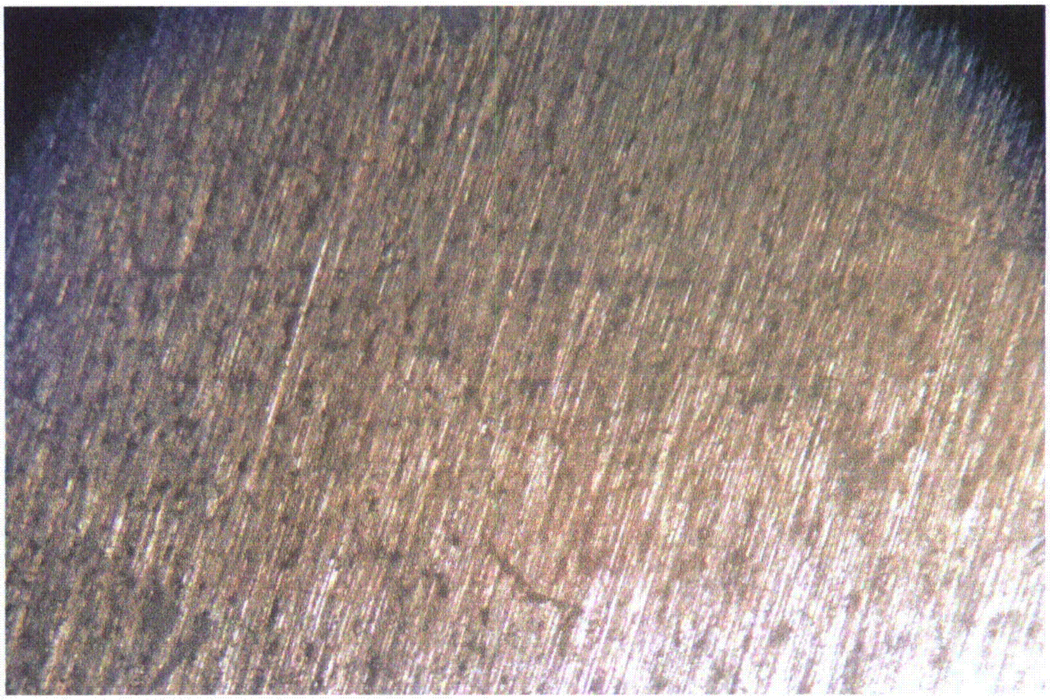

Figure 5-13: Photomicrograph of 16 vol % B_4C Composite As-Fabricated (45X) 4

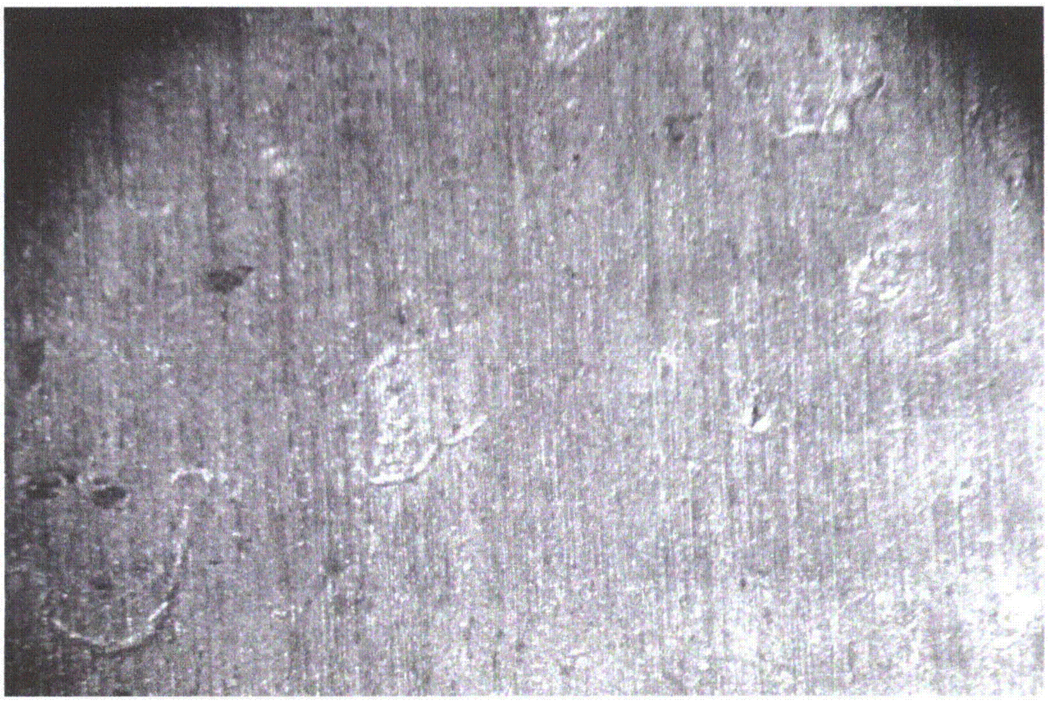

Figure 5-14: Photomicrograph of 25 vol % B_4C Composite As-Fabricated (45X)

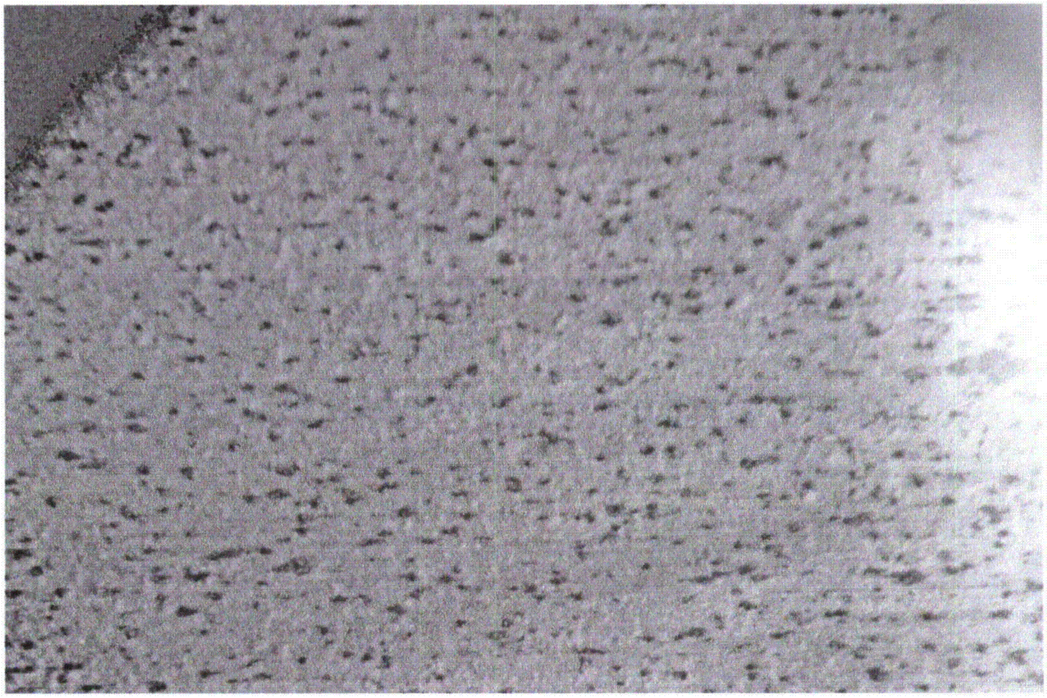

Figure 5-15: Photomicrograph of 16 vol % B_4C Composite after 8000 Hours in Demineralized Water (45X) 4

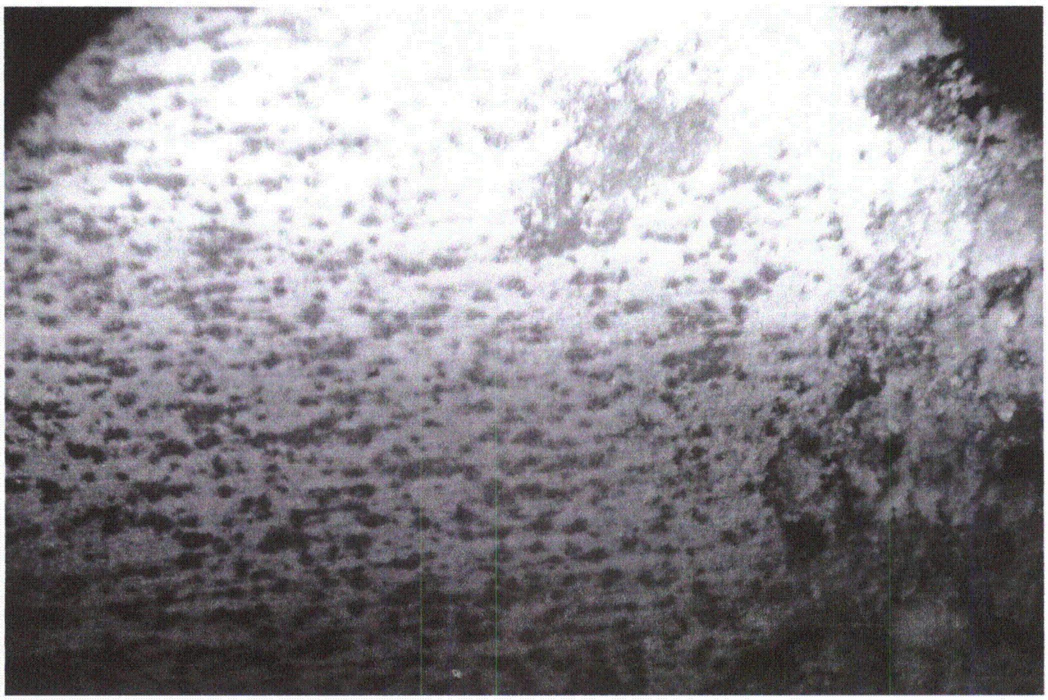

Figure 5-16: Photomicrograph of 16 vol % B_4C Composite after 8000 Hours in Boric Acid (45X)

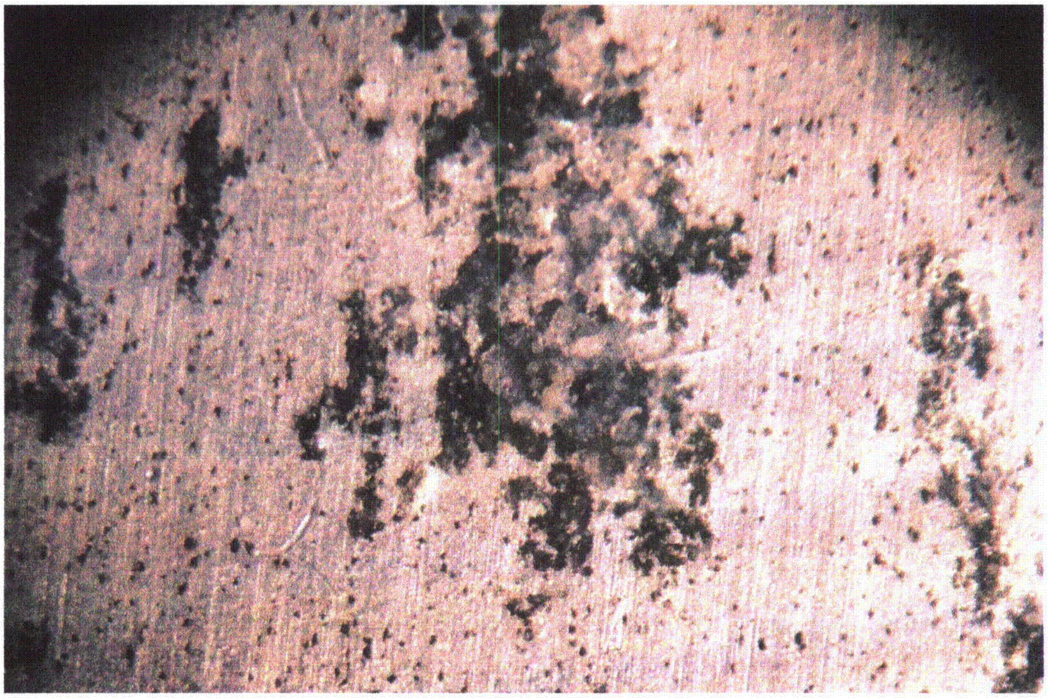

Figure 5-17: Photomicrograph of 25 vol % B_4C Composite after 8000 Hours in Demineralized Water (45X) 4

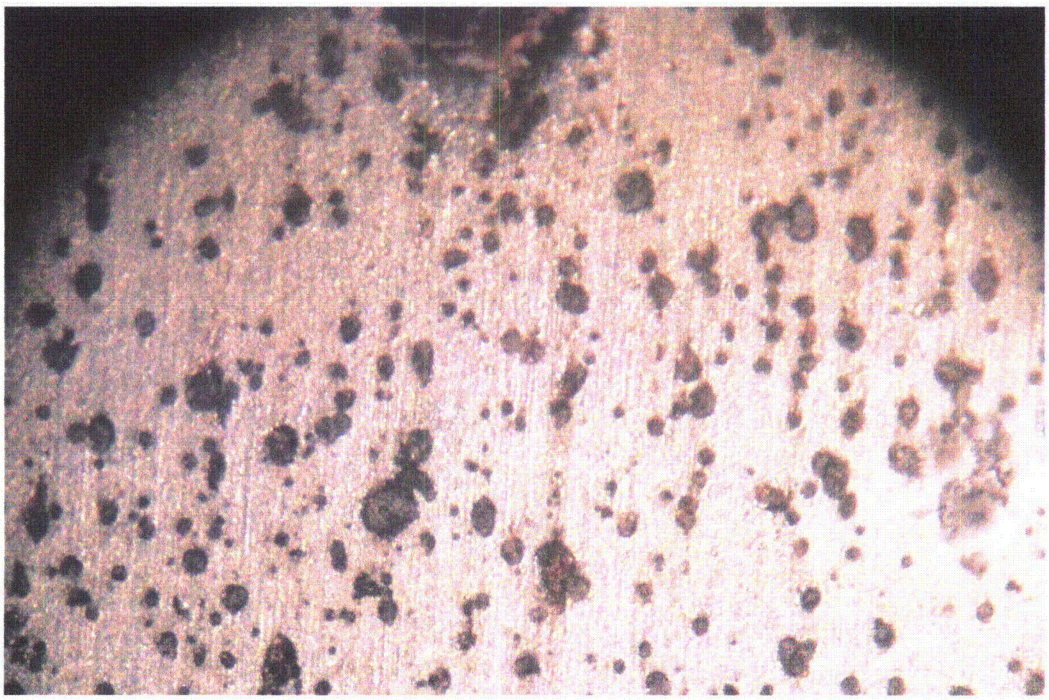

Figure 5-18: Photomicrograph of 25 vol % B_4C Composite after 8000 Hours in Boric Acid (45X)

Quantitative Corrosion Measurements

The change in coupon thickness can provide a semi-quantitative measure of the extent and progression of corrosion. The change in coupon weight, on the other hand, can provide a more accurate measure of the extent and progression of corrosion. As the aluminum base metal on the surface of the coupons is converted to the oxide (either Al_2O_3 or $Al_2O_3 \cdot n\ H_2O$), the volume of the oxide exceeds the volume of the original base metal consumed. Concurrent with this conversion is an increase in thickness and increase in weight.

The pre-test thickness of each general coupon was measured at nine locations. The pre-test thickness of each bend coupon was measured at six locations. The post-test thickness was measured at the same nine and six locations on the general and bend coupons, respectively. The values reported are the average of either nine or six measurements for each coupon. The pre and post test coupons' weights were measured for each coupon after a one hour drying at 110°C to remove surface moisture. 4

Figures 5-19 and 5-20 contain the results of the average coupon thickness changes versus exposure times for the BWR and PWR coupons, respectively. The data show that, with one exception, the coupons show a measurable increase in thickness. The scatter in the data is likely attributable to measuring small changes in thickness in relatively thin samples. To place this data in perspective, a 5% increase in thickness on a coupon of initial thickness of 0.080 inches is 0.004 inches or 4 mils. If it is assumed that both sides of the coupon contribute equally then the increase is 0.002 inches per side. After 8000 hours, the average change in the thickness of the coupons exposed to accelerated BWR conditions is 4.2%; the corresponding value for the PWR coupons is 4.1%. Figures 5-21 and 5-22 contain plots of coupon weight change versus exposure time.

At the 4000 hour and 8000 hour tests, eighteen of the galvanic corrosion couples were removed from each test bath and were subjected to testing. These included three 304L stainless steel couples, three Inconel 718 couples and three Zircaloy coupons at each

B_4C loading. No couples were tested at 2000 hours and 6000 hours. Figures 5-23 and 5-24 show the weight change of the BWR and PWR couple samples after coupon drying.

In accordance with ASTM G-31-72[1] and ASTM G-1-03[2], the coupons were cleaned in 1.42 sp.gr. nitric acid to remove the corrosion products. The intent of cleaning is to remove all of the corrosion products but none of the base metal so that the weight of the corrosion products can be determined. This weight change can subsequently be used to determine the corrosion rate in mils/year.

As noted previously, the oxide on coupons in the BWR test was easily removed by one or two ten-minute soaks in nitric acid at room temperature. For the PWR coupons it required several successive soak periods. After each cleaning cycle, the coupons were dried and reweighed. The cleaning proceeded until the coupons achieved constant weight or visual and/or microscopic examination indicated the oxide film had been removed. 4

Figures 5-25 and 5-26 show the average change in coupon thickness after acid cleaning for the BWR and PWR general and bend coupons, respectively. Figures 5-27 and 5-28 show the change in coupon thickness after acid cleaning for the BWR and PWR galvanic coupons, respectively, after 4000 hours and 8000 hours. These values represent the thickness of oxide removed by acid cleaning. The average change in thickness by coupon type are summarized in Table 5-5. The data in Table 5-5 illustrate the difficulty in obtaining accurate changes in coupon thickness when the specimens are very thin. This is further evidenced by the variability in the coupon thickness data.

The coupon weight changes as a result of acid cleaning are shown in Figures 5-29 and 5-30 for the BWR and PWR general and bend coupons, respectively. The coupon weight changes as a result of acid cleaning are shown in Figures 5-31 and 5-32 for the BWR and PWR galvanic coupons, respectively. The average change in coupon weight by coupon type are summarized in Table 5-6. This table shows the weight changes

exhibit far less variability than the thickness changes in Table 5-5. Accordingly, the weight change data are used subsequently to compute corrosion rates.

Table 5-5

Summary of Coupon Thickness Changes by Coupon Type

	Thickness Change, %			
Coupon Types	**2153 Hours**	**4019 Hours**	**5871 Hours**	**8119 Hours**
BWR General and Bend				
16 vol % B_4C	-1.14% ± 0.59%	-3.08% ± 0.64%	-1.40% ± 1.07%	-0.55% ± 0.88%
25 vol % B_4C	-0.72% ± 0.89%	-2.09% ± 1.40%	0.08% ± 0.44%	-0.94% ± 0.79%
BWR Galvanic				
16 vol % B_4C		-0.07% ± 0.68%		-0.91% ± 0.35%
25 vol % B_4C		-1.05% ± 0.35%		-0.98% ± 0.81%
PWR General and Bend				
16 vol % B_4C	-0.03% ± 0.51%	-2.73% ± 1.14%	-0.70% ± 0.92%	-3.32% ± 4.64%
25 vol % B_4C	-0.55% ± 0.46%	-1.24% ± 1.05%	0.44% ± 1.10%	-0.13% ± 0.82%
PWR Galvanic				
16 vol % B_4C		-1.04% ± 0.81%		-2.55% ± 3.25%
25 vol % B_4C		-1.24% ± 0.27%		-0.40% ± 0.88%

Table 5-6 4

Summary of Coupon Weight Changes by Coupon Type

	Weight Change, %			
Coupon Types	**2153 Hours**	**4019 Hours**	**5871 Hours**	**8119 Hours**
BWR General and Bend				
16 vol % B_4C	-0.15% ± 0.12%	-0.28% ± 0.22%	-0.68% ± 0.19%	-0.50% ± 0.17%
25 vol % B_4C	-0.29% ± 0.27%	-0.36% ± 0.38%	-0.68% ± 0.25%	-0.69% ± 0.75%
BWR Galvanic				
16 vol % B_4C		0.05% ± 0.2%		-0.34% ± 0.19%
25 vol % B_4C		-0.24% ± 0.27%		-0.81% ± 0.28%
PWR General and Bend				
16 vol % B_4C	-0.12% ± 0.04%	-0.07% ± 0.09%	-0.10% ± 0.12%	-0.26% ± 0.37%
25 vol % B_4C	-0.04% ± 0.07%	-0.02% ± 0.05%	-0.17% ± 0.12%	-0.16% ± 0.09%
PWR Galvanic				
16 vol % B_4C		-0.64% ± 0.77%		-0.89% ± 0.46%
25 vol % B_4C		-0.79% ± 0.98%		-0.66% ± 0.46%

Boron-10 Areal Density

The boron-10 areal density of the general coupons was measured using neutron attenuation testing. The results of the post-test measurements were compared with similar testing of archive coupons. Figures 5-33 and 5-34 contain plots of the change in boron-10 areal density versus exposure time for the BWR and PWR coupons, respectively. To place these measurements in perspective, the average areal density of the 16 vol % coupons is 0.010 gms B-10/cm^2; the corresponding areal density of the 25 vol % coupons is 0.0176 gms B-10/cm^2. The variation in areal density changes are within ± 1.0 to 2.0% of zero change, which is within the absolute uncertainty of the areal density measurements. 4

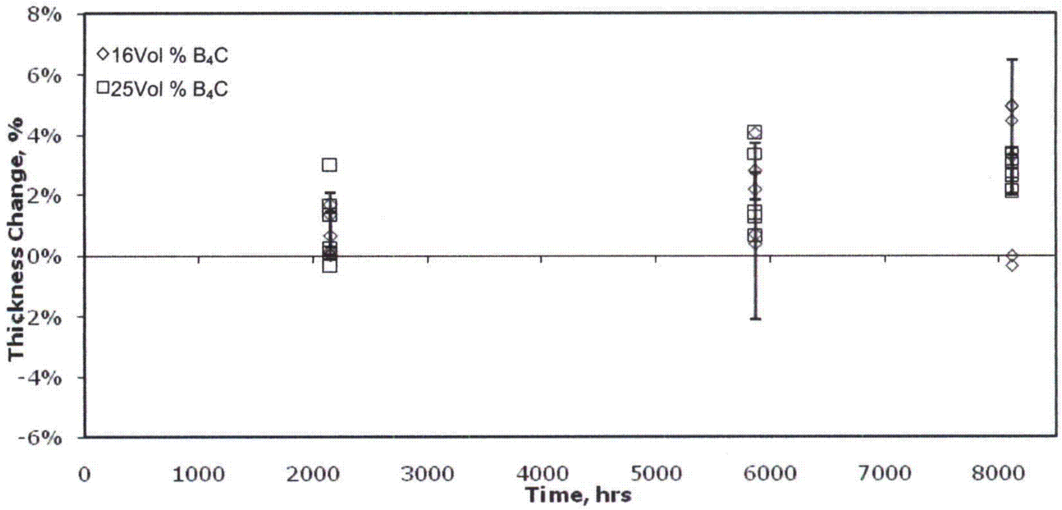

Figure 5-19: BWR Thickness Change (Pre-Test vs. Post-Test)

4

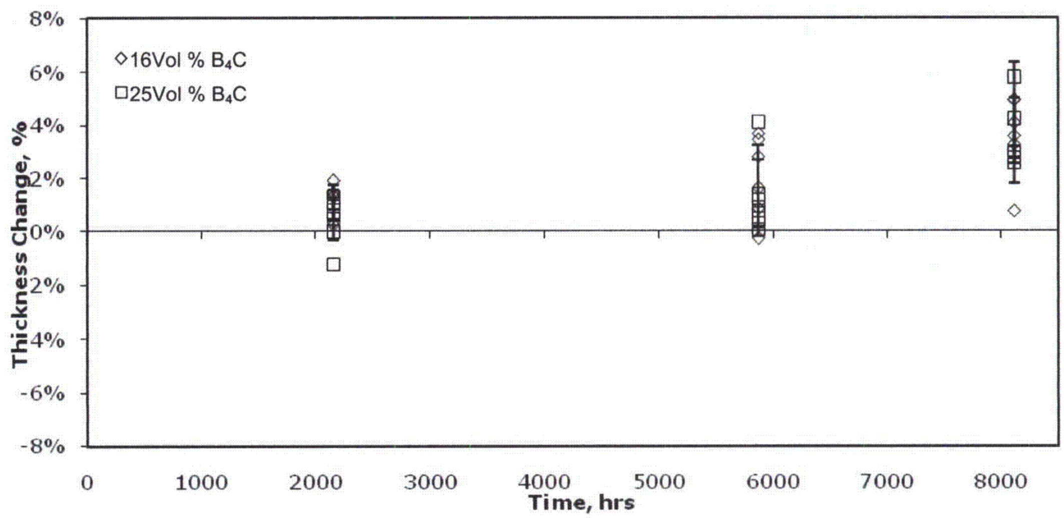

Figure 5-20: PWR Thickness Change (Pre-Test vs. Post-Test)

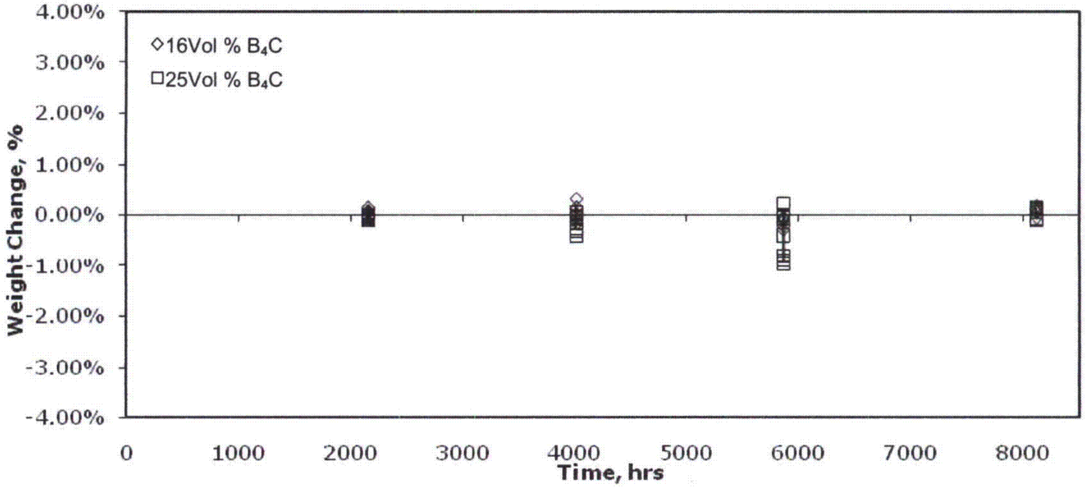

Figure 5-21: BWR Weight Change (Pre-Test vs. Post-Test)

4

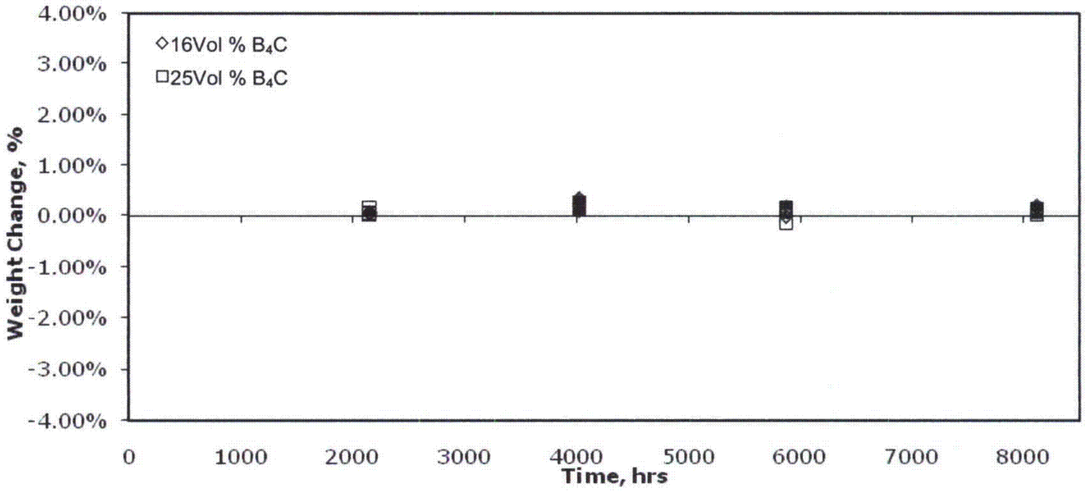

Figure 5-22: PWR Weight Change (Pre-Test vs. Post-Test)

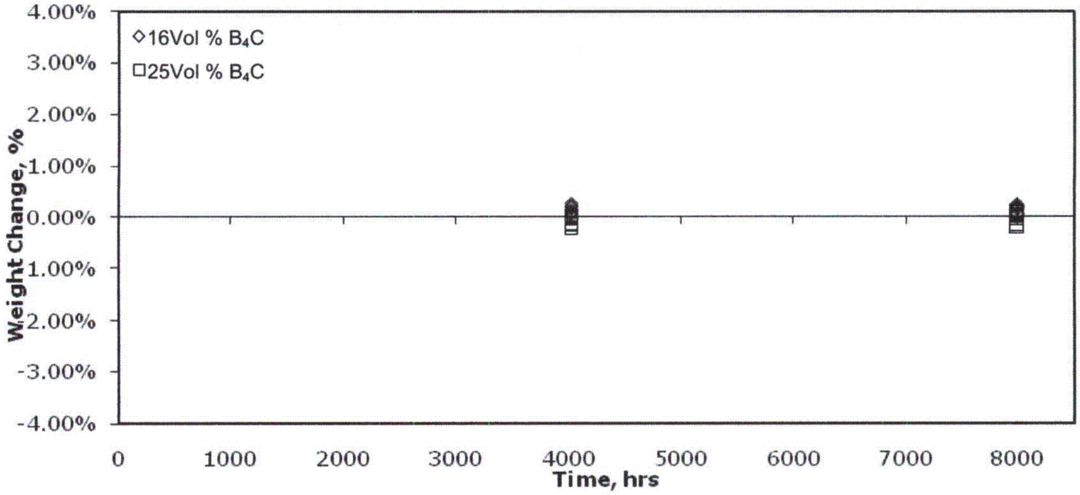

Figure 5-23: BWR Coupon Weight Change versus Time: Galvanic Couple Coupons

4

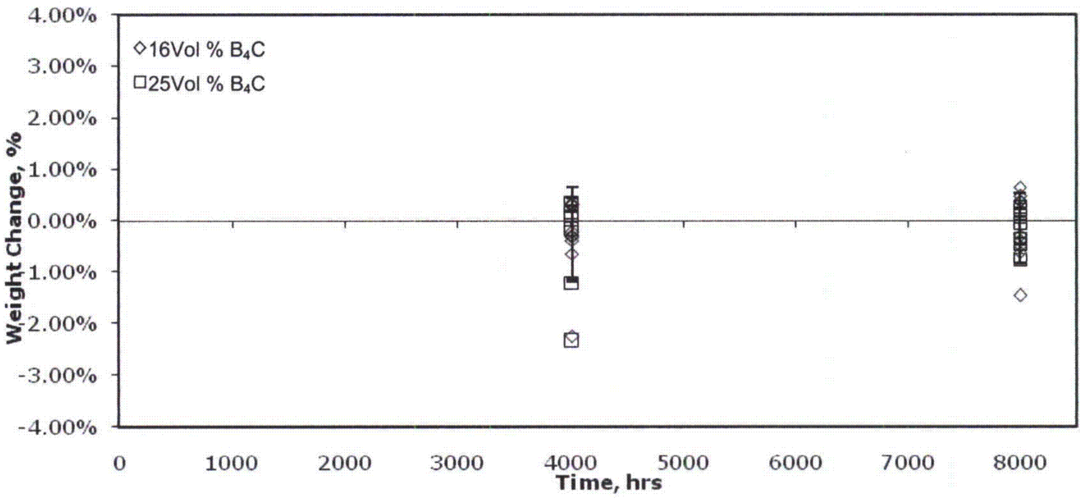

Figure 5-24: PWR Coupon Weight Change versus Time: Galvanic Couple Coupons

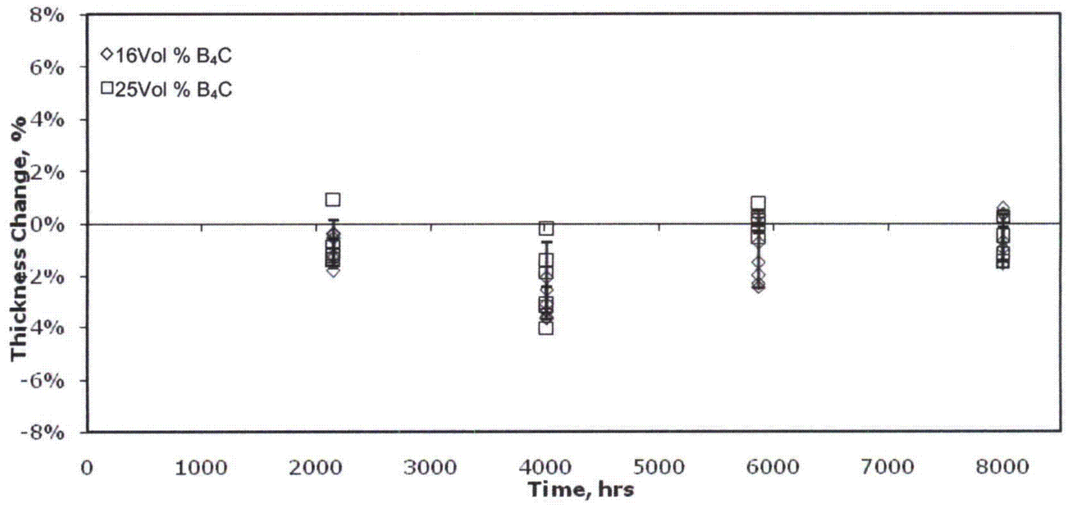

Figure 5-25: BWR Thickness Change (Pre-Test vs. Post-Test) After Acid Cleaning: General and Bend Coupons

4

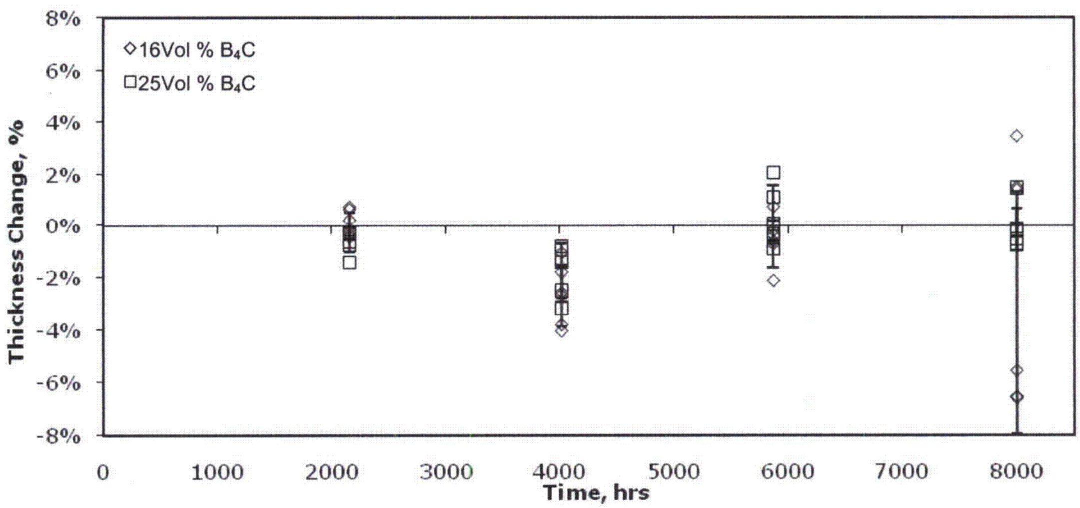

Figure 5-26: PWR Thickness Change (Pre-Test vs. Post-Test) After Acid Cleaning: General and Bend Coupons

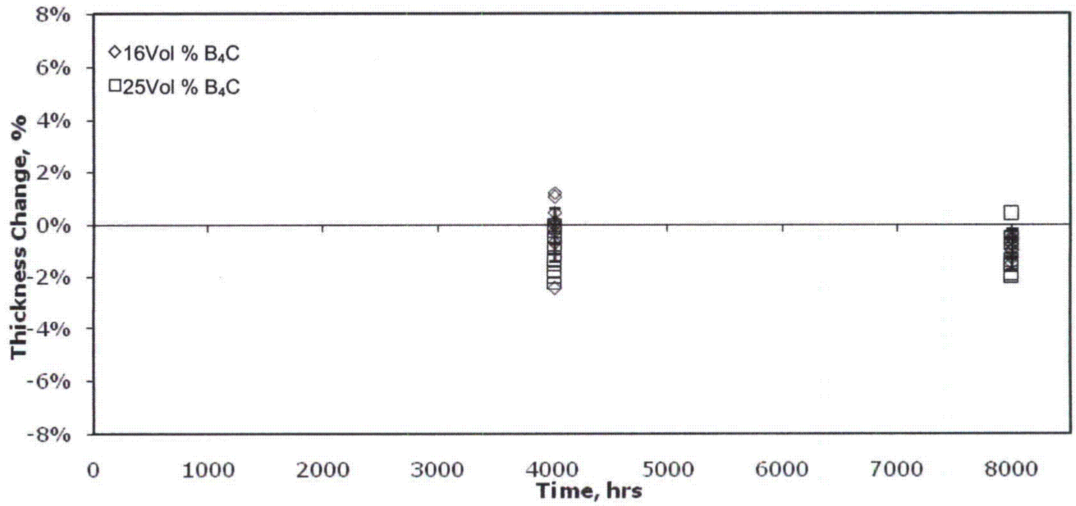

Figure 5-27: BWR Galvanic Coupons After Acid Cleaning: Coupon Thickness Change

4

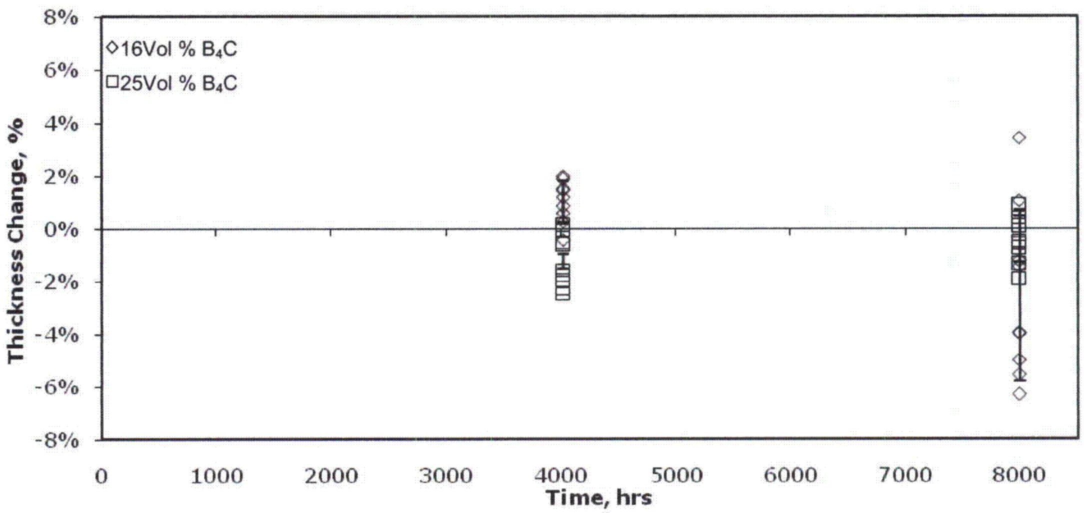

Figure 5-28: PWR Galvanic Coupons After Acid Cleaning: Coupon Thickness Change

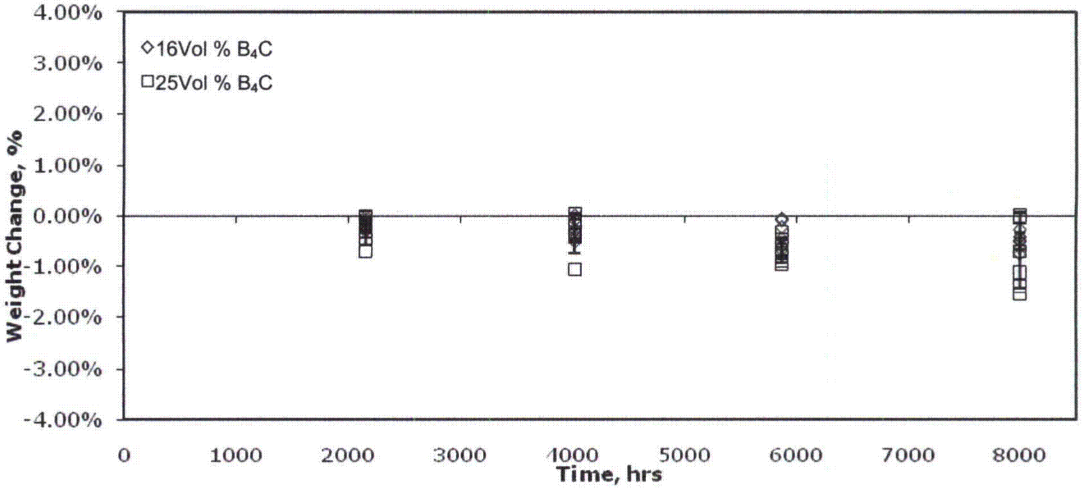

Figure 5-29: BWR Coupon Weight Change (Pre-Test vs. Post-Test) After Acid Cleaning: General and Bend Coupons Only

4

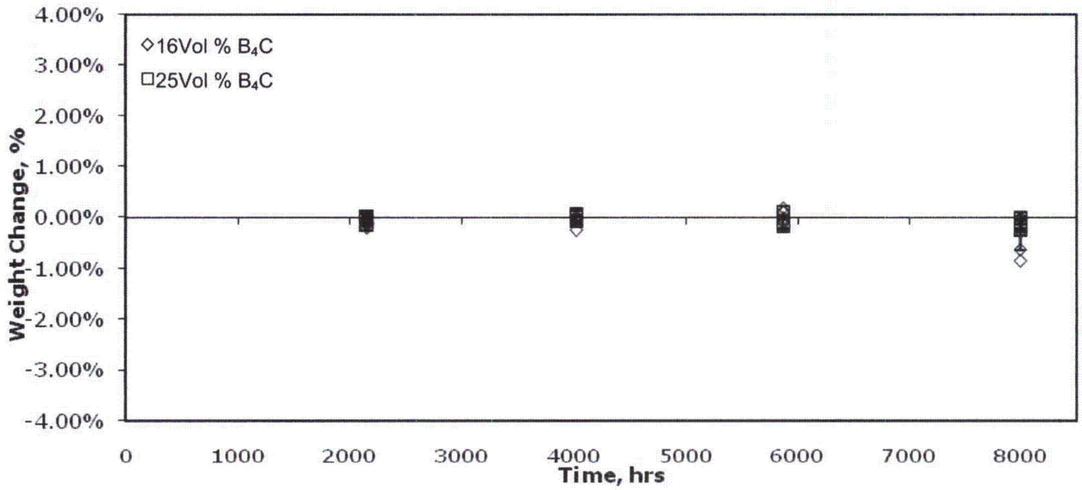

Figure 5-30: PWR Coupon Weight Change (Pre-Test vs. Post-Test) After Acid Cleaning: General and Bend Coupons Only

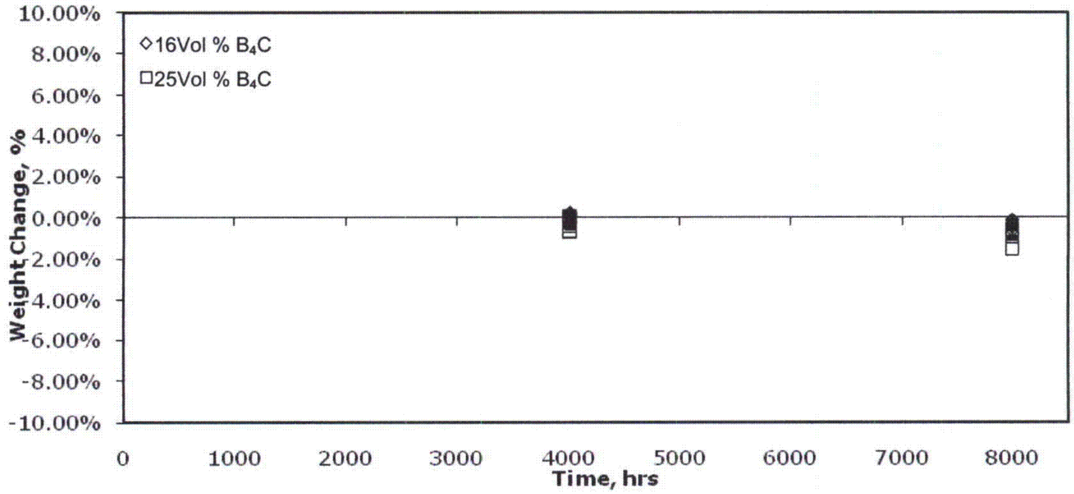

Figure 5-31: BWR Galvanic Coupon Weight Change versus Time 4

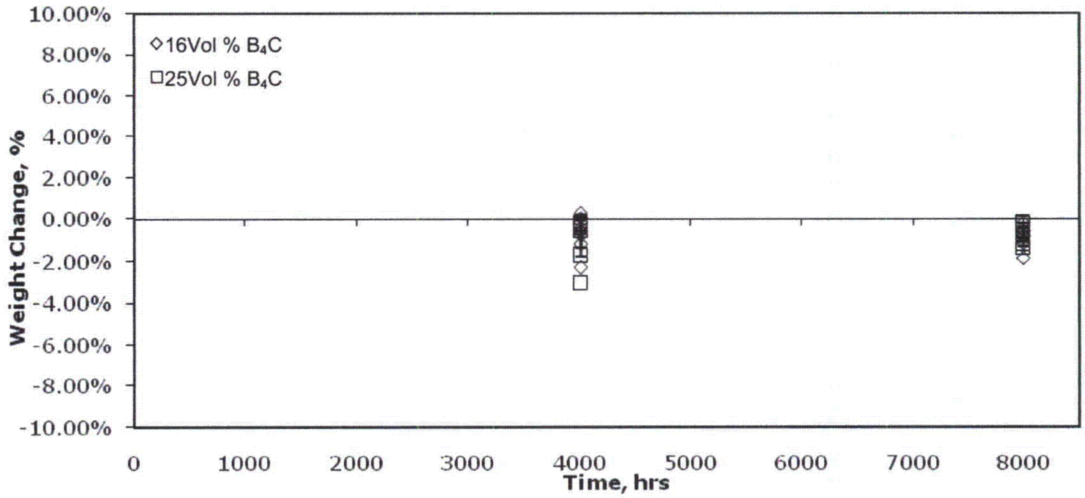

Figure 5-32: PWR Galvanic Coupon Weight Change versus Time

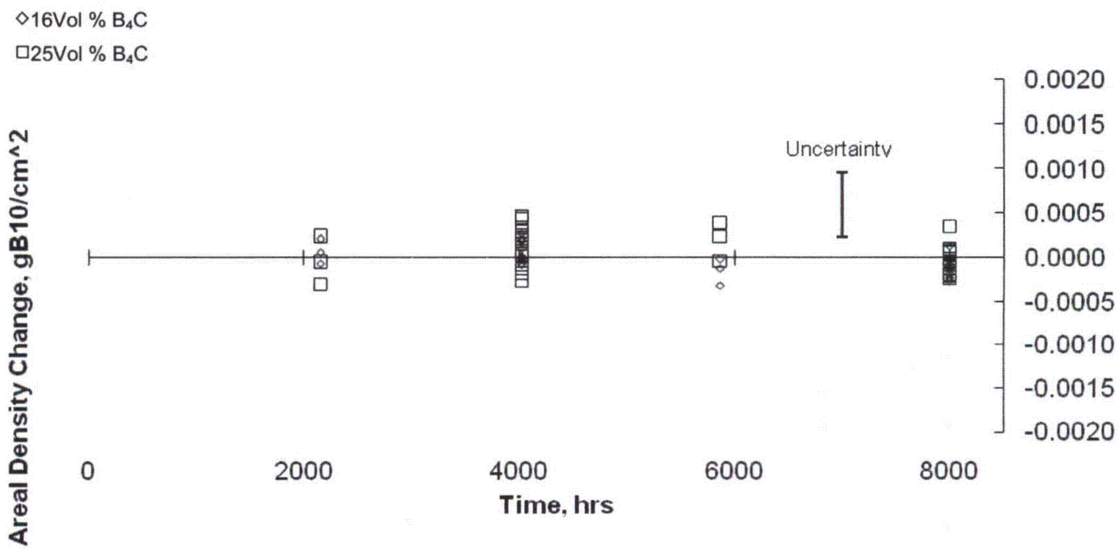

Figure 5-33: BWR Coupon Areal Density Change versus Time 4

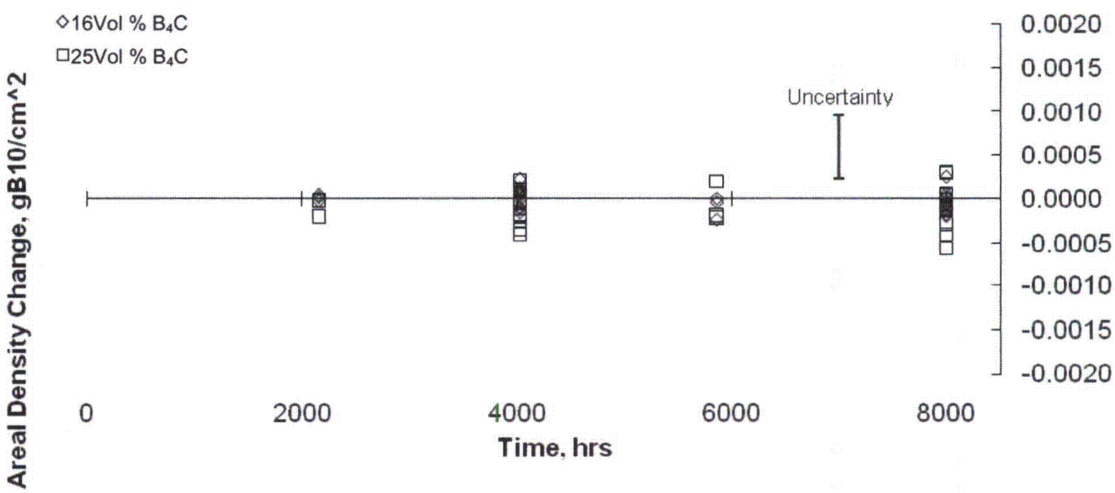

Figure 5-34: PWR Coupon Areal Density Change versus Time

5.5 Discussion of Test Results and Conclusions

Following the guidance provided in Reference 1, the post-test coupon weights after acid cleaning can be compared with pre-test weights to compute the test environment corrosion rate (mils/year) of the various coupon types. Using corrosion data in Reference 3 for AA1200 series aluminum in water at 122° F and 392° F, it is possible to compute the corresponding in-service corrosion rates at typical spent fuel pool conditions and water temperature (typically 80° F). These calculations are contained in the Appendix and the so calculated in-service corrosion rates are summarized in Table 5-7. Table 5-8 contains the equivalent in-service exposure times for each of the four test intervals.

Table 5-7: Average Corrosion Rates

	In-Service Corrosion Rates, mils/year				
Coupon Types	**2153-Hour Test**	**4019-Hour Test**	**5871-Hour Test**	**8119-Hour Test**	
BWR General and Bend					4
16 vol % B_4C	-0.01	-0.01	-0.02	-0.01	
25 vol % B_4C	-0.02	-0.02	-0.02	-0.02	
BWR Galvanic					
16 vol % B_4C		0.01		-0.01	
25 vol % B_4C		-0.01		-0.02	
PWR General and Bend					
16 vol % B_4C	-0.01	-0.01	-0.03	-0.01	
25 vol % B_4C	-0.01	-0.02	-0.01	-0.01	
PWR Galvanic					
16 vol % B_4C		-0.02		-0.02	
25 vol % B_4C		-0.04		-0.01	

Table 5-8: Equivalent Exposure Time

Test Hours @ 195° F	**In-Service Hours @ 80° F**
2153	39050
4019	72911
5871	107447
8119	148605

The computed in-service corrosion rates shown in Table 5-7 are extremely low and in each instance are based on the average weight loss of several coupons. A corrosion rate of -0.02 mils/year can be interpreted to mean that after 100 years an oxide film 2 mils thick would be expected on all surfaces. The reason for this extremely low corrosion rate is that once an oxide film forms on all surfaces, the film tends to be self-passivating; that is, it tends to retard further corrosion. This property of the oxide film formation leads to the excellent corrosion resistance of AA1100 aluminum alloy and the performance of the Rio-Tinto Alcan material shows similar performance. This has been 5
observed in other aluminum boron carbide composites tested by NETCO.[4]

It is further noted that for both the 16 vol % and the 25 vol % coupons, there has been no measurable change in the B-10 areal density, nor has any local corrosion (pitting) or cracking been detected. Optical microscopy of inside and outside radius of bend coupons revealed no cracks or anomalistic corrosion behavior. These observations 4
apply to both the BWR and the PWR test environments.

Once installed, the inserts assume a constant strain condition within the rack cell. This compression leads to internal stresses, especially at the bend, that might make the inserts susceptible to stress corrosion cracking. An examination of the literature on this subject[5-5],[5-6], indicates that "In general, high-purity aluminum and low-strength 5
aluminum alloys are not susceptible to SCC."[5-5] However, surveillance bend coupons to be placed in the pool prior to the installation of the inserts will be maintained under the same strain conditions to provide indication of any unexpected crack phenomena.

Not withstanding the low measured corrosion rates, corrosion itself does not result in any loss of boron carbide. After the corrosion film forms, the boron carbide remains tightly bound in the corrosion layer. This was confirmed by the neutron attenuation measurements for boron-10 areal density, which were performed prior to acid cleaning to remove corrosion products.

As determined by the testing sequences described herein, the low measured corrosion rates under accelerated corrosion test conditions as well as the constancy of boron-10 areal density, recommends that the AA1100/boron carbide composite produced by Rio Tinto Alcan is a highly suitable neutron absorber material for use in spent fuel storage racks.

References Section 5:

5-1 ASTM G-31-72 (Reapproved 2004), Standard Practice for Laboratory Corrosion Testing of Metals.

5-2 ASTM G-1-03, Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.

5-3 Godard, Epson, Bothwell and Kane, The Corrosion of Light Metals, John Wiley & Sons, Inc., New York, 1967.

5-4 Qualification of METAMIC® for Spent-Fuel Storage Applications, Electric Power Research Institute Report 1003137 by Northeast Technology Corp., Kingston, NY. October 2001.

5-5 Davis, J.R. Corrosion of Aluminum and Aluminum Alloys. ASM International. November 2000. Pg. 108 4

5-6 Bauccio, Michael. ASM Metals Reference Book, Third Edition. ASM International. April 2003. Pg. 408

6.0 Fast Start Coupon Surveillance Program Description

The fast start coupon surveillance program consists of a series of 24 coupons cut from extra Alcan composite produced for the LaSalle demonstration. These coupons are 2 x 4 inches in width and length and have two 0.25 inch diameter holes along the top and bottom edge as shown in Figure 6-1. Their thickness is nominally 0.065 inch and each coupon contains 16 vol% boron carbide. The purpose of the fast start program is to provide early performance data on the Alcan composite in the LaSalle Unit 2 pool environment.

Each of the coupons will be connected to the next coupon with a stainless steel link clip. The string of 24 coupons will be attached to a short piece of stainless steel chain, which in turn will be attached to a head assembly (See Figure 6-2). The head assembly contains a hook so that it can be remotely lowered into a rack storage cell in the LaSalle Unit 2 pool. When in place the head piece will rest on top of a storage cell with the string of coupons suspended in the cell below. The length of the connecting chain between the head piece and the string of coupons was adjusted so that all 24 coupons are within the active fuel region of the eight surrounding fuel assemblies.

At each refueling outage the fast start coupons will be in a cell surrounded in all eight locations with freshly discharged fuel. In this manner the gamma energy disposition and temperatures of the coupons will be maximized. Two coupons will be removed every six months from the string and sent to a qualified laboratory for testing and inspection. The coupons have been subjected to pre characterization and will be post test characterized. Table 6-1 contains the pre and post test inspections and measurements.

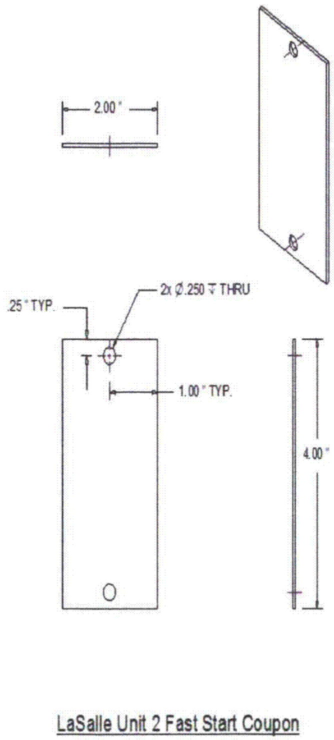

Figure 6-1: Fast Start Surveillance Coupon

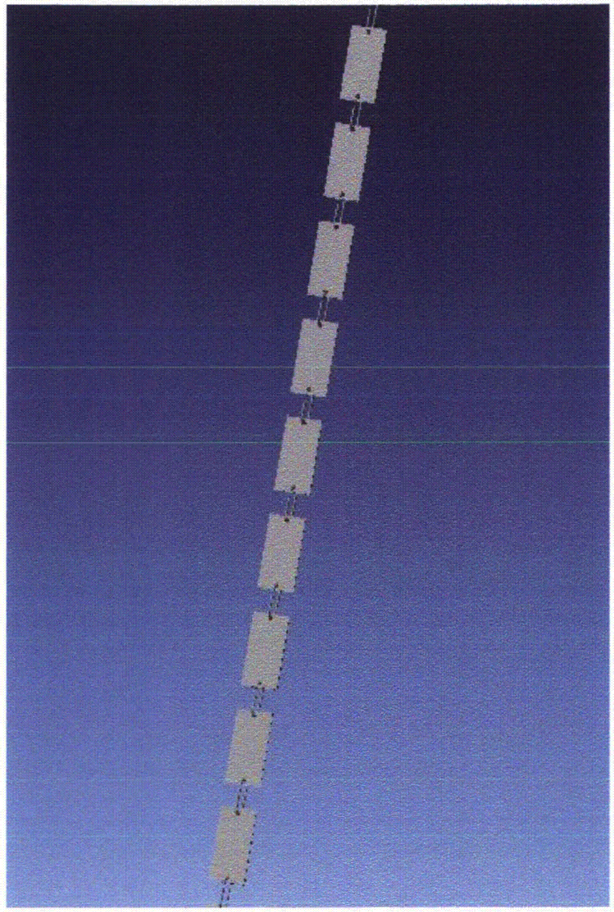

Figure 6-2: Fast Start Coupons String

Table 6-1

Pre and Post Test Coupon Characterization

Test	Pre Characterization	Post Characterization
Visual (Hi resolution digital photo)	√	√
Dimension	√	√
Dry Weight	√	√
Density	√	√
Areal Density	√+	√
Acid Cleaning		√
Weight Loss		√
Corrosion Rate		√
Microscopy		√*

+ On select coupons *as-required

A prime objective of this fast start program is to provide some early data as to the actual corrosion rates anticipated under actual LaSalle spent fuel pool conditions.

7.0 Long-Term Surveillance Program

The long-term surveillance program will consist of a specially designed surveillance tree to which a series of surveillance coupons are attached. The long-term surveillance tree will be placed within the pool as part of the first installation campaign of NETCO-SNAP-INs® and will reside there as long as the fuel racks continue to be used. Periodically, coupons will be removed and sent to a qualified laboratory for testing.

7.1 Tree and Coupon Description

The surveillance tree will be a four-sided structure with 18 - 2" x 4" coupons attached to each side and 12 – 2" bend coupons abutting adjacent faces. The bend coupons will be 3
maintained under a fixed strain in the fixture. They will be manufactured at the same 4
initial angle as the inserts and bent to the square angle of the rack cells. All coupons will contain 17 vol% boron carbide. The types and numbers of coupons included in the program are shown in Table 7-1.

Table 7-1

Long-Term Surveillance Coupons

Coupon Type	Number	Objective	
General	48	Quantify long-term corrosion	
Bend	24	Track effects along bend radii including stress relaxation and stress corrosion cracking	4
Galvanic (bi-metallic)	24	Trend galvanic corrosion with 304SS, In and Zirc coupons	

7.2 Coupon Inspection and Testing

Specific coupons will be removed from tree on a frequency schedule as described subsequently. The general coupons will be subject to pre and post examination according to Table 7-2.

Table 7-2

Long-Term Surveillance General Coupon Characterization

Test	Pre Characterization	Post Characterization
Visual (Hi resolution digital photo)	√	√
Dimension	√	√
Dry Weight	√	√
Areal Density	√+	√
Acid Cleaning		√
Weight Loss		√
Corrosion Rate		√
Microscopy		√*

4

+ On select coupons *as-required

The bend and galvanic coupons will be subject to the tests in Table 7-3.

Table 7-3

Long-Term Surveillance Bend and Galvanic Coupon Characterization

Test	Pre Characterization	Post Characterization
Visual (High Resolution Digital Photo)	√	√
Thickness	√	√
Dry Weight	√	√
Bending Stress (Bend Coupons Only)	√	√
Acid Cleaning		√
Weight Loss and Corrosion Rate		√
Microscopy		√*

4

*as-required

7.3 Frequency for Coupon Inspection

The frequency for coupon inspection will depend on the coupon type and results of previous inspections. The frequency for inspection is shown in Table 7-4.

Table 7-4

Frequency for Coupon Testing

Coupon Type	**First Ten Years**	**After 10 Years with Acceptable Performance**	
General	2 coupons every 2 years	2 coupons every 4 years	
Bend	1 coupon every 2 years	1 coupon every 4 years	
Galvanic Couples 304 Stainless Zirc In	 1 couple every 6 years " "		2

Enclosure 9 to
NRC-19-0004

Fermi 2 NRC Docket No. 50-341
Operating License No. NPF-43

License Amendment Request to Revise Technical Specifications to Utilize Neutron Absorbing Inserts in Criticality Safety Analysis for Fermi 2 Spent Fuel Storage Racks

Regulatory Commitments

List of Regulatory Commitments Associated with License Amendment Request for Neutron-Absorbing Inserts

New Regulatory Commitments	Due Date
DTE will revise the Fermi 2 Updated Final Safety Analysis Report (UFSAR) as follows: 1) UFSAR Section B.1.27 will be revised to explicitly list the Rio-Tinto-Alcan BORALCAN™ composite material as a material to which the program applies. 2) UFSAR Section B.1.27 will be revised to state that the program activities associated with the BORALCAN™ composite material will meet the recommendations and guidance of NEI 16-03-A. 3) UFSAR Section 3.1.2.6.3 will be revised to describe the BORALCAN™ composite material as being relied upon for conformance with General Design Criterion (GDC) 62.	Within the requested 90 day implementation period following either NRC approval or complete installation of the neutron absorbing inserts, whichever is later.

In addition to the new regulatory commitments listed above, Fermi 2 has existing regulatory commitments associated with Boraflex. Upon implementation of this license amendment following approval, Boraflex will no longer be credited to perform any neutron absorption function. As a result, any existing commitment whose intent was associated with Boraflex performing a neutron absorption function will become obsolete. DTE will therefore delete these existing commitments from the Fermi 2 commitment management database.