Keith J. Polson
Site Vice President

DTE Energy Company
6400 N. Dixie Highway, Newport, MI 48166
Tel: 734.586.4849 Fax: 734.586.4172
Email: polsonk@dteenergy.com

DTE Energy

10 CFR 50.54(f)
GL 2016-01

October 11, 2016
NRC-16-0061

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

References: 1) Fermi 2
NRC Docket No. 50-341
NRC License No. NPF-43

2) NRC Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated April 7, 2016 (ML16097A169)

3) NRC Letter to DTE, "Safety Evaluation Report Related to the License Renewal of Fermi 2 (TAC No. MF4222)," dated July 12, 2016 (ML16190A011)

Subject: DTE Response to NRC Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools"

In Reference 2, the NRC issued Generic Letter (GL) 2016-01 to address degradation of neutron-absorbing materials in wet storage systems for reactor fuel at power reactors. The GL was issued for two purposes:

(1) To request that addressees submit information, or provide references to previously docketed information, which demonstrates that credited neutron-absorbing materials in the [spent fuel pool] SFP of power reactors and the fuel storage pool, reactor pool, or other wet locations designed for the purpose of fuel storage, as applicable, for non-power reactors, are in compliance with the licensing and design basis, and with applicable regulatory requirements; and that there are measures in place to maintain this compliance.
(2) To collect the requested information and determine if additional regulatory action is required.

A written response to the GL is required under 10 CFR 50.54(f) and was requested within 210 days of the date of the GL. DTE Electric Company (DTE) has reviewed the GL and is providing the requested information in the enclosures to this letter.

The GL indicated that responses would be accepted based on a categorization, with four different categories provided. The DTE response in the enclosures is based on Category 4. The Fermi 2 spent fuel racks currently credit two different neutron-absorbing materials: Boraflex and Boral. Since the responses to the GL are unique for these two materials, the requested information is being provided in two separate enclosures. Enclosure 1 contains the requested information for racks containing Boraflex. Enclosure 2 contains the requested information for racks containing Boral.

Although Boraflex is currently credited as a neutron-absorbing material, it is important to note that the NRC safety evaluation report (SER) for the license renewal of Fermi 2 (Reference 3) contains a license condition to discontinue reliance on Boraflex to perform a neutron-absorption function. This license condition shall be met prior to the period of extended operation (i.e. March 20, 2025). As soon as this license condition is met by DTE, Boraflex would no longer be considered a credited material per the definition in the GL. The SER for license renewal also contains an evaluation of the Neutron-Absorbing Material Monitoring Program which will be utilized during the license renewal period of extended operation to monitor Boral. As documented in the SER, DTE made commitments to enhance the Neutron-Absorbing Material Monitoring Program prior to September 20, 2024. These license renewal activities are pertinent to the GL response and are discussed in the responses to various items in Enclosures 1 and 2.

No new commitments are being made in this submittal.

Should you have any questions or require additional information, please contact Mr. Scott A. Maglio, Manager – Nuclear Licensing, at (734) 586-5076.

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

Executed on October 11, 2016

Keith J. Polson
Site Vice President

Enclosures: 1) DTE Response to GL 2016-01 for Boraflex Racks
2) DTE Response to GL 2016-01 for Boral Racks

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-16-0061

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

DTE Response to GL 2016-01 for Boraflex Racks

AREA OF REQUESTED INFORMATION – 1 (for Boraflex Racks)

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

DTE RESPONSE:
See the specific responses below.

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

   DTE RESPONSE:
   The neutron-absorbing material used in the Joseph Oat brand fuel storage racks is Boraflex. Boraflex was made by the Bisco Products, Inc. It was manufactured in the February to March 1981 time-frame. Installation into the Fermi 2 SFP was complete by June 1983 which is when the initial neutron attenuation test (aka Blackness Test) was performed.

b) *neutron-absorbing material specifications, such as:*

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

      DTE RESPONSE:
      Boraflex consists of a matrix of poly dimethyl siloxane (PDMS) or silicone rubber with boron carbide (B_4C) filler material. In addition to the boron carbide filler, the manufacturer of the polymer (Dow Corning) added finely divided crystalline silica as a reinforcer and extender. Boraflex batch production records show the content of the neutron-absorbing component of the boron carbide in the Boraflex as 76.9 weight percent total boron.

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

      DTE RESPONSE:
      - Minimum certified areal density (AD): 0.014 grams (g) of B-10 per square centimeter (cm^2)
      - As-built AD (calculated based on batch sample data sheets):
        - Minimum: 0.01512 g B-10 per cm^2
        - Maximum: 0.01793 g B-10 per cm^2
        - Nominal (average): 0.01648 g B-10 per cm^2

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

DTE RESPONSE:
Fermi 2 has no data or information on the porosity of Boraflex. The average density based on sample data was 1.6724 grams per cubic centimeter (g/cc). The Boraflex in the fuel storage cells has the following nominal dimensions: length of 152 inches, width of 5.91 inches, and thickness of 0.070 inches.

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

DTE RESPONSE:
The EPRI Neutron Absorber Handbook (2009 edition) reported on the qualification testing of Boraflex. Details are contained in Section 9.2.5 of the handbook.

d) *configuration in the SFP, such as:*

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

DTE RESPONSE:
The Joseph Oat fuel storage racks at Fermi 2 are constructed of individual elements known as “cruciforms,” “ells,” and “tees.” The cruciform element is made from four angular stainless steel sub-elements with the Boraflex tightly sandwiched between the sub-elements. The long edges of the cruciform are welded with a stainless steel spacer strip via a 2 inch to 4 inch stitch weld. The bottom of the cruciform has 4-¼ inch high stainless steel spacer strips which ensure against slippage of the Boraflex in the downward direction. The top of the cruciform is also end welded using a spacer strip. The “ell” and “tee” elements are constructed similarly using angular sub-elements and flat sub-elements. These elements are welded together to form the rack.

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

DTE RESPONSE:
There is limited contact of the water with the Boraflex due to the Boraflex being positioned between the stainless steel sub-elements and spacer strips. There is water present inside the racks but the Boraflex is not directly exposed to flowing water. Venting is available through the openings where each element is welded to the other elements (i.e., another cruciform, ell, or tee).

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

i) *estimated current minimum areal density;*

DTE RESPONSE:
The estimated current minimum AD from the 2013 BADGER test is 0.0150 g B-10 per cm^2.

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

DTE RESPONSE:
The NCS AOR assumes a nominal AD of 0.01648 g B-10 per cm^2. To simulate a reduction in the B-10 volumetric density, the AD was reduced to 0.015656 g B-10 per cm^2. This is treated as an uncertainty in the analysis.

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

DTE RESPONSE:
An in-situ neutron attenuation ("Blackness") Test was performed in 1992. This test was performed to investigate gapping in the Boraflex racks. Two types of testing were performed. The first type of testing was the standard fast scan of the entire cell length to locate any defects in the Boraflex. The second type of test was a slow scan (stop and count method) at any identified gap locations to determine their location and size.

Approximately 305 cells (1220 panels) were tested via the fast scan method. Four hundred nineteen (419) of these panels were found to have 1 gap or more. Seventy (70) panels were selected for slow scan testing. Of the 70 panels tested, 66 panels were found to have 1 gap and 4 panels were found to have 2 gaps. Eleven (11) panels were found to have a cumulative gap size of between 0 and 1 inch. Forty-seven (47) panels were found to have a cumulative gap size of between 1 and 2 inches. Twelve (12) panels were found to have a cumulative gap size of between 2 and 3 inches. The largest single gap size was 2.65 inches.

An in-situ neutron attenuation ("BADGER") test was performed in October 2013. In this test, 60 panels were measured. The results were provided to the NRC via Enclosure 2 to DTE letter NRC-15-0008 (NRC Accession Number ML15026A624).

AREA OF REQUESTED INFORMATION – 2 (for Boraflex Racks)

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

<u>DTE RESPONSE:</u>
The Fermi 2 Boraflex Monitoring Program consists of:

- Coupon Testing Program
    - Long-Term Tree
    - Accelerated Coupon Tree
- Trending of SFP silica levels
- Review of test data (Blackness or BADGER) from plants with similar rack designs
- Use of RACKLIFE computer code to calculate gamma dose absorbed by the racks and make a prediction of the amount of boron carbide loss
- BADGER testing (as necessary)

A 3-tiered approach is used, with the first four bulleted items listed above as being Tier 1. If the results indicate that the Boraflex degradation is accelerating, then Tier 2 would be utilized, which is BADGER testing (the fifth bulleted item in the list above). Depending on the results of the BADGER Test, Tier 3 may be entered. Tier 3 would either be re-analysis or not crediting Boraflex any longer; either by total re-rack, or by installing inserts (such as the NETCO Snap-In™). This program is required by Fermi 2 Technical Specification 5.5.13. The monitoring program originally consisted solely of the coupon program. The other items were added after Generic Letter 96-04 was issued. The DTE response to Generic Letter 96-04 was provided in DTE letter NRC-96-0120 dated October 23, 1996. This program was developed based on EPRI Guidelines. Note that this program will no longer be needed during the license renewal period of extended operation (PEO) due to the license condition in the NRC Safety Evaluation Report (SER) (NRC Accession Number ML16190A011) to not rely on Boraflex to perform a neutron-absorption function during the PEO.

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

   <u>DTE RESPONSE:</u>
   Since the Boraflex is encased within the rack wall, a direct physical examination is precluded. A coupon program allows access to representative samples without disrupting the integrity of the rack. The design intent from the In-Use Surveillance Program provided by the Joseph Oat Corporation was that the coupon program should include not only the capability to evaluate the material in a normal use mode, but to forecast changes before they occur. The coupons should be representative of the poison material in the rack and encapsulated in a similar manner.

The Fermi 2 Long-Term Tree is re-surrounded every 13 years with 8 freshly discharged fuel bundles that have received exposures that are approximately equivalent to the average bundle exposure during the final third of the operating cycle. This will yield information on the performance of the Boraflex under normal conditions.

The Fermi 2 Accelerated Coupon Tree is re-surrounded each outage with 8 freshly discharged fuel bundles that are among those that have received the highest exposure during the final third of the last operating cycle. This will yield information on the performance of the Boraflex on an accelerated basis to forecast changes before they occur.

The Fermi 2 coupons are representative of Boraflex that is encased in the rack.

Trending of SFP silica level was added after Generic Letter 96-04 was issued to augment the existing coupon surveillance program. SFP silica data are obtained and evaluated at least once per quarter. The evaluation is a qualitative assessment only, and no specific actions need to be taken based solely on concentration or rate of increase. Monitoring of silica level is used to identify early signs of increasing Boraflex degradation.

The review of test data (Blackness or BADGER) from plants with similar rack designs was added after Generic Letter 96-04 was issued to augment the existing coupon surveillance program. Since there were no plans at that time to perform periodic in-situ neutron attenuation testing, it was decided to review the test results of other plants with a similar rack design. Once per cycle, a review is made to see which plants that have racks that are similar to those at Fermi 2 have performed a Blackness or BADGER test. The test reports are requested from the particular utility and reviewed. This review is documented. Although in-situ testing is now being performed at Fermi 2, this review of test data from other plants has been retained in the program.

The use of the RACKLIFE code to calculate gamma dose to the Boraflex panels and predict boron carbide loss was added after Generic Letter 96-04 was issued to augment the existing coupon surveillance program. RACKLIFE is used as a tool to manage gamma exposure to the Boraflex rack panels. It is also used in combination with BADGER test results to predict when Boraflex panels will have degraded below the B-10 areal density limits in the AOR. This is performed once per cycle.

There are limitations to the coupon program. These limitations are discussed below.

The Boraflex used in the Fermi 2 racks came from 46 production batches. The total weight of the Boraflex is estimated to be in units of tons. Each test coupon is 2 inches by 4 inches and weighs approximately 15 grams.

There is no evidence that the coupons were pre-characterized at the factory before being shipped to Fermi 2. An estimate has to be made of the initial length and width using methods

outlined in EPRI Report NP-6159 "An Assessment of Boraflex Performance in Spent-Nuclear-Fuel Storage Racks" (December 1988).

The Boraflex in the fuel storage racks develops gaps. This was first reported in NRC Information Notice 87-43 and is well established in industry and NRC literature. When the racks were made, the Boraflex was un-rolled and glued into place. There were pre-existing stresses that resulted from the bend radii of the rolls of Boraflex which, when glued in place, were not allowed to relax. In addition, gamma radiation causes shrinkage due to the scissioning and cross-linking of the chemical bonds in the silicon-rubber matrix. Boraflex coupons do not develop gaps because they are not restrained in place. Hence, the coupons do not provide any information on the gaps that develop in the racks.

The NRC has stated in NUREG-1801 Revision 2, Section XI.M22 (Boraflex Monitoring), "The experience with Boraflex panels indicates that coupon surveillance programs are not reliable."

The BADGER test will detect and measure gap size.

As part of the NRC SER on license renewal, Fermi 2 has a license condition to no longer credit Boraflex for neutron absorption prior to the license renewal PEO, which begins in March 2025.

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

DTE RESPONSE:
A sample size of 2 coupons from each of the 2 surveillance trees has been established with testing performed at a frequency of every 2 to 4 refuel outages. The periodicity was chosen such that there would be enough coupons to last through the end of the current operating license (2025) and through the end of one license renewal period (2045). This assumes coupons are returned to the surveillance tree after testing and made available for subsequent testing. This frequency was established prior to the establishment of the license condition pertaining to Boraflex during the NRC review of the License Renewal Application (LRA).

ii) *parameters to be inspected and data collected;*

DTE RESPONSE:
The parameters to be inspected are dimensional stability (length, width, and thickness measurements), dry weight, density, and B-10 areal density measurements. A visual inspection is also performed.

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

<u>DTE RESPONSE:</u>
The acceptance criteria are related to length, width, thickness, and B-10 areal density. Specifically, "The total change in length and width of the Boraflex coupon shall not be more than 10.0%."

The criterion of 10% width reduction is related to the 10% uncertainty in the NCS AOR associated with width reduction from shrinkage and dissolution of the silica inside the silicon-rubber matrix of Boraflex. The Boraflex shrinkage is assumed to be isotropic so it was applied to the coupon length, as well.

The acceptance criteria for thickness and B-10 areal density are related as follows:

The B-10 areal density of the Boraflex coupon shall be greater than or equal to:

- 0.015656 g B-10 per cm^2 if the measured thickness is greater than or equal to 0.0690 inches
- 0.01648 g B-10 per cm^2 if the measured thickness is less than 0.0690 inches but greater than 0.0621 inches

Discussion of how these acceptance criteria are consistent with the NCS AOR is provided in the response to item 4.b.

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

<u>DTE RESPONSE:</u>
Coupon monitoring results are reviewed by the qualified engineer that is responsible for the program. Any degradation noted would be resolved through the Corrective Action Program (CAP).

As discussed above, trending of SFP silica level was added after Generic Letter 96-04 was issued to augment the existing coupon surveillance program. SFP silica data are obtained and evaluated at least once per quarter.

v) industry standards used.

<u>DTE RESPONSE:</u>
The following ASTM Standards were cited in the coupon test procedure:

- C-1187, Standard Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks
- D297, Standard Test Methods for Rubber Products - Chemical Analysis
- D1349, Standard Practice for Rubber - Standard Conditions for Testing
- D3767-03, Standard Practice for Rubber - Measurement of Dimensions

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

i) *If there is visual inspection of inservice material:*

DTE RESPONSE:
Fermi 2 does not perform a visual inspection of inservice material in the Boraflex racks. Therefore, no specific responses are provided for items 2.b.i.1 and 2.b.i.2 below.

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

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

ii) *If there is a coupon-monitoring program:*

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

DTE RESPONSE:
The Boraflex coupons are representative of the material in the racks. Their nominal thickness (0.070 inches) matches that shown on rack design drawings. The pre-irradiation density is consistent with the densities measured on the batch samples. Coupons 9A, 9B, and 9C were removed from the SFP and tested prior to irradiation. Their densities were 1.669 g/cc, 1.6678 g/cc, and 1.6645 g/cc, respectively, which is consistent with the range of densities of the batch samples of 1.6495 g/cc to 1.709 g/cc with an overall average of 1.6724 g/cc.

The coupons are contained in stainless steel capsules in a picture-frame arrangement. This is consistent with how the Boraflex is contained within the rack. The original design of the coupons was that they were glued in the capsule and the capsule closed via tack welds. As discussed above, there was no evidence that the coupons had been pre-characterized by the manufacturer before shipment to Fermi 2. After approximately one cycle of irradiation, the coupons were removed from the pool and sent to Pennsylvania State University to be characterized. The glue used during their manufacture had broken down from the irradiation. New capsules were manufactured with a similar picture-frame design. The new capsules utilize capture tabs rather than the original tack welds. Neither the racks nor the coupon capsules are sealed. There is water present inside both, but due to the picture-frame arrangement, the Boraflex is not directly exposed to flowing water. The coupons are flat and nominally 2 inches by 4 inches. They are free within the capsule. There are no bends or shapes. As such, there are no stress-relaxation concerns. There are no galvanic considerations since the Boraflex is a silicon-rubber polymer.

As far as material radiation levels, there is not a way to quantitatively compare the radiation exposure received by the rack to that of the coupon. RACKLIFE can perform a calculation of the gamma dose received by each Boraflex panel but cannot for the coupons. The Accelerated Tree is moved every refuel outage so as to not burn out the Boraflex panels surrounding the tree by constantly re-surrounding the tree with freshly discharged fuel. The coupon program is representative from a radiation exposure perspective. The Accelerated Tree is re-surrounded by 8 freshly discharged fuel bundles whose exposure is among the highest received in the last third of the operating cycle. The racks contain primarily older fuel with a long cooling time. The strategy at Fermi 2 has been to primarily load freshly discharged fuel into the Boral racks (see Enclosure 2 to this letter for response to GL 2016-01 pertaining to the Boral racks) and then relocate it to the Boraflex racks after it has cooled for at least one cycle. From a radiation level perspective, the Accelerated Tree would bound the exposure received by the Boraflex racks whereas the Long Term Tree would be more representative of the manner in which the racks are managed.

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

<u>DTE RESPONSE:</u>
A review of plant records was performed. It is unclear exactly when the Boraflex coupon trees were installed into the SFP. They were most likely installed between 1983 and 1989. The coupons were released for shipment to Fermi 2 from Joseph Oat in 1983 and were in place before the first refuel outage in the fall of 1989.

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

<u>DTE RESPONSE:</u>
The Boraflex coupons are returned to the SFP after testing. This process began in 2003. The reason for re-installing the coupons was to ensure that sufficient coupons would be available through the end of the current operating license (2025) and through the license renewal PEO (2045). The reinserted coupons remain representative of the materials in the rack. When they are removed from the rack for testing at Pennsylvania State University, they are tested and stored under a Q contract with the vendor. When testing is complete and the coupons returned to Fermi 2, they are stored in a secure location until they are re-installed. While they may have been removed from the pool for the duration of one operating cycle, they are still considered to be representative because of the strategy of loading freshly discharged fuel around the Accelerated Tree and preferentially loading cold fuel into the other Boraflex rack cells.

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

Fermi 2 has 4 coupons remaining on the Accelerated Tree that have not been tested yet (in addition to the 1 coupon not currently scheduled to be tested) and 10 that were previously tested but returned to the tree. There are 10 coupons remaining on the Long Term Tree that have not been tested yet and 4 that were previously tested but returned to the tree. Utilizing the policy of re-inserting coupons after testing, this would have ensured there were sufficient coupons available until the end of the current operating license (2025) and through the license renewal PEO (2045). Note that the NRC SER for license renewal now has a license condition for Fermi 2 to not credit Boraflex in the PEO. Also, Fermi 2 has another BADGER test planned for 2018.

The schedule for coupon removal and testing is provided in the table below.

Accelerated Tree		Long Term Tree	
Prior to Refuel Outage	Coupon to be Removed and Tested	Prior to Refuel Outage	Coupon to be Removed and Tested
18	15B, 15C	18	5C, 6A
20	16A, 16B	20	6B, 6C
23	12A*, 12B*	23	7A, 7B
26	12C*, 13A*	26	7C, 8A
30	13B*, 13C*	30	8B, 8C
34	14A*, 14B*	34	3C*, 4A*
38	14C*, 15A*	38	4B*, 4C*

*Coupons previously tested and returned to the tree for subsequent testing.

Fermi 2 is maintaining one coupon on the Accelerated Tree (16C) that is not scheduled for testing. This is to ensure that there was always one coupon that could be tested, if necessary, if all other coupons became damaged during testing.

iii) *If RACKLIFE is used:*

(1) *note the version of RACKLIFE being used (e.g., 1.10, 2.1);*

<u>DTE RESPONSE:</u>
Fermi 2 is running RACKLIFE version 2.01.

(2) *note the frequency at which the RACKLIFE code is run;*

<u>DTE RESPONSE:</u>
Fermi 2 is running RACKLIFE once per cycle.

(3) *describe the confirmatory testing (e.g., in-situ testing) being performed and how the results confirm that RACKLIFE is conservative or representative with respect to neutron attenuation; and*

DTE RESPONSE:
Fermi 2 has been running RACKLIFE since RACKLIFE was issued by EPRI. RACKLIFE is a tool that is used in the rack management process to aid in determining where irradiated fuel is to be placed in the Boraflex racks to minimize degradation. Fermi 2 performed its first BADGER test in October 2013. The results of the BADGER test (B-10 areal density measurements for 60 panels) are correlated with the RACKLIFE percent boron carbide loss predictions to establish a relationship between RACKLIFE and BADGER for those 60 panels. This cannot be extended beyond the 60 panel BADGER population because initial areal density data could not be located from Joseph Oat Corporation. Hence, it cannot be determined if RACKLIFE is conservative or representative with only one data point at this time. Fermi 2 is planning to perform another BADGER test in 2018. It is planned for a sample size of 60 panels not previously tested plus a number of panels that had been previously tested in 2013. The number of panels to be re-tested from the 2013 BADGER test has not been determined yet. Once those data from the re-tested panels are made available from the 2018 BADGER test, then the correlation between RACKLIFE and BADGER can be evaluated and adjusted as necessary.

(4) *provide the current minimum RACKLIFE predicted areal density of the neutron-absorbing material in the SFP. Discuss how this areal density is calculated in RACKLIFE. Include in the discussion whether the areal densities calculated in RACKLIFE are based on the actual as-manufactured areal density of each panel, the nominal areal density of all of the panels, the minimum certified areal density, the minimum as-manufactured areal density, or the areal density credited by the NCS AOR. Also discuss the use of the escape coefficient and the total silica rate of Boraflex degradation in the SFP.*

DTE RESPONSE:
RACKLIFE does not predict areal density. It predicts percent loss of boron carbide. A prediction of boron carbide loss, without a starting point to predict loss from, is not meaningful, other than as a qualitative tool for where to load irradiated fuel during the refuel outage. RACKLIFE calculates percent boron carbide loss via a mass balance based on silica transport. The peak panel boron carbide loss as of 5/30/15 (last RACKLIFE run) was 3.85%. The average boron carbide loss from irradiated panels was 3.40%. Average boron carbide loss from all panels was 3.40%.

The percent boron carbide loss prediction in RACKLIFE is based on the Boraflex thickness and corresponding mass density that were used to calculate the minimum areal density from the Bisco data sheets. These changes were made as a result of NRC Information Notice 2012-13.

An output from RACKLIFE is the SFP silica concentration over time. The escape coefficient used in the RACKLIFE calculations is selected by matching the measured silica concentration line with the calculated silica line. Adjusting the escape coefficient raises or lowers the calculated silica line. This is an iterative process until the two lines are in relative agreement. The escape coefficient can vary from cycle to cycle. Generally, the escape coefficient will increase with panel degradation.

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

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

DTE RESPONSE:
BADGER testing panels are typically chosen based on several considerations. First and foremost is the testing of panels that have experienced the most severe service histories in the spent fuel pool. This is typically done using the RACKLIFE model. These panels are chosen based on the panel estimated absorbed dose and predicted boron carbide loss as calculated by RACKLIFE. For typical BADGER tests, a minimum of 59 panels is typically chosen (with additional panels selected as alternates or supplemental panels) and the panels divided up into severe, moderate and low loss categories.

Given that many pools are relatively full and a large buffer zone is needed for the BADGER test to avoid gamma interference, consideration must also be given to minimize the number of fuel assembly moves needed to vacate a testing area in the spent fuel racks.

In order to attain a 95% degree of confidence that 95% of a population lies above the smallest observed value, a sample size of 59 is required. This "95/95" criterion is a commonly accepted statistical practice and referenced in NRC publications including NUREG/CR-6698 "Guide for Validation of Nuclear Criticality Safety Calculational Methodology." Other places where the NRC has accepted the 95/95 criterion are:

- Regulatory Guide 1.105, Rev. 3 (December 1999, Regulatory Position C.1)
- NRC presentation, "NRC Staff Interpretation of 95/95 Tolerance Limits in Safety System Setpoint Analysis," dated 9/28/10 at NRC Headquarters in Rockville, MD, slide 8

Since 59 samples was the criterion to meet the 95/95 criterion, a round number of 60 samples are typically chosen. This is statistically significant enough that the result can be extrapolated to the state of the entire pool. The sample size of 60 panels has

also become common in the industry. This is also listed as one of the options available for determining an adequate number of panels to be tested in NEI 16-03, Rev. 0 (dated August 2016), Section 2.2, which was provided to the NRC for its review and endorsement.

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

DTE RESPONSE:
Fermi 2 has only performed one BADGER test (October 2013). Hence, there are not enough data points to trend. Fermi 2's next BADGER test is planned for 2018. It is intended to re-test some of the panels that were previously tested in 2013. The number of panels to be re-tested has not been determined yet.

(3) *describe the sources of uncertainties when using the in-situ testing device and how they are incorporated in the testing results. Include the uncertainties outlined in the technical letter report titled "Initial Assessment of Uncertainties Associated with BADGER Methodology," September 30, 2012 (Agencywide Document Access and Management System Accession No. ML12254A064). Discuss the effect of rack cell deformation and detector or head misalignment, such as tilt, twist, offset, or other misalignments of the heads and how they are managed and accounted for in the analysis; and*

DTE RESPONSE:
The uncertainty is in the repeatability of a single measurement, in that if the BADGER probes run in and out of the same cell in a series of repeat measurements of the same panel, there will be variation from one measurement to the next. This is a result of the variation in the heads being aligned, neutron scattering, and variations in the neutron spectrum as a result of using a neutron source with a continuous energy distribution. The statistical uncertainty is determined from natural counting uncertainty that is propagated over all data handling equations.

The uncertainty values used in the BADGER report are the calculational uncertainties in the areal density measurement at each elevation-specific areal density. The uncertainty for the overall panel is determined conservatively by choosing the highest elevation-specific uncertainty over the entire panel length. These uncertainty values were reported at the level of two standard deviations (2σ).

In the BADGER report, the minimum areal density that was reported represented the 95/95 minimum areal density value. The 95/95 minimum areal density value is the minimum value calculated per the NUREG/CR-6698 guidance. It was assumed that the data were not normally distributed and that there were at least 59 samples along the panel. Per NUREG/CR-6698, if the data are not normally distributed and there are at least 59 samples, then when the data (areal density values) are ranked, the lowest value becomes the one-sided 95/95 minimum value. There were 9 panels for

which there were fewer than 59 intact elevation-specific areal density values. This was due to the presence of gaps. In these cases, the minimum areal density value was conservatively calculated by taking the three standard deviations (3σ) measurement uncertainty and subtracting it from the average areal density.

It is difficult to make a comparison of the BADGER calculated uncertainty to those outlined in the NRC's technical letter report (TLR) titled "Initial Assessment of Uncertainties Associated with BADGER Methodology," September 30, 2012. The report makes the following statements: "In the course of conducting the uncertainty assessment, it was found that no information was available regarding specific performance testing of the device to identify and evaluate sources of error." It goes on to say, "Because of limitations and constraints affiliated with obtaining test reports, procurement specifications, technical specifications, and operating procedures (including those for quality control), uncertainties of individual components cannot be quantified nor combined in any scientifically defensible manner, with the information available to the authors. As such, no justification can be made for an estimate of total measurement uncertainty for the BADGER system."

Table 6-1 in the NRC TLR is a Summary Table of Measurement System Sources of Uncertainty. A majority (35 out of 43) of the items in the "Uncertainty Range" column had the value of "INQ" which "indicates that insufficient data was available for review to support quantifying an uncertainty range for a given parameter."

DTE comments regarding some of the items in Table 6-1 that didn't have the INQ value are as follows:

Item 5.1.1 Count Rate - Section 5.1.1 of the TLR states "No experimental data was provided to estimate the impact of 'net neutron count rate from direct neutron absorption' on implementation of BADGER." Table 6-1 states "These effects require additional evaluation." This item would need to be evaluated by the BADGER vendor and cannot be answered by the licensee.

Item 5.3.2 Gamma Interference - This section discusses excessive gamma interference due to close proximity to other spent fuel bundles, with the failure to properly discriminate creating uncertainty and potentially damaging the detectors. In Section 5.3, the author acknowledged that the number of cleared cells proximate to the detectors was unknown, and can vary from one BADGER campaign to another. Interference from both neutron and gamma can be introduced. In order to measure the amount of background gammas (and neutrons) it would be require a "dry run" of the entire system without the californium (Cf) source in the heads to determine if there is any background gamma or background neutron flux being detected. If any was detected, a larger number of fuel bundles would need to be relocated away from the test cells. This is not in the current test methodology. Fermi 2 cleared a 3-row boundary away from the test panels. There were no issues with detectors becoming inoperable or other issues noted during the test regarding gamma interference.

Item 5.5.1 Apparatus Geometry - "Head Misalignment" - This section discusses incidents where it has been reported that the BADGER sticks or jams in some warped panels. There were no reported incidents in the Fermi 2 BADGER test of the BADGER head sticking. The main reason that there was no sticking of the BADGER heads is that the Joseph Oat Rack design at Fermi 2 does not utilize wrapper plates and has thicker gage stainless steel for both walls. The biggest interference would come from excessive weld slag in the corners of the storage cell. Chamfers on the heads prevent this.

Item 5.6.4 Calibration - "Relevance of standard panel material to rack panel material, e.g., using a Boraflex calibration assembly to measure Carborundum or Boral" - Fermi 2's calibration cell contained Boraflex standards that were used for calibrating the BADGER system for use on Boraflex racks. The Boral in the calibration cell was used strictly for shielding.

Item 5.6.8 Calibration - "Uncertainties in the calibration slope, especially as it applies to flux-trap racks" - This item is primarily focused on flux-trap type racks which Fermi 2 does not have.

Item 5.7.1 Data processing - "Reliance on operator experience to detect and characterize heterogeneous degradation" - This item focuses on recognizing degradation features of neutron absorbers other than Boraflex. This isn't applicable since the Fermi 2 BADGER test was on the Boraflex racks. Also, this was more of an issue with the older BADGER system, which required operator characterization of the panel regions of lower count rate. Much of this reliance on operator experience is gone with the new system, as much of the "heterogeneous" degradation was actually a result of neutron backscatter from neutrons thermalized in water behind the detectors. This has been reduced by filling the region behind the detectors with boron carbide power.

The NRC TLR was issued in 2012 and evaluated the older BADGER equipment. The new and improved BADGER equipment utilizes spring loaded plungers in the heads to better position the heads in the cell. The newer BADGER equipment became available in 2013.

Regarding "the effect of rack cell deformation and detector or head misalignment, such as tilt, twist, offset, or other misalignments of the heads and how they are managed and accounted for in the analysis,"- the BADGER heads were specifically manufactured for the Fermi 2 Boraflex racks based on rack drawings from the Joseph Oat Corporation. The calibration cell was built specifically for Fermi 2 based on the same Joseph Oat drawings. This was to minimize the likelihood of misalignments discussed in the TLR. The new and improved BADGER heads utilizing the spring-loaded plungers help to stabilize the heads in the rack cells to minimize misalignment. There were no incidents reported of the heads getting stuck or otherwise affected by

any potential rack cell deformation. Measurement uncertainty was calculated and reported on a per-cell basis.

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

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

DTE RESPONSE:
Calibration of the BADGER tool is performed at a minimum of 2 times per day during a test by performing a scan of the calibration standards (typically 3 known areal density loadings) and the un-attenuated region above the areal density standards.

The Boraflex standards used in the calibration cell consist of 3 Boraflex samples that are 8 inches long each and 1 full length (32 inches) Boraflex panel.

The materials in the calibration cell are subjected to a commercial grade dedication and are verified to conform to critical characteristics to meet the as-built rack drawings. Critical characteristics are defined and verified via measurement, neutron attenuation testing and/or chemical analysis.

BADGER infers the AD of the rack panels being tested based on fits from the known standards in the calibration cell.

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

DTE RESPONSE:
BADGER is a relational test. It uses neutron transmission (counts per second from the detectors) in the calculation for AD. Degradation or aging would most likely mean an increase of neutron transmission as more neutrons pass from the source, through the degraded material, and reach the detectors. The range of ADs of the Boraflex samples in the calibration cell encompasses the likely AD of the degraded Boraflex in the rack so that the calibration curve generated in the calibration cell would remain valid.

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

DTE RESPONSE:
Calibration did not include a measurement of an SFP "reference panel." Calibration was performed solely using the calibration cell. Therefore, no specific responses are provided for items 2.b.iv.4.c.i through 2.b.iv.4.c.iii below.

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

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

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

AREA OF REQUESTED INFORMATION – 3 (for Boraflex Racks)

For any Boraflex, Carborundum, or Tetrabor being credited, describe the technical basis for determining the interval of surveillance or monitoring for the credited neutron-absorbing material. Include a justification of why the material properties of the neutron-absorbing material will continue to be consistent with the assumptions in the SFP NCS AOR between surveillances or monitoring intervals.

<u>DTE RESPONSE:</u>
The schedule for testing Boraflex is as follows:

- Prior to refuel outage 18 (spring 2017): Test 4 Boraflex coupons
- 2018: Perform second BADGER test
- Prior to refuel outage 20 (spring 2020): Test 4 Boraflex coupons
- Fall 2024: No longer credit Boraflex for criticality control in accordance with the NRC SER license condition for license renewal.

The basis for the interval of the Boraflex coupon monitoring program was to ensure there were sufficient coupons to last to the end of the current operating license (2025) and through the license renewal PEO (2045). This was established prior to the NRC SER license condition for license renewal to not credit Boraflex in the PEO. The plan to perform BADGER testing every 5 years was based on the frequency stated in the Aging Management Program in NUREG-1801 Revision 2, Section XI.M22 (Boraflex Monitoring), which recommends measuring AD with a minimum frequency of once every 5 years.

The SFP NCS AOR assumed a nominal AD of 0.01648 g B-10 per cm^2 with a reduction taken to 0.015656 g B-10 per cm^2 as an uncertainty. None of the coupon test results indicated a coupon AD of 0.015656 g B-10 per cm^2 or lower. There were a few panels that tested below 0.015656 g B-10 per cm^2 in the 2013 BADGER test. Those cells have been restricted from being used. RACKLIFE will be used to track the panels tested in the BADGER test. When RACKLIFE predicts the AD for tested panels will decrease below 0.015656 g B-10 per cm^2, fuel will be removed from those cells and the panels restricted from use. The rate of degradation in the Boraflex racks is low. This is supported by the low boron carbide loss prediction by RACKLIFE, as discussed previously in the response to item 2.b.iii.

Since there were a few panels that did test below 0.015656 g B-10 per cm^2, it is not unreasonable to believe that there are more panels that were not tested that are also below 0.015656 g B-10 per cm^2. When BADGER testing identifies those specific panels, the fuel contained in those cells will likewise be removed and the cells restricted from use.

Fermi 2 had a sensitivity study performed of AD versus fuel bundle reactivity. The result was that considering the highest fuel bundle reactivity that Fermi 2 has ever had, that an AD as low as 0.0120 g B-10 per cm^2 could be managed without exceeding a rack k-effective of 0.945. There were no panels in the 2013 BADGER test that challenged 0.0120 g B-10 per cm^2 and an administrative limit was placed on maximum bundle reactivities in Fermi 2 procedures. While

this sensitivity study is not the SFP NCS AOR, it was performed by the fuel vendor who had previously performed the Fermi 2 NCS AOR. Fuel bundles will be removed from their SFP cells when either BADGER or RACKLIFE indicate the AD of 0.015656 g B-10 per cm^2 will be challenged.

It cannot be said with 100% certainty that the material properties of the Boraflex will continue to be consistent with the assumptions in the SFP NCS AOR between surveillances or monitoring intervals. It can be said, however, with a high degree of confidence that the material properties of the Boraflex will be greater than that assumed in the sensitivity study between surveillance or monitoring periods until the time when Fermi 2 will no longer credit Boraflex in order to meet the NRC SER license condition for license renewal. This conclusion is based on the results of the BADGER and coupon tests. The sensitivity study described above was examined by NRC staff during the Fermi 2 license renewal process.

AREA OF REQUESTED INFORMATION – 4 (for Boraflex Racks)

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

<u>DTE RESPONSE:</u>
See the specific responses below.

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

   <u>DTE RESPONSE:</u>
   The base Monte Carlo model used to simulate the Boraflex spent fuel storage rack utilizes a single two-dimensional lattice description contained in an associated storage cell. Reflective boundary conditions are imposed in the X-Y plane on the four peripheral surfaces of the model. Axially reflective boundary conditions are imposed in the Z plane, conservatively simulating an axially infinite pool geometry. For the gap analysis, a special Monte Carlo model was developed to represent a three-dimensional lattice. This model represented a 5x5 array of fuel storage positions infinitely reflected in the X-Y plane but having a 1-foot water reflector region above and below the fuel storage rack in the axial (Z) direction.

   A reduction in B-10 volumetric density is modeled as an uncertainty in the analysis. The overall average of calculated B-10 areal densities was determined from the Bisco data sheets. This was 0.01648 g B-10 per cm^2. This was the nominal B-10 AD for the analysis. This nominal value was reduced by 5% to 0.015656 g B-10 per cm^2. The NCS AOR reported that this was consistent with typical areal density tolerance specifications of 92% to 95% of nominal and should bound any Boraflex dissolution and thinning.

   A reduction in Boraflex thickness was modeled as an uncertainty in the analysis. The nominal thickness of 0.070 inches that was specified by the manufacturer was reduced to 0.0690 inches. This value is the 99% lower-confidence interval value for the panel thickness based on the Bisco samples and is used as the nominal thickness for the analysis. This nominal thickness of 0.0690 inches was reduced by an additional 10% to 0.0621 inches for the uncertainty analysis. This is consistent with the Joseph Oat drawings which report a 10% tolerance on the nominal panel thickness of 0.070 inches.

   A reduction in Boraflex width was modeled as an uncertainty in the analysis. The nominal value for Boraflex width is 5.75 inches. A reduction to 5.50 inches was assumed for this uncertainty. This is 95.6% of the nominal value. The analysis states that typical minimum

specifications for Boraflex panels are in the range of 96% to 98% of the nominal manufactured specification.

The uncertainty associated with Boraflex width as a result of Boraflex degradation (shrinkage and dissolution) was modeled as a bias. A 10% reduction from the 5.5 inches discussed above yields an effective Boraflex panel width of 4.95 inches for 100% of the panels.

Gap sizes ranging from 11 inches to 12 inches were considered for gaps assumed in 100% of the panels. The model consisted of a 5x5 reflected array of storage positions with a total of 60 unique Boraflex panels. Two separate probability distribution functions (pdf) were created. The first pdf randomly sampled gap sizes from 11 inches to 12 inches for all 60 panels. The second pdf then randomly placed these gaps along the axial length of each panel from 12 inches to 156 inches. This representation is assumed to bound the condition of panels having multiple smaller gaps provided the total (cumulative) gap size does not exceed 11 inches.

Boraflex does not develop blisters. Localized effects, such as non-uniform degradation, are not modeled in the NCS AOR.

b) *Describe how the results of the monitoring or surveillance program are used to ensure that the actual condition of the neutron-absorbing material is bounded by the SFP NCS AOR. If a coupon monitoring program is used, provide a description and technical basis for the coupon tests and acceptance criteria used to ensure the material properties of the neutron-absorbing material are maintained within the assumptions of the NCS AOR. Include a discussion on the measured dimensional changes, visual inspection, observed surface corrosion, observed degradation or deformation of the material (e.g., blistering, bulging, pitting, or warping), and neutron-attenuation measurements of the coupons.*

<u>DTE RESPONSE:</u>
As discussed previously in the response for item 2.a, the parameters to be inspected in the coupon test are dimensional stability (length, width, and thickness measurements), dry weight, density, and B-10 areal density measurements, with a visual inspection also performed.

The acceptance criteria are related to length, width, thickness, and B-10 areal density. Specifically, "The total change in length and width of the Boraflex coupon shall not be more than 10.0%."

The criterion of 10% width reduction is related to the 10% uncertainty in the NCS AOR associated with width reduction from shrinkage and dissolution of the silica inside the silicon-rubber matrix of Boraflex. The Boraflex shrinkage is assumed to be isotropic so it was applied to the coupon length, as well.

The acceptance criteria for thickness and B-10 areal density are related as follows:

The B-10 areal density of the Boraflex coupon shall be greater than or equal to:

- 0.015656 g B-10 per cm^2 if the measured thickness is greater than or equal to 0.0690 inches
- 0.01648 g B-10 per cm^2 if the measured thickness is less than 0.0690 inches but greater than 0.0621 inches

The NCS AOR assumed a nominal thickness of 0.0690 inches and a nominal AD of 0.01648 g B-10 per cm^2. The uncertainty in the AD density (0.015656 g B-10 per cm^2) was performed at a thickness of 0.0690 inches. The uncertainty in thickness (0.0621 inches) was performed at an AD of 0.01648 g B-10 per cm^2. Hence, acceptance criteria are modeled after the NCS AOR.

The visual inspection and parameters of dry weight and density are not acceptance criteria but are measured for supporting information.

The above-stated acceptance criteria have been met for all coupon tests performed to date. The largest individual change in coupon length/width was 5.7%. The lowest individual thickness measured was 0.0674 inches (areal density was 0.0173 g B-10 per cm^2). The results of the visual inspection have all been good. Some warping was noted on the coupons removed prior to refueling outage 16 (tested on 10/16/14) but, as stated, all the acceptance criteria were satisfied. The minimum AD noted was 0.0172 g B-10 per cm^2 which is well above the acceptance criterion of 0.01648 g B-10 per cm^2. (This minimum AD was determined by subtracting 3σ measurement uncertainty from the measured AD.)

The results of the 2013 BADGER test were provided to the NRC via Enclosure 2 to DTE letter NRC-15-0008 (NRC Accession Number ML15026A624).

Boraflex does not develop blisters, bulges, or pits.

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

<u>DTE RESPONSE:</u>
Bias and uncertainty of the monitoring program are not used in the SFP NCS AOR.

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

<u>DTE RESPONSE:</u>
Biases and uncertainties are taken in the analysis to account for degradation. All panels are treated the same with the exception that gaps are assumed to be randomly distributed.

AREA OF REQUESTED INFORMATION – 5 (for Boraflex Racks)

For any Boraflex, Carborundum, or Tetrabor being credited, describe the technical basis for concluding that the safety function for the credited neutron-absorbing material in the SFP will be maintained during design-basis events (e.g., seismic events, loss of SFP cooling, fuel assembly drop accidents, and any other plant-specific design-basis events that may affect the neutron-absorbing material).

DTE RESPONSE:
See the specific responses below.

a) *For each design-basis event that would have an effect on the neutron-absorbing material, describe the technical basis for determining the effects of the design-basis event on the material condition of the neutron-absorbing material during the design-basis event, including:*

   i) *shifting or settling relative to the active fuel;*

   DTE RESPONSE:
   See the response to item 5.a.iii below.

   ii) *increased dissolution or corrosion; and*

   DTE RESPONSE:
   See the response to item 5.a.iii below.

   iii) *changes of state or loss of material properties that hinder the neutron-absorbing material's ability to perform its safety function.*

   DTE RESPONSE:
   The Joseph Oat design Boraflex racks at Fermi 2 are a "picture-frame" type design. There are end strips at the top and bottom of each panel that prevent the Boraflex panel from shifting. In addition, the Boraflex panels are 152 inches long. These panels overlap the 150 inch-long active fuel length by 1 inch at the top and bottom, respectively.

   EPRI has performed an evaluation of irradiated Boraflex under seismic conditions. The objectives of this evaluation were to 1) measure the flexural strength and Young's Modulus of irradiated Boraflex over a range of gamma exposures, and 2) to compare the peak stresses transferred to the Boraflex during the postulated safe-shutdown earthquake with experimentally determined flexural strength. The result was that the computed Boraflex stresses were substantially below the threshold stress for fracture. For the rack with the highest Boraflex stresses the margin to the threshold stress for cracking was approximately 35%. The Fermi 2 Joseph Oat rack design and Fermi 2 seismic data were used in the evaluation.

In addition to the EPRI evaluation, Holtec performed an analysis of irradiated Boraflex integrity under seismic loading specifically for the Fermi 2 racks. The results were that no yielding of the stainless steel would occur, and the maximum stress in the Boraflex was well below the value required to initiate material cracking.

Hence, Fermi 2 has 2 independent analyses using Fermi 2 data that conclude that the safety function of the Boraflex will be maintained during a seismic event.

There were no specific analyses located in the plant records that specifically analyzed the effects on the Boraflex for a total loss of SFP cooling. However, in this event, the SFP water would heat up at a rate dependent on the decay heat load of the fuel in the pool. It is well-established that the solubility of a silica/siloxane network in water is directly related to temperature. In EPRI Report TR-107333 "The Boraflex Rack Life Extension Computer Code - RACKLIFE Theory and Numerics," dated September 1997, Figure 3-5 shows reactive silica equilibrium concentration directly related to temperature. In the NRC's technical letter titled "Boraflex, RACKLIFE, and BADGER - Description and Uncertainties," it is suggested that solubility increases almost linearly as temperature increases. In the NCS AOR a temperature of 20°C was assumed for the base analysis. A bulk pool water temperature increase above 20°C would result in a lower effective water density which would make the system more subcritical. If the condition of the Boraflex in the SFP is bounded by the assumptions in the NCS AOR, then an increase in SFP temperature due to a loss of SFP cooling would have a negative reactivity effect. It is not expected that a loss of SFP cooling would be of a duration significant enough to affect dissolution to the point that the NCS AOR would become non-conservative. (The GL 2016-01 request did not specify the time duration for the loss of SFP cooling event.) A more rigorous evaluation would require new analyses which GL 2016-01 specifically stated were not required.

There were no specific analyses located in the plant records that specifically analyzed the effects on the Boraflex of fuel assembly drop. However, the Joseph Oat (Boraflex) racks are designed to withstand a 600 lb fuel assembly dropped on the rack with an impact energy of 2000 ft-lbs dropped from a height of 40 inches. The Joseph Oat TM-588 Report makes a calculation of a stress of 26,070 psi which is below the yield stress of stainless steel, which the report implies is 30,000 psi. The conclusion is that there would not be any deformation of the rack.

The Joseph Oat racks are of the cruciform, ell, and tee design. The Boraflex is encased between angular sub-elements with a 4.25 inch end strip at the bottom and a 0.5 inch end strip at the top. There are 18.75 inches between the top of the Boraflex and the top of the rack cell. Any impact of a fuel assembly on the top of the rack should be absorbed by the stainless steel and not the Boraflex. The NCS AOR analyzed the effect of a dropped fuel assembly onto a rack loaded with the most reactive lattice fuel analyzed. The dropping of an assembly does not change the multiplication factor for the entire storage system as a whole because of the distance between the top of the upper tie plate bale handle and the

actual top of active fuel, which is greater than 12 inches. A more rigorous evaluation would require new analyses which GL 2016-01 specifically stated were not required.

NUREG-0798 documents the NRC's SER related to the operation of the Enrico Fermi Atomic Power Plant, Unit No. 2. In Section 9.1.2 of the SER, the NRC documented its review of the Boraflex racks at Fermi 2 and stated “Based on our review as described above, we also conclude that the design of the spent fuel storage racks meet the recommendations of Regulatory Guide 1.13 and the applicable requirements of General Design Criteria 2, 61, and 62, and are, therefore, acceptable.”

b) *Describe how the monitoring program ensures that the current material condition of the neutron-absorbing material will accommodate the stressors during a design-basis event and remain within the assumptions of the NCS AOR, including:*

i) *monitoring methodology;*

<u>DTE RESPONSE:</u>
See the response to item 5.b.iv below.

ii) *parameters monitored;*

<u>DTE RESPONSE:</u>
See the response to item 5.b.iv below.

iii) *acceptance criteria; and*

<u>DTE RESPONSE:</u>
See the response to item 5.b.iv below.

iv) *intervals of monitoring.*

<u>DTE RESPONSE:</u>
It was never the intent of the monitoring program to ensure that the Boraflex (or any neutron absorber) would accommodate the stressors during a design-basis event. In the Licensing Input document (Joseph Oat document TM-586) regarding the in-service surveillance program it states “…it is prudent that each of the system components be monitored to some extent throughout the service life to assure that the actual in-service performance remains within acceptable parameters…” It goes on to say “A poison surveillance program will be conducted which allows access to representative poison samples without disrupting the integrity of the storage system. Such a program must include not only the capability to evaluate the material in a normal use mode, but to forecast changes that might occur within the storage system at a time significantly prior to the normal use mode occurrence of such changes.” The intent was clearly to monitor the integrity of the neutron absorber for degradation in the SFP environment, in the normal use mode, not for design basis events.

NUREG-0798 documents the NRC's SER related to the operation of the Enrico Fermi Atomic Power Plant, Unit No. 2. Section 9.1.5 of the SER states "To provide added assurance that no unexpected corrosion or degradation of the materials will compromise the integrity of the racks, the applicant has committed to conduct a long-term fuel storage cell surveillance program. Surveillance samples are in the form of removable stainless steel-clad Boraflex sheets, which are prototypical of the fuel storage cell walls. These specimens will be removed and examined periodically. We will include a requirement for this monitoring program in the Fermi 2 Technical Specifications."

Section 5.5.13 of the Fermi 2 Technical Specifications states: "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."

The SER goes on to say "We have reviewed the surveillance program and we conclude that the monitoring of the materials in the spent fuel pool, as proposed by the licensee, will provide reasonable assurance that the Boraflex material will continue to perform its function for the design life of the pool. We conclude that the spent fuel pool materials of construction meet the requirements of General Design Criterion 61, and are acceptable."

Enclosure 2 to
NRC-16-0061

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

DTE Response to GL 2016-01 for Boral Racks

AREA OF REQUESTED INFORMATION – 1 (for Boral Racks)

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

<u>DTE RESPONSE:</u>
See the specific responses below.

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

<u>DTE RESPONSE:</u>
The neutron-absorbing material in the Holtec fuel storage racks is Boral. There were two separate campaigns of the Holtec fuel storage racks: Campaign 1 and Campaign 2. Note that throughout this enclosure, the responses will apply to both campaigns unless otherwise specified.

The Campaign 1 rack Boral was manufactured by AAR in 2000. Racks B, C1, and C2 were installed into the SFP in 2001. Rack A was installed in 2005.

The Campaign 2 rack Boral was manufactured by AAR in the late 2005 to early 2006 time-frame. It was installed into the SFP in 2007.

b) *neutron-absorbing material specifications, such as:*

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

<u>DTE RESPONSE:</u>
Boral is a hot-rolled composite sheet consisting of (1) a core of uniformly mixed and distributed boron carbide (B_4C) and alloy 1100 aluminum particles; and (2) an alloy 1100 aluminum surface cladding, on both sides of the core, serving as a solid barrier.

Boral is not specified on a weight percent basis of the neutron-absorbing component, therefore this sub-item is not applicable to this material.

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

<u>DTE RESPONSE:</u>
Campaign 1:

- The minimum certified areal density (AD) from the manufacturer could not be located from a review of the records. However, Table 3.1.1 "Key Design Data for New Fermi-2 Modules" of the Licensing Report Document HI-992154 states the minimum B-10 areal density to be 0.020 grams (g) of B-10 per square centimeter

(cm^2). (The non-proprietary version of the report is contained in NRC Accession Number ML993440246.)

- The minimum as-built AD was 0.0209 g B-10 per cm^2
- The maximum as-built AD was 0.0249 g B-10 per cm^2
- The nominal (average) as-built AD was 0.0229 g B-10 per cm^2

Campaign 2:

- The minimum certified AD was 0.020 g B-10 per cm^2
- The minimum as-built AD was 0.0201 g B-10 per cm^2
- The maximum as-built AD was 0.0276 g B-10 per cm^2
- The nominal (average) as-built AD was 0.0232 g B-10 per cm^2

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

DTE RESPONSE:
Boral porosity was not provided in the vendor documentation. For Campaign 1, Boral density was not provided in the vendor documentation. However, the average density of the test coupons was 2.47 grams per cubic centimeter (g/cc). For Campaign 2, the density ranges from 2.4685 g/cc to 2.9271 g/cc. The average density was 2.5427 g/cc. The dimensions of the Boral panels are 0.075 inches thick by 4.75 inches wide by 152 inches long.

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

DTE RESPONSE:
The EPRI Neutron Absorber Handbook (2009 edition) reported on the qualification testing of Boral. Details are contained in Section 5.2.5 of the handbook.

d) configuration in the SFP, such as:

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

DTE RESPONSE:
The racks are composed of square cross-section boxes with the Boral panels held in place by stainless steel sheathing with axial spacer strips. The sheathing is attached to the box via skip welds.

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

DTE RESPONSE:
The Boral is exposed to the SFP water. Further details are contained in Holtec Report HI-992154 that was provided to the NRC via letter NRC-99-0084. Figure 3.1.2 in

HI-992154 shows a depiction of the Boral and sheathing attachment to the box. (The non-proprietary version of the report is contained in NRC Accession Number ML993440246.)

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

i) *estimated current minimum areal density;*

DTE RESPONSE:
Results of coupon testing of the neutron absorber have provided no indication of loss of neutron-absorbing material. Therefore, the estimated current minimum areal density is the same as when the material was fabricated and installed in the SFP.

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

DTE RESPONSE:
The current credited areal density of the neutron-absorbing material in the NCS AOR is a nominal 0.0216 g B-10 per cm^2, with 0.0200 g B-10 per cm^2 assumed in the uncertainty calculation.

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

DTE RESPONSE:
There is no recorded degradation or deformation of the Boral material in the SFP as there has been no visual or in-situ inspection of the Boral material in the rack. Results from coupon testing are presented in the response to item 4.

AREA OF REQUESTED INFORMATION – 2 (for Boral Racks)

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

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

DTE RESPONSE:
Fermi 2 has a coupon monitoring program for Boral. It uses material from some of the same manufacturing lots as the as-installed material. The coupons are able to detect aging/degradation mechanisms that the in-service neutron-absorber materials experience. The coupon tree is placed in a location in the spent fuel pool near freshly discharged fuel, which provides exposure to gamma and neutron irradiation and higher than average water temperatures.

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

DTE RESPONSE:
The frequency for testing coupons was based on having enough coupons to last through the end of the current operating license (2025) and through the end of one license renewal period (2045) without re-using coupons. For Campaign 1 racks, the coupons are removed after every 3 to 6 refuel outages (approximately 4.5 to 9 years) per the current schedule. For Campaign 2 racks, the coupons are removed after every 3 to 4 refuel outages (approximately 4.5 to 6 years) per the current schedule. Since it will be necessary to monitor the condition of the Boral after the end of the license renewal period, the program was revised to re-use coupons so that coupons will be available throughout the time period in which fuel will be stored in the rack. Coupons being returned to the pool will not be oven-dried because oven-drying, in and of itself, can result in blister development.

As part of the License Renewal Application process, the recommendation for the Aging Management Program in NUREG-1801 Revision 2, Section XI.M40 "Monitoring of Neutron-Absorbing Materials Other Than Boraflex," Item 4, states: "The frequency of the inspection and testing depends on the condition of the neutron-absorbing material and is determined and justified with plant-specific operating experience by the licensee, not to exceed 10 years." Hence, prior to the period of extended operation (PEO), the monitoring program will be revised to establish an inspection frequency, justified with plant-specific operating experience, of at least once every ten years, based on the condition of the neutron-absorbing material. This enhancement to the program is a DTE

commitment that is documented in the NRC Safety Evaluation Report (SER) (NRC Accession Number ML16190A011) for the license renewal of Fermi 2.

The program calls for 1 coupon to be tested at each testing interval. In addition, Fermi 2 has one coupon from Campaign 1 designated for blister-only trending. This coupon would be pulled periodically (in addition to the regularly scheduled coupon) to monitor blister growth.

ii) parameters to be inspected and data collected;

<u>DTE RESPONSE:</u>
A visual inspection is performed of the coupon and jacket. The inspection includes examination of any blisters and pits, if present. Length, width, thickness, weight, density, and B-10 areal density measurements are taken. Occasionally a radiograph is performed.

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

<u>DTE RESPONSE:</u>
There are two acceptance criteria associated with the Boral coupon program that were provided by Holtec (the rack manufacturer):

- B-10 areal density shall be greater than or equal to 0.0205 g B-10 per cm^2. This represents a decrease of 5% from the nominal B-10 loading associated with measurement uncertainty. The nominal AD in the NCS AOR is 0.0216 g B-10 per cm^2. A value of 0.0200 g B-10 per cm^2 is used in the uncertainty calculation to account for manufacturing tolerance.
- An increase in thickness in any point on the Boral coupon should not exceed 10% of the initial thickness at that point. A 10% increase would indicate swelling, which could indicate degradation.

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

<u>DTE RESPONSE:</u>
Coupon monitoring results are reviewed by the qualified engineer that is responsible for the program. Any degradation noted would be resolved through the Corrective Action Program (CAP). Trending of the data has not been performed because the coupons had not been returned to the pool after testing and successive coupons may be from different production lots. Since the program was revised to allow coupons to be returned to the SFP after testing, and the Campaign 1 blister-only coupon was created, trending can now be performed. Fermi 2 has an enhancement to the program to add trending to the monitoring program which is a DTE commitment that is documented in the NRC SER for the license renewal of Fermi 2.

v) industry standards used.

DTE RESPONSE:
ASTM C992 "Standard Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Fuel Storage Racks in a Pool Environment"

ASTM C1187 "Standard Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Fuel Storage Racks In a Pool Environment"

ASTM E2971 "Standard Test Method for Determination of Effective Boron-10 Areal Density in Aluminum Neutron Absorbers using Neutron Attenuation Measurements"

ASTM G1 "Recommended Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens"

ASTM G4 "Standard Guide for Conducting Corrosion Coupon Tests in Field Applications"

ASTM G16 "Recommended Practice for Applying Statistics to Analysis of Corrosion Data"

ASTM G46 "Standard Practice for Examination and Evaluation of Pitting Corrosion"

ASTM G69 "Standard Test Method for Measurement of Corrosion Potentials of Aluminum Alloys"

NIST-traceable standard weights and gage blocks were used to verify the accuracy of the dimensional measurements and the weights used to calculate the coupon density.

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

i) *If there is visual inspection of inservice material:*

DTE RESPONSE:
Fermi 2 does not perform a visual inspection of inservice material in the Boral racks. Therefore, no specific responses are provided for items 2.b.i.1 and 2.b.i.2 below.

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

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

ii) *If there is a coupon-monitoring program:*

(1) *provide a description and technical basis for how the coupons are representative of the material in the racks. Include in the discussion the material radiation exposure*

levels, SFP environment conditions, exposure to the SFP water, location of the coupons, configuration of the coupons (e.g., jacketing or sheathing, venting bolted on, glued on, or free in the jacket, water flow past the material, bends, shapes, galvanic considerations, and stress-relaxation considerations), and dimensions of the coupons;

DTE RESPONSE:
The coupons are made from production lots used in the Boral fuel storage racks. The coupons are on a coupon tree that sits in one of the Boral fuel storage rack cells. For material radiation exposure, the monitoring program calls for the tree to be re-surrounded during each refuel outage with 8 freshly discharged fuel assemblies that are among those that have received the highest exposure during the final third of the last operating cycle. Since the tree is located in a fuel storage rack cell, it is exposed to the same SFP water that the Boral panels in the SFP rack are. The coupons are enclosed in a stainless steel jacket in a picture-frame arrangement. The cover plate is held in place by screws. The coupons are free in the jacket and the jacket is not sealed. The coupons are rectangular in shape and are 4 inches x 8 inches x 0.075 inches thick. There are no bends or stress-relaxation considerations. There are no galvanic considerations. The Boral coupon is in contact with the stainless steel jacket as the Boral panel is in contact with the stainless steel rack. If there were any galvanic concerns for the material in the rack it would be observed in the coupon.

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

DTE RESPONSE:
The coupon tree for the Campaign 1 racks was installed in the pool on 5/16/01.
The coupon tree for the Campaign 2 racks was installed in the pool on 8/21/07.

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

DTE RESPONSE:
Originally the coupons were not intended to be returned to the pool for further evaluation. In 2012 an archive sample coupon for Campaign 1 was placed in a capsule and installed on the tree to be tested, returned to the pool, and subsequently re-tested to monitor and trend blister growth. Subsequent to that, the program was revised to return previously tested coupons from both campaigns to the pool for further evaluation. The purpose of this was so that coupons would remain available for the life of the SFP. These coupons will remain representative of the materials in the rack because the program was also revised to no longer dry the coupons in an oven. They are allowed to dry in a desiccator. Drying in an oven can cause blister growth and would not be representative of the Boral in the rack.

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

DTE RESPONSE:
For Campaign 1, there are currently 5 coupons remaining to be tested and 1 coupon just recently tested that will be returned to the pool for evaluation. For Campaign 2, there are currently 6 coupons remaining to be tested and 1 coupon just recently tested that will be returned to the pool for evaluation. The current schedule for coupon removal and testing for both campaigns is provided in the table below.

Campaign 1		Campaign 2	
Prior to Refuel Outage	Coupon to be Removed and Tested	Prior to Refuel Outage	Coupon to be Removed and Tested
20 (Spring 2020)	6	20 (Spring 2020)	15
23 (Fall 2024)	N/A	23 (Fall 2024)	16
26 (Spring 2029)	7	26 (Spring 2029)	17
30 (Spring 2035)	8	30 (Spring 2035)	18
34 (Spring 2041)	9	34 (Spring 2041)	19
N/A (Spring 2046)	10	N/A (Spring 2046)	20

The current schedule was based on having enough coupons to last through the end of the current operating license (2025) and through the license renewal PEO (2045) without re-using coupons. The Aging Management Program in NUREG-1801 Revision 2, Section XI.M40, states that the frequency of testing will be based on the test results and not to exceed 10 years. Prior to entry into the PEO the schedule will be adjusted for consistency with this recommendation, as documented in the NRC SER for license renewal of Fermi 2 and include re-used coupons. The re-use of coupons should ensure that there will be enough coupons for testing for the life of the SFP.

iii) If RACKLIFE is used:

DTE RESPONSE:
As indicated by the table in GL 2016-01 Appendix A, this request is not applicable for Boral racks (i.e. RACKLIFE is not used). Therefore, no specific responses are provided for items 2.b.iii.1 through 2.b.iii.4 below.

(1) note the version of RACKLIFE being used (e.g., 1.10, 2.1);

(2) note the frequency at which the RACKLIFE code is run;

(3) describe the confirmatory testing (e.g., in-situ testing) being performed and how the results confirm that RACKLIFE is conservative or representative with respect to neutron attenuation; and

(4) provide the current minimum RACKLIFE predicted areal density of the neutron-absorbing material in the SFP. Discuss how this areal density is calculated in RACKLIFE. Include in the discussion whether the areal densities calculated in RACKLIFE are based on the actual as-manufactured areal density of each panel, the nominal areal density of all of the panels, the minimum certified areal density, the minimum as-manufactured areal density, or the areal density credited by the NCS AOR. Also discuss the use of the escape coefficient and the total silica rate of Boraflex degradation in the SFP.

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

<u>DTE RESPONSE:</u>
Fermi 2 does not perform in-situ testing of the Boral racks. Therefore, no specific responses are provided for items 2.b.iv.1 through 2.b.iv.4 and their associated sub-items below.

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

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

(3) describe the sources of uncertainties when using the in-situ testing device and how they are incorporated in the testing results. Include the uncertainties outlined in the technical letter report titled "Initial Assessment of Uncertainties Associated with BADGER Methodology," September 30, 2012 (Agencywide Document Access and Management System Accession No. ML12254A064). Discuss the effect of rack cell deformation and detector or head misalignment, such as tilt, twist, offset, or other misalignments of the heads and how they are managed and accounted for in the analysis; and

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

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

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

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

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

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

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

AREA OF REQUESTED INFORMATION – 3 (for Boral Racks)

For any Boraflex, Carborundum, or Tetrabor being credited, describe the technical basis for determining the interval of surveillance or monitoring for the credited neutron-absorbing material. Include a justification of why the material properties of the neutron-absorbing material will continue to be consistent with the assumptions in the SFP NCS AOR between surveillances or monitoring intervals.

DTE RESPONSE:
As indicated by the table in GL 2016-01 Appendix A, this request is not applicable for Boral racks.

AREA OF REQUESTED INFORMATION – 4 (for Boral Racks)

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

DTE RESPONSE:
See the specific responses below.

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

   DTE RESPONSE:
   The Boral is modeled in the NCS AOR in the as-manufactured condition. The AOR does not address degraded Boral. This is based on the fundamental assumption that Boral does not degrade in a manner that affects its ability to absorb neutrons (i.e. B-10 areal density). Boral has been observed to develop blisters and pits. These are discussed in the response to item 4.b below. Since blisters and pits have not been observed to affect the neutron-absorption capability of Boral, they are not addressed in the NCS AOR. Boral is a robust material. This is substantiated by NRC letter from Laurence I. Kopp to Dr. Krishna P. Singh, dated February 16, 1995 (NRC Accession Number 9502230383), that deemed Boral was of sufficient robustness to not require a monitoring program.

b) *Describe how the results of the monitoring or surveillance program are used to ensure that the actual condition of the neutron-absorbing material is bounded by the SFP NCS AOR. If a coupon monitoring program is used, provide a description and technical basis for the coupon tests and acceptance criteria used to ensure the material properties of the neutron-absorbing material are maintained within the assumptions of the NCS AOR. Include a discussion on the measured dimensional changes, visual inspection, observed surface corrosion, observed degradation or deformation of the material (e.g., blistering, bulging, pitting, or warping), and neutron-attenuation measurements of the coupons.*

   DTE RESPONSE:
   The description and technical basis for the coupon tests and acceptance criteria used to ensure the material properties of the neutron-absorbing material are maintained within the assumptions of the NCS AOR was previously addressed in item 2.a. The results of the Boral coupon testing are provided below for Campaign 1 and Campaign 2.

   Five Boral test coupons from the Campaign 1 racks have been tested. Results of the Campaign 1 coupon testing are as follows:

- Capsule 1, coupon number IF010040-2-8 (removed in March 2003): Good overall condition, no anomalies. All surfaces have a fairly heavy oxide layer. Average change in length: -0.06%, average change in width: -0.05%, average thickness: 0.0848 inches, average change in thickness: 4% (acceptance criterion of ≤ 10%), average AD: 0.0264 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2).

- Capsule 2, coupon number IF010040-2-7 (removed in September 2004): Good overall condition, no anomalies. All surfaces have a fairly heavy oxide layer. Average change in length: -0.12%, average change in width: -0.03%, average thickness: 0.0857 inches, average change in thickness: 6% (acceptance criterion of ≤ 10%), average AD: 0.0261 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2).

- Capsule 3, coupon number IF010040-2-5 (removed in January 2006): Uniform oxide film. Water spots. There is a corrosion pit at the center of each water spot. Average change in length: -0.09%, average change in width: -0.02%, average thickness: 0.0838 inches, average change in thickness: 3% (acceptance criterion of ≤ 10%), average AD: 0.0258 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2). There were 6 pits that were characterized. The pits ranged from 0.002 inches to 0.011 inches deep with an average depth of 0.0065 inches. The pit size ranged from 0.012 to 0.081 inches across with an average size of 0.036 inches. It was noted in the report that 2 of the pits had penetrated the clad, but they were primarily a matter of aesthetics and did not compromise the function of the Boral.

- Capsule 4, coupon number IF010041-2-7 (removed in March 2009): Average change in length: 0.01%, average change in width: 0.03%, average thickness (excluding blisters): 0.0809 inches, average change in thickness: 2% (acceptance criterion of ≤ 10%), average AD: 0.0252 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2). Numerous blisters were noted. Eighteen (18) were noted on the front of the coupon that ranged from 0.25 inches to 2.1 inches. Sixteen (16) blisters were noted on the back of the coupon that ranged from 0.25 inches to 0.75 inches. A few small corrosion pits were noted.

- Capsule 5, coupon number IF010040-2-6 (removed in August 2015): Average change in length: 0.07%, average change in width: -0.03%, average thickness: 0.08019 inches, average change in thickness: 1.25% (acceptance criterion of ≤ 10%), average AD: 0.0250 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2). Numerous blisters were noted. Twenty (20) were noted on the front of the coupon and eighteen (18) blisters were noted on the back of the coupon. The average height of the blisters was 0.01565 inches, the average area was 0.30654 square inches, and the average volume was 0.0054 cubic inches. An AD measurement was made on the largest blister. The AD was measured at 0.0255 g B-10 per cm^2 (the coupon had a pre-characterized AD of 0.0245 g B-10 per cm^2). Hence, there was no reduction of AD under the blister. Fourteen (14) pits were observed. The pits ranged in width

from 0.014 inches to 0.073 inches. The average width was 0.037 inches. The pits ranged in depth from 0.00188 inches to 0.01354 inches. The average depth was 0.0094 inches. A neutron radiograph was taken of the coupon. No signs of significant localized areal density loss were observed on the coupon.

- Coupon number IF010041-2-8 was an archive coupon that was encapsulated and placed in the SFP on 3/22/12 to serve as a blister-only coupon. The intent of this coupon was to trend blister growth on the same coupon. This coupon is not subject to oven drying. Coupon was removed for testing on 8/26/15. No blisters were observed, but there were several small pits.

Four Boral test coupons from the Campaign 2 racks have been tested. Results of the Campaign 2 coupon testing are as follows:

- Capsule 11, YD610122-1-5 (removed in March 2009): Good overall condition, no significant deterioration, degradation or other anomalies. Average change in length: 0.04%, average change in width: 0.08%, average thickness: 0.0803 inches, average change in thickness: 3% (acceptance criterion of ≤ 10%), average AD: 0.0246 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2). No blisters, 2 small corrosion pits.

- Capsule 12, YD610122-1-6 (removed in October 2010): Good condition, no pits, 1 incipient blister that was too small to measure. Average change in length: 0.04%, average change in width: -0.09%, average thickness: 0.080 inches, average change in thickness: 0.98% (acceptance criterion of ≤ 10%), average AD: 0.0247 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2).

- Capsule 13, YD610122-1-7 (removed in March 2012): Good overall condition, no pits. Average change in length: 0.06%, average change in width: 0.08%, average thickness: 0.08039 inches, average change in thickness: 0.488% (acceptance criterion of ≤ 10%), average AD: 0.0244 g B-10 per cm^2 (acceptance criterion of ≥ 0.0205 g B-10 per cm^2). Eight blisters were noted. Blister heights ranged from 0.001 inches to 0.004 inches. Average blister height was 0.0019 inches. Blister area ranged from 0.0017 square inches to 0.0165 square inches. Average blister area was 0.00745 square inches. Total blister area was 0.0593 square inches. Blister volume ranged from 8.4E-07 cubic inches to 2.0E-05 cubic inches. Average blister volume was 7.99E-06 cubic inches. Total blister volume was 6.41E-05 cubic inches. AD taken on the largest blister: 0.0247 g B-10 per cm^2 (the coupon had a pre-characterized AD of 0.0247 g B-10 per cm^2).

- Capsule 14, YD610122-1-8 (removed in August 2015): Good overall condition, no pits, no blisters. Average change in length: 0.04%, average change in width: 0.05%, average thickness: 0.08052 inches, average change in thickness: 0.65% (acceptance criterion of ≤ 10%), average AD: 0.0253 g B-10 per cm^2 (acceptance criterion of

≥ 0.0205 g B-10 per cm^2). A neutron radiograph was taken of the coupon. No signs of significant localized areal density loss were observed.

Regarding pits, the EPRI Handbook of Neutron Absorbers, 2009 edition, Section 5.2.6 (page 5-34), states that this in-service degradation due to pitting corrosion has not resulted in any decrease in B-10 areal density. It goes on to conclude the 1100 alloy matrix of Boral continues to serve as a suitable matrix to retain boron carbide.

It is also relevant to note that in EPRI's Long-Term Accelerated Corrosion Testing of Boral, no statistically significant change in AD has been observed in coupons that have had their clad removed after 2 years at elevated temperatures.

Regarding blisters, the EPRI Handbook of Neutron Absorbers, 2009 edition, Section 5.2.6 (page 5-35), states that blisters have not been observed to alter the neutron-absorption properties of Boral. Only in PWR Region 1 flux-trap type racks (not used at Fermi 2) can blisters have an effect on reactivity.

As discussed in the paragraphs above about the testing of Fermi 2 coupon capsules 5 (Campaign 1) and 13 (Campaign 2), an AD measurement was made on the largest blister observed and there was no decrease in AD.

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

DTE RESPONSE:
Bias and uncertainty of the monitoring program are not used in the SFP NCS AOR.

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

DTE RESPONSE:
No degradation is modeled in the NCS AOR.

AREA OF REQUESTED INFORMATION – 5 (for Boral Racks)

For any Boraflex, Carborundum, or Tetrabor being credited, describe the technical basis for concluding that the safety function for the credited neutron-absorbing material in the SFP will be maintained during design-basis events (e.g., seismic events, loss of SFP cooling, fuel assembly drop accidents, and any other plant-specific design-basis events that may affect the neutron-absorbing material).

<u>DTE RESPONSE:</u>
As indicated by the table in GL 2016-01 Appendix A, this request is not applicable for Boral racks. Therefore, no specific responses are provided for items 5.a and 5.b and their associated sub-items below.

a) *For each design-basis event that would have an effect on the neutron-absorbing material, describe the technical basis for determining the effects of the design-basis event on the material condition of the neutron-absorbing material during the design-basis event, including:*

   i) *shifting or settling relative to the active fuel;*

   ii) *increased dissolution or corrosion; and*

   iii) *changes of state or loss of material properties that hinder the neutron-absorbing material's ability to perform its safety function.*

b) *Describe how the monitoring program ensures that the current material condition of the neutron-absorbing material will accommodate the stressors during a design-basis event and remain within the assumptions of the NCS AOR, including:*

   i) *monitoring methodology;*

   ii) *parameters monitored;*

   iii) *acceptance criteria; and*

   iv) *intervals of monitoring.*