UNIVERSITY *of* MISSOURI

RESEARCH REACTOR CENTER

November 2, 2016

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

REFERENCE: Docket 50-186
University of Missouri-Columbia Research Reactor
Amended Facility Operating License No. R-103

SUBJECT: Written communication as specified by 10 CFR 50.4 and 50.54(f) regarding response to "NRC Generic Letter 2016-01: Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated April 7, 2016

The following is the University of Missouri-Columbia Research Reactor (MURR) response to U.S. Nuclear Regulatory Commission (NRC) Generic Letter 2016-01, "Monitoring of Neutron-Absorbing Materials in Spent Fuel Pools," dated April 7, 2016. The NRC issued this generic letter to address degradation of neutron-absorbing materials in wet storage systems for reactor fuel at power and non-power reactors. Specifically, the NRC requests that each non-power reactor addressee provide information for use in determining the reliance on neutron-absorbing materials for nuclear criticality safety (NCS) of reactor fuel or spent fuel in storage contained within reactor pools, fuel storage pools, or other wet locations designed for the purpose of fuel storage, as applicable. The NRC's questions, and MURR's response to each question, are as follows:

(1) Are neutron-absorbing materials used in a reactor pool, fuel storage pool, or other wet locations designed for the storage of reactor or spent fuel?

Yes, neutron-absorbing materials, specifically BORAL®, are utilized in the MURR pool in facilities specifically designed to store reactor and spent fuel. There are 88 in-pool storage locations for new or irradiated fuel elements. These storage locations are situated in three (3) areas within the reactor pool and are designated as the "X," "Y," and "Z" fuel storage baskets. The "Z" storage basket contains 48 fuel element storage locations; consisting of two (2) levels, referred to as "upper" and "lower," of 24 locations per level. The "X" and "Y" storage baskets each contain 20 fuel element storage locations on a single level.

The MURR facility was originally designed and built with only 28 in-pool fuel element storage locations. The "X" and "Y" storage baskets each had only six (6) storage locations while the "Z" storage basket consisted of 16 storage locations – two racks (6 and 10) in the lower level. In 1972,

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due to an increase in operating schedule and with an uprate in power from 5 to 10 MWs planned in the near future, an additional rack of eight (8) storage locations was added to the lower level of the "Z" storage basket, thus providing a total of 36 fuel element storage locations in the pool (24 in the "Z" storage basket).

In 1976, a 14 element rack was added to the upper level of the "Z" storage basket which increased the overall capacity of the "Z" storage basket from 24 to 38.

In 1978, a 10 element rack was added to the upper level of the "Z" storage basket which increased the overall capacity of the "Z" storage basket from 38 to 48.

In 1991, due to the inability to ship spent fuel from the facility because the cask (GE-700) that was used to ship research reactor fuel at the time was removed from service, two (2) new fuel storage baskets were fabricated to increase the onsite storage capacity. These baskets, which were attached to the "X" and "Y" storage baskets, each held 12 fuel elements and were designated "MH-X" and "MH-Y."

In 2004, the "X," "Y," "MH-X" and "MH-Y" fuels storage baskets were replaced with new "X" and "Y" storage baskets, which increased the total storage capacity in these baskets from 36 to 40 locations. This brought the total storage capacity for new or irradiated fuel in the reactor pool to 88 locations.

(2) *If neutron-absorbing materials are used, is their use credited in the licensing or design basis (i.e., criticality safety analysis) for the storage of reactor fuel or spent fuel in a reactor pool, fuel storage pool, or other wet locations, as applicable?*

Yes, MURR has a Technical Specification (TS) specific to the storage of reactor fuel. TS 3.8.d states, "All fuel elements outside the reactor core shall be stored in a geometry such that the calculated K_{eff} is less than 0.9 under all conditions of moderation."

Criticality calculations were performed for all fuel storage baskets prior to installation, including 1/M criticality plots where possible after installation.

As a part of answering Request for Additional Information (RAI) in support of facility relicensing this past year, updated criticality (i.e. KCODE) calculations using MCNP version 5 with the Evaluated Nuclear Data Files ENDF/B-VII.0 data libraries were performed for two detailed instances of the "Z" storage basket configuration: (1) a single basket (lower), and (2) both lower and upper baskets together. For the two instances, the basket(s) were filled to their maximum capacities (24 fuel elements) with fresh, highly-enriched uranium (HEU) UAl_x MURR fuel elements. These configurations describe the most conservative, worst-case conditions for the "Z" storage baskets. Table 1 provides the computed K_{eff} using the MCNP models of the two configurations of the "Z" storage basket.

Table 1
K_{eff} Values for Worst-Case for Upper and Lower "Z' Storage Basket Configurations

Basket Configuration	Fuel Element Configuration	Storage Capacity	K_{eff}
Lower	Fresh	Max – 24 Fuel Elements	0.499
Lower + Upper	Fresh	Max – 48 Fuel Elements	0.559

The 2004 MCNP calculations for the new "X" and "Y" storage baskets indicated a K_{eff} value of 0.635 for each fuel storage basket fully loaded with twenty (20) fresh HEU fuel elements.

Note: Amended Facility License No. R-103, Section 2.B.(2), states, "... to receive, posses, and use up to 60 kilograms of contained uranium-235 of any enrichment, providing that no more than 5 kilograms of this amount is unirradiated; ...". Six fresh MURR fuel elements, containing 775 grams of uranium-235 each, equals 4.65 kilograms; therefore, at the most only six (6) fresh fuel elements can be in any given fuel storage basket at any one time.

(3) *If neutron-absorbing materials are credited in the facility licensing or design basis for the storage of reactor or spent fuel in a reactor pool, fuel storage pool, or other wet locations, as applicable, then provide a description of, and technical basis for, any surveillance or monitoring programs used to confirm continued acceptable performance of the neutron-absorbing materials over time.*

A series of MCNP5 calculations were performed using the KCODE feature to study the effect of losing the absorbing material (i.e., BORAL) that controls the criticality of the MURR fuel storage baskets when they are loaded with fuel elements. In particular, this study focused on the "X" and "Y" storage baskets, which are of identical design and have a maximum storage capacity of 20 MURR fuel elements each, as well as the upper and lower levels of the "Z" storage basket. To avoid redundancy in the calculations since the "Y" storage basket is identical in design to the "X" storage basket; the simulations were only performed for the "X" storage basket.

The BORAL degradation was simulated by simply decreasing the height of the BORAL that surrounds each fuel storage location by a fraction of the height of the basket. The removed fraction of BORAL mass was conservatively replaced by the equivalent fraction of aluminum. For the study, two (2) fuel states were used; an ultra-conservative case (Case I) where all fuel elements are fresh (i.e., 0 MWD) and another (Case II) where all fuel elements are irradiated and are at their typical discharged burnup level (i.e., 147 MWD). Table 2 shows a comparison of the predicted K_{eff} corresponding to the two (2) cases and their various "X" storage basket configurations. Table 3 provides a comparison of the predicted K_{eff} corresponding to various "Z" storage basket configurations with fresh and irradiated fuel elements to a burnup level at about half the discharge value.

Table 2
K_{eff} for Various "X" Storage Basket and Fuel Configurations

Basket Configuration	K_{eff}	Notes
Case I – 20 Fresh Fuel Elements		
No BORAL	1.159	
BORAL 33% Height of Basket	1.111	
BORAL 50% Height of Basket	1.034	
BORAL 55% Height of Basket	0.999	Critical BORAL height
BORAL 64% Height of Basket	0.896	Below Technical Specification limit
BORAL 67% Height of Basket	0.863	
BORAL 75% Height of Basket	0.713	
BORAL 100% Height of Basket	0.598[1]	
CASE II – 20 Irradiated Fuel Elements; 147 MWd Burnup on Each Element		
No BORAL	1.061	
BORAL 40% Height of Basket	0.993	Critical BORAL height
BORAL 55% Height of Basket	0.910	
BORAL 75% Height of Basket	0.644	Below Technical Specification limit

Note 1: Previously, during the initial design and commissioning of the "X" and "Y" storage baskets, criticality calculations were performed using Version 4B of the criticality estimation code MCNP. For the newer set of calculations, MCNP version 5 was used (in 2016). The cross section values used by MCNP for criticality calculations are continually updated as the Evaluated Nuclear Data Files (ENDF) are updated making the current calculations more accurate compared to the 2002 calculations. Therefore, a K_{eff} of 0.635 was calculated in 2004 for the "X" and "Y" storage baskets whereas a K_{eff} of 0.598 was calculated in 2016 for the same storage baskets.

For compliancy with the TS K_{eff} limit of less than 0.9 under all conditions of moderation regardless of the fuel status, the BORAL levels in the baskets must be maintained at a height above 64% of the basket height. Therefore, the below stated surveillance is required to periodically check the integrity of the "X" and "Y" storage baskets.

Table 3
K_{eff} for Various Upper and Lower "Z" Storage Basket and Fuel Configurations

Case	Basket Configuration	Fuel Element Configuration	K_{eff}
Only Lower	No BORAL	24 Fresh	0.881
Only Lower	No BORAL	10 Fresh & 14 Irradiated (70 MWd)	0.862
Upper + Lower	No BORAL	Upper – 24 Fresh Lower – 24 Fresh	0.988
Upper + Lower	No BORAL	Upper – 12 Fresh & 12 Irradiated (70 MWd) Lower – 24 Irradiated (70 MWd)	0.937
Upper + Lower	No BORAL	Upper – 6 Fresh & 18 Irradiated (70 MWd) Lower – 24 Irradiated (70 MWd)	0.945
Upper + Lower	No BORAL	Upper – 24 Irradiated (70 MWd) Lower – 6 Fresh & 18 Irradiated (70 MWd)	0.936
Upper + Lower	Upper all BORAL / Lower no BORAL	Upper – 24 Fresh Lower – 24 Fresh	0.887

For compliancy with the TS K_{eff} limit of less than 0.9 under all conditions of moderation regardless of the fuel status, the below stated surveillances are required to periodically check the integrity of the upper and lower "Z" storage baskets.

SURVEILLANCE 1 – Lower "Z" Storage Basket

Since the provided criticality analyses shows that the lower "Z" storage basket without neutron-absorbing materials can be full of fresh fuel elements with a K_{eff} of less than 0.9, then MURR will commit to conducting the following inspection every five (5) years to the lower "Z" storage basket as a defense-in-depth measure:

a. Visually inspect all fuel storage positions in the lower "Z" storage basket for corrosion, blistering, bulging, or any other abnormalities.

b. Insert and retract a test jig of specified minimum dimensions into each fuel storage position of the lower "Z" fuel storage basket to ensure no binding occurs. This test jig will provide a measurement to ensure that unacceptable bulging or blistering of the BORAL plates has not occurred.

SURVEILLANCE 2 – "X," "Y," and Upper "Z" Storage Baskets

Since the provided criticality analysis shows the possibility of K_{eff} exceeding 0.9 in the "X," "Y," and upper "Z" storage baskets due to a reduction in BORAL, then MURR will commit to conducting the

following inspections every two (2) years for the "X" and "Y" storage baskets, and prior to every use of the upper "Z" storage basket. If the upper "Z" storage basket is used, the upper "Z" storage basket will be inspected every two (2) years while in use.

a. Visually inspect all fuel storage positions of the "X," "Y," and upper "Z" storage baskets for corrosion, blistering, bulging, or any other abnormalities.

b. Insert and retract a test jig of specified minimum dimensions into each fuel storage position of the "X," "Y," and upper "Z" storage baskets and ensure no binding occurs. This test jig will provide a measurement to ensure that unacceptable bulging or blistering of the BORAL plates has not occurred.

If there are any questions regarding this response, please contact me at (573) 882-4211. I declare under penalty of perjury that the foregoing is true and correct.

Sincerely,

Ralph A. Butler, P.E.
Director

xc: Reactor Safety Subcommittee
Mr. Alexander Adams Jr., U.S. Nuclear Regulatory Commission
Mr. Geoffrey Wertz, U.S. Nuclear Regulatory Commission
Mr. Johnny Eads, U.S. Nuclear Regulatory Commission

State of Missouri
County of Boone
Subscribed and sworn to before me this
2 day of November, 2016
Jacqueline L. Matyas
JACQUELINE L. MATYAS, Notary Public
My Commission Expires: March 26, 2019

NOTARY PUBLIC NOTARY SEAL STATE OF MISSOURI

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My Commission Expires
March 26, 2019
Howard County
Commission #15634308