ENCLOSURE 2

RESPONSE TO AREAS OF REQUESTED INFORMATION IN APPENDIX A OF GENERIC LETTER 2016-01, "MONITORING OF NEUTRON-ABSORBING MATERIALS IN SPENT FUEL POOLS"

NON-PROPRIETARY

(Proprietary portions of document that have been removed are indicated by white space in [ ].)

RESPONSE TO AREAS OF REQUESTED INFORMATION IN APPENDIX A OF GENERIC LETTER 2016-01, "MONITORING OF NEUTRON-ABSORBING MATERIALS IN SPENT FUEL POOLS" (NON-PROPRIETARY)

The following information is provided using detailed criteria and guidance provided by the Nuclear Energy Institute. The response criteria are provided in bolded italics; the Nebraska Public Power District (NPPD) responses are provided in standard font.

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

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

NPPD Response: Cooper Nuclear Station (CNS) has two types of absorber material: Boral and Metamic. Boral was manufactured by Brooks and Perkins. Year of manufacture was 1977 and year of material installation was 1979. Metamic was manufactured by Holtec International. Year of manufacture was 2006 and year of material installation was 2008.

b) neutron-absorbing material specifications, such as:

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

NPPD Response: Boral is a sandwich material having exterior faces of an aluminum alloy and a core composed of aluminum and boron carbide. The boron carbide powder used to create the core contains a minimum total boron content of 70% by weight. Metamic is a metal matrix composite material consisting of a matrix of aluminum reinforced by boron carbide. The minimum boron carbide content is [ ] by weight.

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

NPPD Response: Boral has a minimum certified boron areal density of 0.126 gm/cm^2 (equivalent to 0.0252 gm/cm^2 boron-10 areal density). Boral minimum as-built boron areal density is 0.126 gm/cm^2 (equivalent to 0.0252 gm/cm^2 boron-10 areal density) and maximum as-built boron areal density is 0.183 gm/cm^2 (equivalent to 0.0366 gm/cm^2 boron-10 areal density). Metamic has a minimum certified boron-10 areal density of [ ] gm/cm^2. The nominal boron-10 areal density for Metamic is [ ] gm/cm^2. Metamic minimum as-built boron-10 areal density is [ ] gm/cm^2. Metamic maximum as-built boron-10 areal density is [ ] gm/cm^2.

After a reasonable search of the plant's records, including docketed information, NPPD determined that the Boral nominal areal density was not part of the original licensing basis or previously requested by the Nuclear Regulatory Commission (NRC) as part of the licensing action that approved the neutron absorber monitoring program.

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

NPPD Response: Boral panel dimensions are reported at a length of 150 and 3/8 inches. Two panel widths are reported: wider width of 45 and 21/32 inches and narrow width of 39 and 3/32 inches. Overall thickness is a maximum of 0.293 inches and Boral core thickness of 0.085 inch minimum.

Metamic is a porosity-free material. Metamic density is [ ] gm/cm^3. The Metamic panels are 152 inches long and 4.75 inches wide.

After a reasonable search of the plant's records, including docketed information, NPPD determined that the Boral porosity and density were not part of the original licensing basis or previously requested by the NRC as part of the licensing action that approved the neutron absorber monitoring program.

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

NPPD Response: Boral irradiation tests were performed by Brooks and Perkins. The test report is Brooks and Perkins Report No. 572, "Experimental Observation of BORAL Plates Encased in Stainless Steel Under the Influence of Gamma and Neutron Fluxes," February 1976. Testing approach and results from testing were specified as follows:

> BORAL plates were encased in stainless steel jackets and subjected to gamma radiation simulating spent fuel pool conditions. One sample was tested dry to 9.6×10^8 rad and another sample with 25 ml distilled water injected into the stainless steel jacket was tested to 2.4×10^8 rad. Brooks and Perkins has concluded from their overall test program that "under irradiation fluxes and water conditions expected in a power reactor spent fuel pool, the BORAL samples exhibited no detectable gas evolution, pressure buildup, or damage due to temperature or other effects."

Metamic was subjected to qualification testing in an extensive array of tests performed by the Electric Power Research Institute (EPRI) (EPRI Report 1003137, "Qualification of METAMIC for Spent Fuel Storage Application," October 2001). Functional performance of the material was evaluated at elevated temperatures (up to 900 degrees F) and radiation levels (1E+11 rads gamma). The results documented indicate that Metamic maintains its physical and neutron absorption properties with little variation in its properties from an unirradiated state. Main conclusions from the testing were specified as follows:

- The metal matrix configuration produced by the powder metallurgy process with almost a complete absence of open porosity in Metamic ensures that its density is essentially equal to the theoretical density.
- The physical and neutronic properties of Metamic are essentially unaltered under exposure to elevated temperatures (750 to 900 degrees F).
- No detectable change in the neutron attenuation characteristics under accelerated corrosion test conditions has been observed.

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);

NPPD Response: The Boral core is clad in aluminum sheets and seal welded around the edges. The sheets are inserted into the racks between rows of aluminum storage cans in one direction. The Metamic panels are attached to cell walls. They are held firmly in place in a stainless steel pocket around each box.

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

NPPD Response: The Boral core is clad in aluminum sheets, which are seal welded around the edges so the Boral is not exposed to the SFP water. The Metamic is contained within a stainless steel pocket and is exposed to the SFP water.

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

i) estimated current minimum areal density;

NPPD Response: Neutron attenuation testing of sample coupons was performed in 1982, 1992, and 2012 for Boral and in 2012 for Metamic. Results of this testing provide no indication of loss of neutron absorber material; therefore, the estimated current minimum areal density is the current credited areal density in the NCS AOR reported in item 1.e.ii below.

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

NPPD Response: The current credited nominal B-10 areal density for Boral in the NCS AOR is 0.0263 gm/cm^2 and the current credited minimum B-10 areal density for Boral is 0.02511 gm/cm^2. The current credited nominal B-10 areal density for Metamic in the NCS AOR is [ ] gm/cm^2. Please note that the minimum credited Metamic areal density of [ ] gm/cm^2 is [ ] gm/cm^2 higher than the minimum certified density of [ ] gm/cm^2

reported in item 1.b.ii above. This is the result of rounding in the calculation of the minimum certified density.

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

NPPD Response: NPPD recorded minor surface indications and minor changes in measured parameters in past Boral coupon surveillances. NPPD recorded swelling in two surveillances (1982 and 1992) in Boral coupons. No recorded degradation or deformation has been noted in Boral rack panels. No recorded degradation or deformation has been noted in Metamic coupons or rack panels.

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

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

NPPD Response: Coupon-monitoring programs are the surveillance method for both Boral and Metamic. Representative coupon samples are used to monitor performance of the neutron absorber materials without disrupting the integrity of the rack storage panels.

The Boral program uses three types of sample coupons. The first coupon type is galvanic, consisting of a plate of 304 stainless steel bolted to a plate of aluminum, which simulates the rack, sub-base, and seismic bracing materials. The other two coupon types are Boral, consisting of a Boral core clad on both sides with aluminum. The boron carbide in the Boral coupons is from the same lots as those used to manufacture the racks. These coupons simulate the plates used between the rows of fuel cells for reactivity control. One type of Boral coupon is seal welded on all edges, simulating the configuration in the plates used in the racks. The other type is seal welded on three sides only to simulate Boral exposure to the spent fuel pool water if this occurred in the rack plates. There are 3 open-ended Boral coupons, 14 sealed Boral coupons, and 2 galvanic coupons.

The Metamic program uses poison sample coupons. The Metamic coupons are from the same poison lots as those used to construct the rack panels. There are 10 Metamic coupons. Data from characterization of the physical and chemical properties of the coupons is used to provide confirmation that the poison material in the racks has the capability to continue to maintain pool k-effective within limits.

There are two coupon surveillance assemblies, one which holds the Boral program coupons and a separate assembly which holds the Metamic coupons. The assemblies are stored in spent fuel pool rack locations near freshly discharged assemblies in order to bound the irradiation and environmental conditions experienced by the rack panels.

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

NPPD Response: The Boral program frequency was set at 8 years based on results from previous testing. This frequency applies to the visual examination and physical measurements. All coupons are subjected to the visual examination and physical measurements. Neutron attenuation testing is performed on representative sample coupons with one test occurring prior to the Period of Extended Operation for CNS and another test to be performed within the first 10 years of the Period of Extended Operation.

The Metamic program uses intervals set prior to the start of the program as committed to the NRC. The intervals are 2, 4, 8, 12, 16, 20, 24, and 28 years after irradiated fuel is stored in the Metamic racks. These intervals apply to visual examination and physical measurements taken on one coupon. The intervals are 4, 12, and 20 years for neutron attenuation testing with more frequent neutron attenuation done if warranted by results from the visual examination or physical measurements.

ii) parameters to be inspected and data collected;

NPPD Response: For the Boral program, the galvanic coupon inspection is a visual examination that characterizes corrosion on the coupon and near the bolt holes (bolts used to connect aluminum and stainless steel portions of the coupon). The Boral coupons undergo a visual examination for signs of corrosion, pitting, cracking, indications of weld failure, and indications of distortion (such as twisting, bowing, or swelling). Data collected are observations from the visual examination. The Boral coupons also undergo physical dimension checks. The physical dimensions measured are weight and thickness for all coupons and distance from edge to Boral core on open-ended coupons. Data collected are the weight, thickness at three points on each coupon, and distance from edge to Boral core for open-ended coupons.

For the Metamic program, the visual examination looks for edge or corner defects and any discoloration, swelling, or surface pitting that may be present. Data collected are photographs of the coupons. The Metamic coupons also undergo physical dimension checks of length, width, thickness, and weight. Data collected are the length in three locations, width in three locations, thickness in five locations, and dry weight.

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;

NPPD Response: The Boral program has acceptance criteria for the physical dimension checks by comparing data collected to initial values. If these are not met, neutron attenuation testing is evaluated to ensure adequate material capability exists. Acceptance criterion for this testing is that a decrease in B-10 content does not result in a failure to maintain the 5% sub-criticality margin for the spent fuel pool or, in other words, the determined B-10 areal density is higher than the minimum areal density used in the NCS AOR.

The Metamic program has acceptance criteria for the physical dimension checks by comparing data collected to pre-irradiation values. If these are not met, neutron attenuation testing is performed to assure material capability. The acceptance criterion for neutron attenuation testing is no more than a 5% decrease in B-10 content from pre-irradiation value.

Material dimensions and boron content are assumptions in the NCS AOR. Ensuring that any changes noted during surveillances are properly evaluated ensures the safety function of the racks continues to be met.

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

NPPD Response: All coupons are visually inspected during each surveillance and physical dimensions checked. Inspection results are compared with previous tests.

v) industry standards used.

NPPD Response: After thorough search of plant records, including docketed information, NPPD did not find any industry standards cited in development of the coupon monitoring programs.

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

i) If there is visual inspection of inservice material:

NPPD Response: NPPD does not credit visual inspection of inservice material in the monitoring programs.

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;

NPPD Response: Both coupon monitoring programs have coupons of sample poison material stored in the spent fuel pool environment on surveillance assemblies. All coupons for Boral program are on one surveillance assembly and all coupons for Metamic program are on a second surveillance assembly. Each surveillance assembly is in the pool in a fuel rack cell surrounded by irradiated fuel assemblies.

The Boral program galvanic coupons each consist of a plate of 304 stainless steel bolted to a plate of 6061-T6 aluminum using five bolts of 18-8 stainless steel. The five bolts are torqued to different values to simulate possible loading conditions. This simulates the Boral rack construction materials of 6061 aluminum and other interfacing structural component construction of type 304 stainless steel. The galvanic coupons are approximately 3/4 by 3 by 11 inches.

The Boral program sealed coupons are constructed of a Boral core clad by aluminum and seal welded to prevent pool water intrusion (the sealed coupons are similar to rack construction). The Boral program open-ended coupons are constructed similarly to the sealed coupons, but are only seal welded on three sides. This allows for monitoring Boral core material that may be exposed to pool water if the seal weld leaks. Boral coupon core material contains B_4C from same lots used in rack panel Boral material. The Boral coupons are approximately 0.177 by 3 by 11 inches.

The Metamic coupons are samples of the material; they are not jacketed or sheathed. This simulates the Metamic panels adjacent to the racks. Metamic coupons are from same lots as used in rack panel Metamic material. The Metamic coupons are approximately 6 by 4 by 0.075 inches.

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

NPPD Response: The Metamic coupons were installed in 2008.

After a reasonable search of the plants records, including docketed information, NPPD determined that the exact date of coupon installation for Boral was not part of the original licensing basis or previously requested by the NRC as part of the licensing action that approved the neutron absorber monitoring program. Best estimate for this date based on records that were available is 1979 or early 1980.

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;***

NPPD Response: Coupons are returned to SFP. All coupons for each program are on one surveillance assembly, so all coupons must be physically removed from the pool at the time of each surveillance. Time out of the SFP is limited to that needed to perform surveillance activities. Coupons do not typically undergo destructive testing (e.g., removal from jacket for

Boral samples); therefore, the coupons' exposure to the SFP environment remains representative of the rack material.

> 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.***

NPPD Response: The Boral program has 17 Boral coupons in the pool (3 open-ended, 14 sealed) and 2 galvanic coupons. Since NPPD returns the coupons to the pool as specified in 2.b.ii.3 above and does not typically engage in destructive examination, sufficient coupons exist to test until the end of plant extended license in 2034.

The last test for the Boral program was in 2012. Remaining testing between now and end of plant extended license for Boral at existing 8 year frequency results in tests by 2020 and 2028 (visual examination and physical dimension checks). Remaining neutron attenuation testing for Boral is required within 10 years of start of Period of Extended Operation (2014) and results in test by 2024.

The Metamic program has 10 coupons. One coupon is required for test at each interval. Three tests have been performed: 2010, 2012, and 2016. Remaining testing for Metamic given intervals specified in 2.a.i above results in tests by 2020, 2024, 2028, 2032, and 2036 (visual examination and physical dimension checks). Remaining neutron attenuation tests given intervals specified in 2.a.i above results in tests by 2020 and 2028. With this test schedule, sufficient coupons exist to test as required by the test program.

iii) If RACKLIFE is used:

NPPD Response: NPPD does not use Boraflex as a neutron absorber, so RACKLIFE is not used.

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

NPPD Response: NPPD does not use in-situ testing on neutron absorbers.

3) 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.

NPPD Response: NPPD does not use Boraflex, Carborundum, or Tetrabor as neutron-absorbing materials.

4) ***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.***

   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.***

NPPD Response: The Boral is modeled in the as-manufactured condition in the base case of the NCS AOR.

In Boral coupon surveillances in 1982 and 1992, NPPD noted some swelling. Areas of swelling on the coupons showed increased thickness over initial values. Neutron attenuation testing and neutron radiography did not reveal a loss of neutron absorber material or change in distribution of the material in the affected coupons.

The modeling in the NCS AOR addresses degradation noted in the surveillance program, specifically the swelling mechanism. The reactivity effect of swelling in rack panels was modeled for three separate scenarios within the NCS AOR in order to bound potential pool reactivity impacts from this degradation mechanism.

Scenario 1: All Boral in racks assumed to enlarge by 10% of thickness. This was modeled by increasing the Boral sheet thickness and decreasing Boral density to 90% of its value.

Scenario 2: Thickness of one Boral cell increases such that the whole corresponding water in flux-traps of that cell disappears. This was modeled by replacing the whole water in flux-traps for one cell out of eleven cells with air.

Scenario 3: Whole water in all Boral cell flux-traps disappears.

The maximum reactivity effect of the scenarios is compared and a bounding reactivity effect is used when determining the rack k-effective value calculated 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.

NPPD Response: Representative coupon samples are used to monitor performance of the neutron absorber materials without disrupting the integrity of the rack storage panels. The Boral program uses three types of sample coupons. The first coupon type is galvanic, consisting of a plate of 304 stainless steel bolted to a plate of aluminum, which simulates the rack, sub-base, and seismic bracing materials. The other two coupon types are Boral, consisting of a Boral core clad on both sides with aluminum. The boron carbide in the Boral coupons is from the same lots as those used to manufacture the racks. These coupons simulate the plates used between the rows of fuel cells for reactivity control. One type of Boral coupon is seal welded on all edges, simulating the configuration in the plates used in the racks. The other type is seal welded on three sides only to simulate Boral exposure to the spent fuel pool water if this occurred in the rack plates. There are 3 open-ended Boral coupons, 14 sealed Boral coupons, and 2 galvanic coupons.

A surveillance assembly holds all the program coupons. The assembly is stored in spent fuel pool rack locations near freshly discharged assemblies in order to bound the irradiation and environmental conditions experienced by the rack panels.

The Boral program has acceptance criteria for the physical dimension checks by comparing data collected to initial values. If these are not met, neutron attenuation testing is evaluated to ensure adequate material capability exists. Acceptance criterion for this testing is that a decrease in B-10 content does not result in a failure to maintain the 5% sub-criticality margin for the spent fuel pool or, in other words, the determined B-10 areal density is higher than the minimum areal density used in the NCS AOR.

Material dimensions and boron content are assumptions in the NCS AOR. Ensuring that any changes noted during surveillances are properly evaluated ensures the safety function of the racks continues to be met.

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

NPPD Response: The NPPD SFP NCS AOR does not explicitly incorporate coupon monitoring biases or uncertainties.

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

NPPD Response: Other than scenarios reported in item 4.a above, the NCS AOR does not account for degradation in adjacent panels.

5) ***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).***

NPPD Response: NPPD does not use Boraflex, Carborundum, or Tetrabor as neutron-absorbing materials.