

# Evaluation of Neutron Absorber Panels from Zion Spent Fuel Pool

Hatice Akkurt<sup>1</sup>, Matt Harris<sup>2</sup>, Ashleigh Quigley<sup>2</sup>

<sup>1</sup>Electric Power Research Institute (ERI)

<sup>2</sup>Curtiss-Wright Corporation

ANS Winter 2016 November 8, 2016



### **Neutron Absorber Materials**

Neutron absorber materials are used to increase storage space while maintaining criticality safety margins

- Boral
- Boraflex (only few credits)
- Metamic
- Alcan
- Carborundum
- Borated SS

In addition to the U.S., Boral is used in many countries including Taiwan, Korea, Mexico

# \*Only6 out of 28 pools take credit for Boraflex as absorber

# NEI Industry Neutron Absorber Survey for US, 2013

- 70% response rate
- 104 pools: Shared pools treated as single response
- Several pools have multiple neutron absorbers



### **Neutron Absorber Material: Boral**

- AI-1100 alloy particles mixed with finely divided boron carbide powder
- Aging/Degradation issues:
  - Blistering
  - Pitting (small, localized)
- EPRI Boral database contains data from many Spent Fuel Polls (SFPs) extending over 25 years
  - To date, no observed loss or redistribution of B<sub>4</sub>C
- Concern over long term performance and impact on criticality; hence, potential safety impact
  - A draft Generic Letter, for comments, was issued by the NRC in March 2014.
  - The Generic Letter was revised and issued in final form in April 2016
  - Responses were due November 3, 2016









### **Technical Questions for Neutron Absorber Materials**

- 1. What are the conditions of the neutron absorber panels in SFPs? Is there any gross degradation that could cause potential concern for criticality safety of the pools in the near or long term?
- 2. Is the coupon monitoring approach adequate for monitoring the conditions of the panels as part of an aging management program?
- For plants that do not have coupons, do current in situ measurement approaches provide accurate results? Could such in situ approaches be used as an alternative monitoring approach?





## **Zion Comparative Analysis Project**



#### Objectives

- Evaluate the condition of the Boral panels after being in Zion SFP over 22 years
- Verify that the current monitoring approaches provide meaningful results
  - The two monitoring approaches are:
    - Periodic measurements on surveillance coupons
    - In-situ measurement using BADGER

#### EPRI and NRC signed a MOU for this project



## **Zion Power Station & Spent Fuel Pool**

- Westinghouse PWR operated from 1973 to 1997
  - Fuel in SFP since 1997
- Re-racked using Boral panels in 1993
  - Coupons in the pool
  - Access to previous coupon measurements





- Fuel off-loading started in December 2013 as part of decommissioning schedule
- 2 regions, Region 1 and 2



## **Zion Water Chemistry**

Water chemistry measurements performed every 7 days; unless need for more frequent measurements





## **Zion Water Chemistry**



Based on EPRI water chemistry guidelines: CI & Sulfate concentration < 150 ppb



## **Zion Coupons**

- Coupon Tree removed from Zion SFP
- 10 coupons shipped to PSU for analyses
  - Access to previous coupon measurement reports



#### **Coupon Analysis**

- Length measurements: L1, L2, L3
- Width measurements: W1, W2, w3
- Weight, thickness, density measurements

#### Areal density measurements:

- After Irradiation areal density measurements at 5 locations, A, B, C, D, E
- Pre-irradiation areal density measurements at 3 locations, A, C, E





- Coupon L = 15" +/- 0.063";
  W = 7.5" +/- 0.063"
- All coupons were encapsulated using SS
- <u>Thickness:</u>
  - Region 1: 0.101"
  - Region 2: 0.085".



## **Zion Coupon Areal Density Measurements**



- Between 1994 and 2009, one coupon from each region was analyzed
- The areal density measurements from 2015 are compared to the previous coupons measurements, performed between 1994 and 2009
- The areal density measurements from 2015 are in excellent agreement with the pre-characterized values

Zion coupon results presented in detail I EPRI report **3002008195**, "*Evaluation* of *BORAL*® *Coupons from Zion Spent Fuel Pool*", October 2016

Available from www.epri.com



### Zion Module Removal & Panel Harvesting





Module B – After 1<sup>st</sup> cut

- **Two modules** (one from Region1 and one from Region 2) removed from Zion SFP and shipped to Alaron for panel harvesting
- Based on BADGER measurements, 6 panels from Region 1 and 6 panels from region 2 were selected for analyses
- Two of the Region 1 panels were damaged during processing
- Those panels were kept for Areal Density measurements (to compare against BADGER) but two additional panels harvested for full analyses





2K20S Panel damaged during cutting after removal from Zion SFP



### From Panels to Samples



Region 2 panels are being measured, labeled, and marked for sectioning

- Each panel (144") divided into 12 sections
- EPRI & NRC received 6 sections/panel
  - Alternated between odd-even
    number for different panels
- EPRI panels shipped to PSU for analyses
- NRC panels shipped to SRNL for analyses







#### Samples packed for shipment



## **Overview of Condition of Panels**

Based on visual inspection, general observations are:

- With the exception of externally damaged panels, both Region 1 and Region 2 panels were in good condition
- Only one very small blister on one of the section of the panels (which was identified under microscope)
- Externally damaged panels showed blisters but those occurred after removal from the Zion SFP
- Showed general corrosion, flow patterns, some pitting but no evidence of significant degradation
- Overall, Region 1 panels were in much better condition
  - No SS encapsulation allowed a thick oxide layer formation, which acted as protective layer









#### **Zion Panel Areal Density (AD) Measurements**

Areal density measurements performed on all EPRI samples



For each sample, areal density measurements performed at 6 locations

- Panel length=144"
- Divided into 12" sections
- Distributed alternating odd/even numbers/panel between NRC & EPRI
  - 6 EPRI sections/panel
  - 6 points for AD measurement/section
- <u>Region 1</u>: 8 Panels → 288 AD measurement points
- <u>Region 2</u>: 6 panels → 216 AD measurement points



### **Region 1 Panel Areal Density (AD) Measurements**



- All of the measured AD values are above minimum certified AD values
- All of the **measured AD values** are **above nominal AD values** (error bars represent 3sigma)
- There are variations in AD within the same panel
- There are variations in AD for the panels that are in the same cell
  - 2J19N & 2J19W are from the same cell
  - 2L19E, 2L19N, 2L19S are from the same cell
- Panels 2K20S and 2K21 are the damaged panels



## **Region 2 Panel Areal Density Measurements**



- All of the measured AD values are above minimum certified AD values
- Few of the measured AD values are below nominal AD values (error bars represent 3sigma)
- There are variations in AD within the same panel
- There are variations in AD for the panels that are in the same cell
  - 5L9E & 5L9S are from the same cell
  - 5M7E & 5M7S are from the same cell
  - 5M12E & 5M12S are from the same cell



### **Distribution of Areal Density Measurements for Zion Panels**



#### **Region 1 - Tech Spec:**

Min. certified AD=0.030 &

Nominal AD=0.0324 g <sup>10</sup>B/cm<sup>2</sup>

#### Region 1 – AD Measurements:

Min.=0.0331; Mean=0.0351; Max=0.0370 g<sup>10</sup>B/cm<sup>2</sup>



Region 2 - Tech Spec:

Min. certified AD=0.024 &

Nominal AD=0.027 g <sup>10</sup>B/cm<sup>2</sup>

#### **Region 2 – AD Measurements:**

Min.=0.0265; Mean=0.0279; Max=0.0295 g<sup>10</sup>B/cm<sup>2</sup>



### Variations in Areal Density for Zion Panels – Region 1



#### **Variations in Areal Density**

- From panel to panel; for different points in the same panel; for different points within the same section
- No dependence in AD with axial height



### **Variations in Areal Density for Zion Panels – Region 2**



#### **Variations in Areal Density**

- From panel to panel; for different points in the same panel; for different points within the same section
- No dependence in AD with axial height



### **Summary and Future Work**

- To evaluate the condition of neutron absorber materials with real data, panels removed from Zion SFP.
  - Panels were in Zion SFP for over 20 years.
- Panels are in general in very good condition.
  - Minor pitting and only one very small blister on one sample.
- Panel areal density values do not show any indication of boron loss.
  - Areal density values for both Region 1 & Region 2 are above minimum value for all points
- EPRI report (3002008195) on Zion coupon is published.
- EPRI report (3002008196) on Zion panels will be published this year.
- In situ measurement analysis is ongoing. Reasons behind discrepancies between BADGER and panel results are not clear yet.





### **Together...Shaping the Future of Electricity**

