Neutron Absorber Surveillance
Industry Perspective

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Neutron Absorber Surveillance
Industry Perspective - Topics

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- **TVA Fleet Neutron Absorber Program**
  - ✓Background
  - ✓Browns Ferry
  - ✓Sequoyah
  - ✓Watts Bar
- **Aging Management of Neutron Absorbers**
- **Generic Industry Actions**

Neutron Absorber Surveillance

Fleet Neutron Absorber Surveillance - Background

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	BFN U1	BFN U2	BFN U3	SQN	WBN
Type of Rack	High Density	High Density	High Density	High Density	Med Density
Rack Vendor	GE	GE	GE	Holtec	PaR
In-Service Date	1978	1978	1978	1995	1980 *
Rack Material	SS	SS	SS	304 SS	304 SS
Neutron Absorber Material	Boral	Boral	Boral	Boral	Boral
Vented	Yes	Yes	Yes	Yes	No / Yes **
Coupons Available	No	No	Yes	Yes	No
Date Coupons Installed	N/A	N/A	1983	1995	N/A
Initial Testing	100% Neutron Attenuation	100% Neutron Attenuation	100% Neutron Attenuation	Not Required	100% Neutron Attenuation ***

* PaR racks were initially installed at SQN – transferred to WBN in 1997.
** Sealed during use at SQN – vented before installation at WBN.
*** Performed during initial installation at SQN in 1980.

Neutron Absorber Surveillance

Fleet Neutron Absorber Surveillance - Background

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Issues Identified Between 1978-1985

- **Rack wall swelling due to off-gassing of absorber material into the sealed cavity where the material resides**
- **Blistering of Boral due to water intrusion into the absorber matrix**

Issue	Site	Date	Material	Report
Rack Wall Swelling	Haddam Neck	Apr 1978	Carborundum	LER 78-004
Rack Wall Swelling	Monticello	Aug 1978	Boral	Observed during fab
Rack Wall Swelling	Kewaunee	Dec 1980	B4C	LER 80-039 & 040 SER 13-81
Rack Wall Swelling	Maine Yankee	Oct 1982	Boral	LER 82-033 IN 83-29
Blistering of Al Clad	Cooper	1982	Boral	
Blistering of Al Clad	Zion	1982	Boral	
Blistering of Al Clad	Browns Ferry	Oct 1985	Boral	

Neutron Absorber Surveillance

Browns Ferry Neutron Absorber Surveillance

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- **Initial 100% Neutron Attenuation Test performed to verify presence of absorber plates**
- **Initial Coupon Surveillance program intended to verify that edge corrosion rate predicted by GE was conservative**
- **Cavity where Boral resides was vented before installation to prevent rack wall swelling – racks off-gassed for three days after exposure to water**

- **Coupons are not from the same lots as the Boral in the racks**
- **Coupons were pre-characterized**
- **16 coupons initially installed**
- **Initial commitment required examination of two coupons every two years for six years**

Neutron Absorber Surveillance

Browns Ferry Neutron Absorber Surveillance

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- **First coupon retrieved in 1985 - <u>blisters found</u>**
- **The presence of blisters led to retrieving an additional four coupons for destructive testing. The following tests were performed by GE and the University of Michigan:**
  - ✓ Visuals
  - ✓ Dimensional Measurements
  - ✓ Neutron Attenuation
  - ✓ Neutron Radiographs
  - ✓ B-10 areal density
  - ✓ Scanning Electron Microscopy (SEM)
- **Test results revealed that the material was performing as designed, even at the blister sites. No safety issues.**

Neutron Absorber Surveillance

Browns Ferry Neutron Absorber Surveillance

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- **Blisters were unexpected, and as a result, the surveillance program was expanded to include monitoring blister formation and behavior (and any additional anomaly observed such as pitting)**
- **Surveillance frequency was increased**
- **11 coupons were left available for program in the SFP (sheathed)**
- **5 bare Boral plates were installed in 1987 (unsheathed)**
- **Routine evaluations performed by site Metallurgical Engineer**

Neutron Absorber Surveillance

Browns Ferry Neutron Absorber Surveillance

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Coupon surveillance performances:

Date	Destructive Exam	Inspection Type
Oct 1985	All destructively examined	Visual / Dimensional Neutron Attenuation
Jan 1987	None	Visual / Dimensional
Oct 1987	None – Unsheathed one coupon	Visual / Dimensional Dye Penetrant
Jun 1988	None – Unsheathed one coupon	Visual / Dimensional
Jun 1989	None – Unsheathed one coupon	Visual / Dimensional
Mar 1991	None – Unsheathed one coupon	Visual / Dimensional Liquid Penetrant
Jul 1992	None	Visual / Dimensional
Aug 1993	None	Visual / Dimensional
Aug 1994	None	Visual / Dimensional
Dec 1995	None	Visual / Dimensional
Oct 2003	None	Visual / Dimensional
Aug 2010	None	Visual / Dimensional

Neutron Absorber Surveillance

Browns Ferry Neutron Absorber Surveillance

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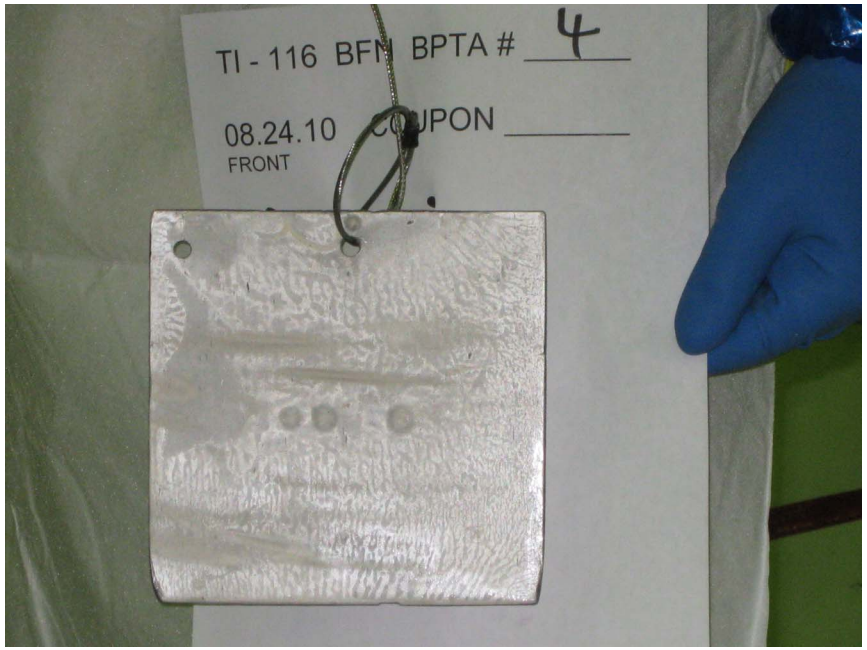
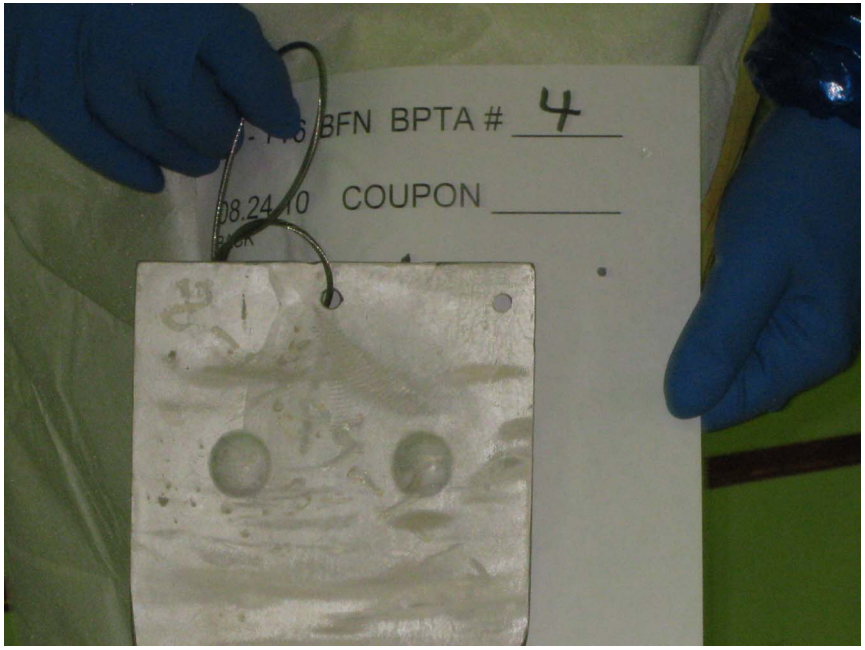
Bare coupon from the 2010 surveillance (unsheathed in 1988). Resided in SFP for 27 years. Essentially no change since 1995.

Coupon #29
Front



Coupon #29
Back



Neutron Absorber Surveillance

Sequoyah Neutron Absorber Surveillance

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- **Coupons are from the same lots of material as that in the racks**
- **Coupon pre-characterized:**
  - ✓ Visual condition
  - ✓ Dry weight
  - ✓ Dimensions
  - ✓ Density
  - ✓ B-10 areal density
- **12 coupons were installed at the same time as the racks**
- **Coupon exposure was accelerated – surrounded by recently discharged fuel with the highest burnup for at least 5 back to back to back discharges**
- **No commitment to examine coupons was necessary for re-racking. Boral deemed stable – monitor industry. (Evidenced by NRC letters to Holtec in 1995 and Korea Hydro in 2003)**

Neutron Absorber Surveillance

Watts Bar Neutron Absorber Surveillance

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- **Initial 100% Neutron Attenuation Test performed to verify presence of absorber plates (in 1980 at SQN)**
- **No coupons exist for current racks**
- **Original rack design contained Boral in a sealed cavity, therefore no need for surveillance**

- **Boral cavity was vented prior to installation to prevent rack wall swelling**
- **No commitment to have a surveillance program was necessary for re-racking. Boral deemed stable – monitor industry. (Evidenced by NRC letters to Holtec in 1995 and Korea Hydro in 2003)**

Neutron Absorber Surveillance

Neutron Absorber Aging Management Program

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- **IN 2009-26 – Degradation of Neutron Absorbing Materials in the SFP**
- **NUREG-1801 – Generic Aging Lessons Learned (GALL), Section XI.M40 Monitoring of Neutron-Absorbing Materials Other than Boraflex (License Renewal)**
- **IN 2012-13 – Boraflex Degradation Surveillance Programs and Corrective Actions in the SFP**

This recent Industry Operating Experience led to:

- **Performing criticality evaluation for WBN racks (flux trap racks) accounting for blisters – Determined no impact on criticality**
- **Implementation of a Fleet-wide SFP Neutron Absorber Material Monitoring Program incorporating Aging Management plans**

Neutron Absorber Surveillance

Neutron Absorber Aging Management Program

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- **Program consists of tiered approach**
- **Provides for three types of testing:**
  - ✓Basic Coupon Surveillance
  - ✓Full Coupon Surveillance
  - ✓In-Situ Testing
- **Type and frequency of testing determined by events and conditions**
- **Need to ensure coupons are available for the life of the SFP racks**

Neutron Absorber Surveillance

Neutron Absorber Aging Management Program

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Impact on Fleet Program

	BFN	SQN	WBN
Current Requirements	Coupons ✓ Visual ✓ Dimensional ✓ Dormant since 2003	None	None
New Program Requirements	Coupons ✓ Visual ✓ Dimensional ✓ Restarted in 2010 ✓ Blackness Testing of coupons prior to period of extended operation (license renewal) ✓ Frequency to be determined by results but not to exceed 10 yrs In-Situ inspection of racks if indicated by coupons	Coupons ✓ Visual ✓ Dimensional ✓ Blackness Testing of coupons prior to period of extended operation (license renewal) ✓ Frequency to be determined by results but not to exceed 10 yrs In-Situ inspection of racks if indicated by coupons	In-Situ Inspections ✓ Blackness Testing of racks ✓ Frequency to be determined by results but not to exceed 10 yrs

Program Elements

1. Coupons Surveillance Program

A. Coupons (description)
B. Coupon Characterization
   (1) Visual condition
   (2) Dry weight
   (3) Dimensions
   (4) Specific gravity and density
   (5) B-10 areal density
C. Accelerated Coupon Exposure

D. Coupon Surveillance Inspection Scope

(1) Basic Coupon Surveillance

a. Visual Observations and photograph

b. Dimensional Measurements (Length, Width, and Thickness) of coupon

c. Dimensional Measurements (length, width, and height) of any anomaly (such as blisters)

d. Weight (without drying)

Neutron Absorber Surveillance

Neutron Absorber Aging Management Program

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(2) Full Coupon Surveillance

In addition to the items required for Basic Coupons Surveillance:

a. Density measurements

b. B-10 Areal Density Measurements (Blackness Testing)

c. Microscopic Analysis (Pit size and Depth)

d. Localized Degradation Characterization

e. Characterization of Material Anomalies

f. Evaluation of Gap Formation

Neutron Absorber Surveillance

Neutron Absorber Aging Management Program

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E. Coupon Surveillance Frequency

F. Coupon Surveillance Acceptance Criteria

(1) A decrease of no more than 5% in B-10 areal density, as determined by blackness testing, is acceptable.

(2) An increase in thickness at any point should not exceed 10% of the initial thickness at that point.

2. In-Situ Inspections

A. In-Situ Inspection Scope

B. In-Situ Inspection Frequency

Neutron Absorber Surveillance

Neutron Absorber Aging Management Program

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C. In-Situ Testing Acceptance Criteria

(1) A decrease of no more than 5% in B-10 areal density, as determined by blackness testing, is acceptable.

3. Spent Fuel Pool Environment

4. Fuel Handling in the Spent Fuel Pool

5. Industry Operating Experience with Neutron Absorbers

6. Future Spent Fuel Pool Racks

Neutron Absorber Surveillance

Industry Actions

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Current industry actions are being led by EPRI through the Neutron Absorber User's Group (NAUG):

- **Yearly meetings focused on neutron absorbers (28 years)**
- **TR-1019110,** "Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications," November 2009
- **Projects for 2012:**
  - ✓ **TR-1025204**, "Strategy for Managing the Long Term Use of BORAL in Spent Fuel Storage Pools," July 2012
  - ✓ Begin Boral 5-Year accelerated corrosion test
- **Top 3 projects identified:**
  - ✓ Industry-wide Boral coupon surveillance plan
  - ✓ Testing of used Boral racks
  - ✓ Research on new materials

Considering development of neutron absorber surveillance guidelines

- **Would be included in the NEI Criticality Guidance**