CURTISS WRIGHT Flow Control Company

Improved BADGER

Industry Meeting with NRC
Neutron Absorber Material Degradation

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Evolution of BADGER

- IN 87-43, IN 93-70 & IN 95-38 identified Boraflex performance issues
- Industry requested EPRI to develop Boraflex performance monitoring tools
- 1995 Initial BADGER fabrication
- June – August 1995 Initial clean pool tests in Penn State RSEC Cobalt-60 pool
- April 1996 – Demonstration at Peach Bottom
- January 1997 – PWR BADGER demonstration at McGuire Unit 1
- 2003/4 redesign of control software, detector connections

Need for Improvement

- GALL Report (NUREG-1801) Aging Management Plans require in-situ testing for life extension
- Increased reliance on BADGER as an "Operability Determinant"
  - BADGER is no longer viewed as a "Management Tool"
- Limitations of Use for High Areal Density Absorbers (i.e., Carborundum)
- NRC issuance of BADGER/RACKLIFE Technical Letter Reports
  - "Boraflex, RACKLIFE and BADGER: Description and Uncertainties"
  - "Initial Assessment of Uncertainties Associated with the BADGER Methodology"

BADGER Design Improvement Process

Phase I:

- Specifically addresses short term improvements
- Key Improvements to address **reliability, repeatability and accuracy**
- Head improvements
  - Improved shielding
  - Alignment
  - Cable shielding
  - Water tight connections

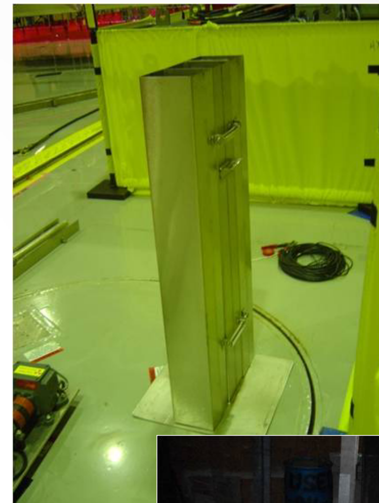
Phase II:

- Longer term
- Software redesign
- Analysis Method(real-time?)
- Drive System overhaul (Now under way)

Design Improvement Requirements

Neutronic

- System must provide a counting geometry that limits interference from undesirable neutron sources which are not transmission neutrons
- Interference of rack characteristics which may affect final results must be quantifiable
- Calibration standards must closely mimic the rack material or provide a result which has been demonstrated to be conservative
- Calibration cell dimensions and wall thicknesses should mimic rack cells
- Calibration cell materials should mimic rack cell materials
- Calibration cell neutron absorber configurations should mimic rack cell configuration
- Calibration standards will be of known and certifiable ^{10}B areal density



Design Improvement Requirements

Mechanical

- BADGER test equipment has been specifically designed for compatibility with plant rack design. This would include: calibration cell, source head, and detector head
- Unencumbered insertion, removal and vertical motion in the fuel cell of the BADGER probe head
- Probes must maintain identical axial position at all measurement points
- Probes must be aligned such that they are in close contact with the cell walls containing the panel being scanned

Design Improvement Requirements

Electrical

- Power supply filters, or other means necessary to ensure the testing results are not compromised by the supply voltage
- Neutron count signal cable connections are secure and reliable and during operation - not subject to water intrusion
- Neutron count signal cable connections are secure and reliable and during operation not subject to mechanical degradation due to unavoidable cable tugging and displacement during operation
- Detector isolation circuitry adequate to preclude noise disruption of neutron count signals
- Proper EMI/RFI shielding to prevent signal ingress/egress

Phase I

- Head Alignment
  - Side-to-side movement of BADGER heads contributes to uncertainty of measurements
  - Older Heads were built to tight cell ID tolerances to eliminate “sway”
  - In some instances, heads would “Stick” if tolerances were tight or rack fabrication artifacts (weld beads, cell deformation, etc.) were larger than indicated.
  - Head walls were thin gage to allow for spacing of detectors and connector flange, preventing the ability to cut chamfers or allow for large bend radii.
  - Implemented a series of ball-bearing spring plungers on 3 sides to align heads

Phase I

- Detector Shielding
  - Previous designs shielded by single layer of BORAL
  - Up to 30% of counts may result from backscattered neutrons
  - Experimented with borated polyethylene
  - New design utilizes a robust quantity of aluminum-boron carbide metal matrix composite to shield the detectors from neutron backscatter

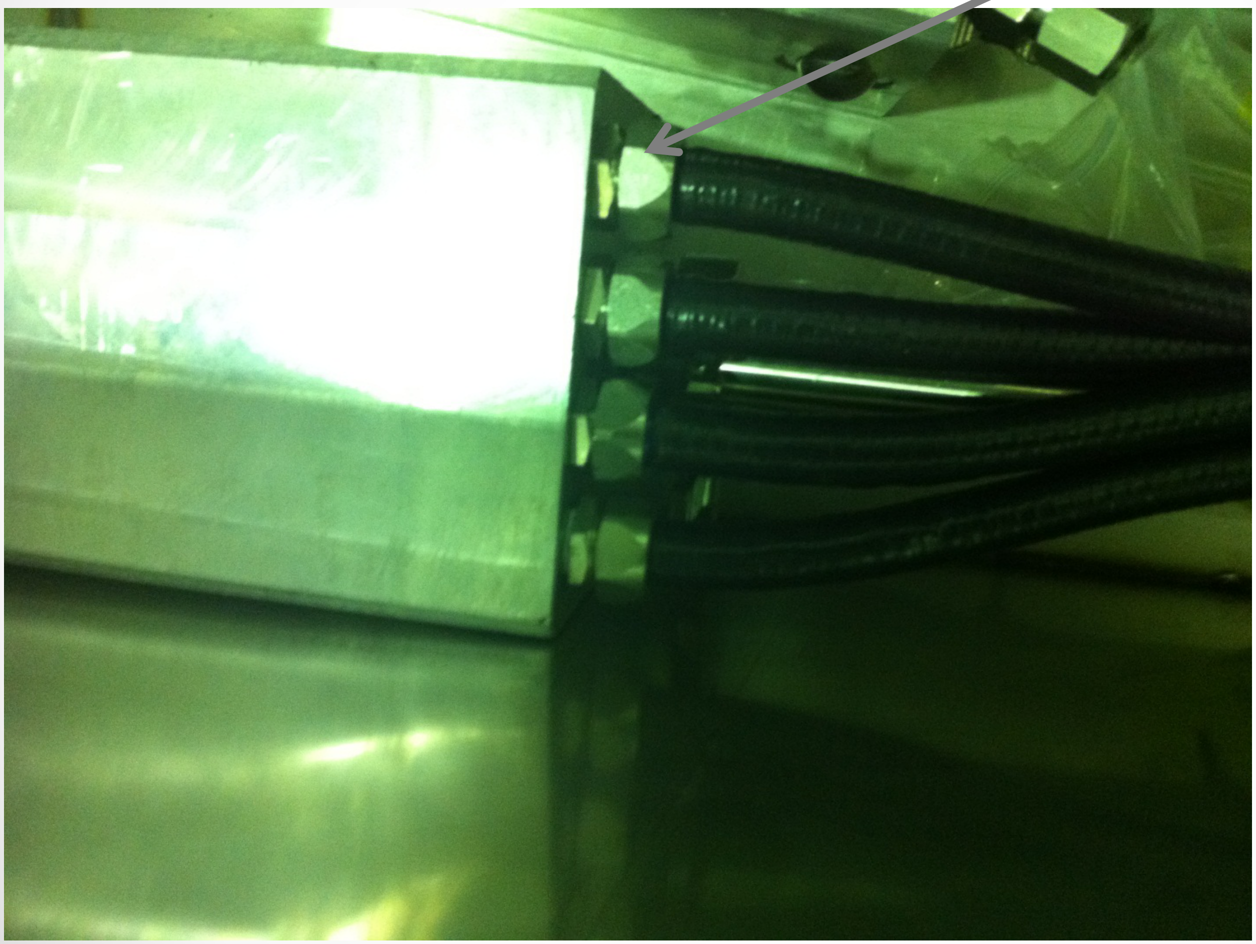
Phase I

- Cable Shielding
  - 45ft coaxial detector cables (typical length is 5ft for BF_3 tubes)
  - Picks up gamma noise from fuel and 'hot' components
  - New design houses coax inside a stainless steel shielded conduit

- Water Tight Connections
  - Previous design utilized a sealed coax straight plug into a bulkhead-type fitting(o-ring).
    - Bulkhead fitting was water-tight; straight plug was not.
    - Attempted to seal with combination of RTV, heat shrink tubing and self-sealing electrical tape.
  - New design utilizes improved connectors
    - Water tight to ~90ft
    - Allows closer spacing of detectors such that additional shielding can be placed on the sides.

Phase I

Detector Connections



Current Testing Status

- Clean Pool test at PSU - September
- Motor Control issues resulted in later test date
- Decision to redesign and update entire motor drive
- Phase II initiated