Use of RACKLIFE and BADGER and Input to Criticality Analysis

Public Meeting on Neutron Absorbing Material Degradation

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Overview

- RACKLIFE and BADGER have been used to model and measure Boraflex degradation for almost 20 years
- Initiated around time of GL 96-04
- No SFP criticality events
- Historically, RACKLIFE and BADGER have been used to show that the degradation remains acceptable on a pool-wide basis
  - Criticality analysis have modeled gaps, shrinkage and overall degradation
  - RACKLIFE and BADGER have supported these inputs
  - RACKLIFE used inputs representative of the entire pool
- As degradation levels have increased, BADGER and RACKLIFE have been used to declare individual cells inoperable (unavailable to store fuel)
  - BADGER measurements made on individual panels
  - RACKLIFE inputs have been modified to bound all individual panels
- Currently used as temporary solution until credit for Boraflex is discontinued

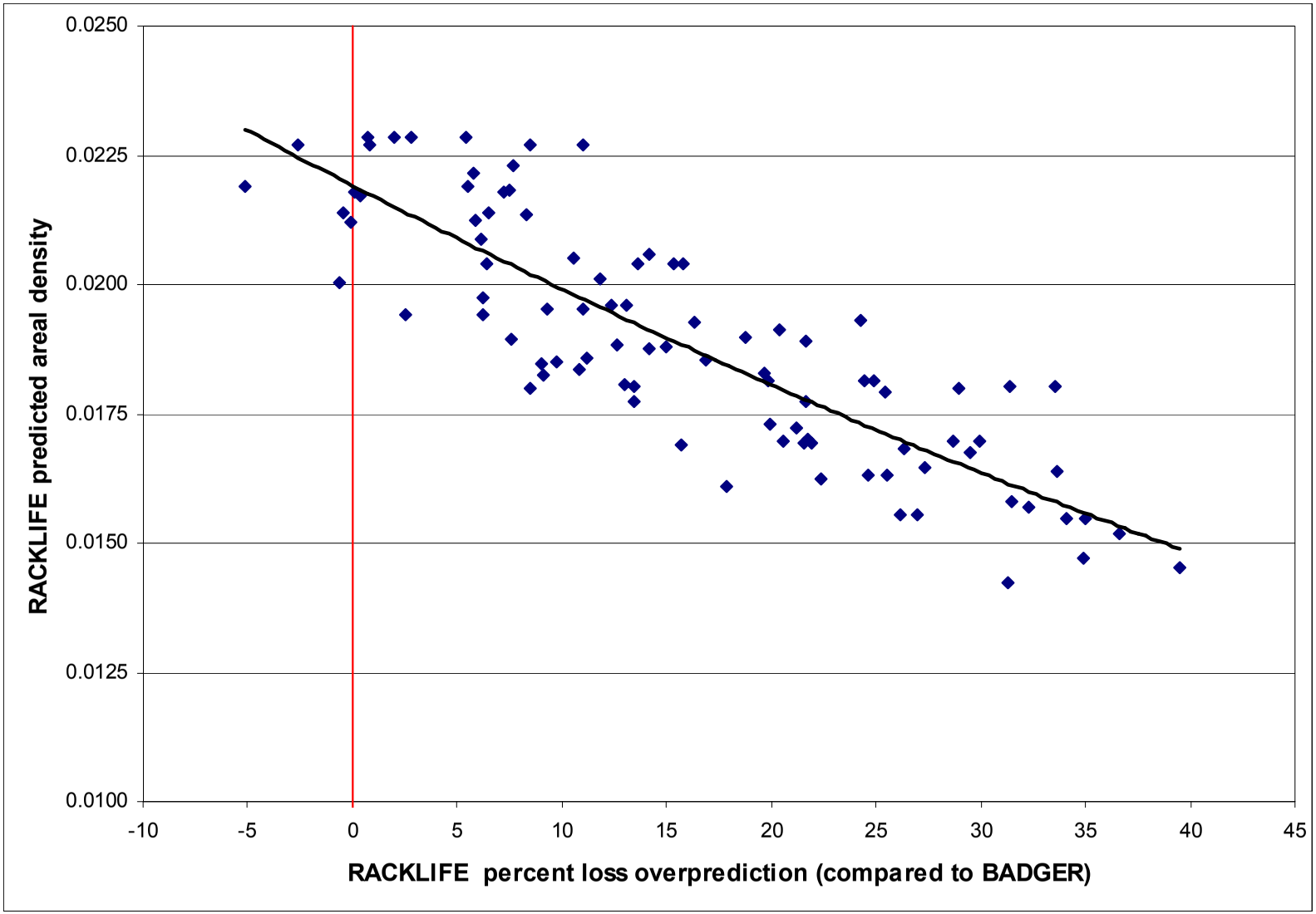
RACKLIFE Input

- Significant effort recently to validate and update all RACKLIFE inputs
- Validation of general input parameters
  - Pool Geometry parameters generally use values from plant drawings and Boraflex batch data
  - Boraflex thickness adjusted to match minimum as-built Boraflex areal density (from batch data)
- Periodic input data updates
  - Pool history (silica, temperature, pH)
  - Assembly movement and power history (determines accumulated dose on individual panels)
- Escape Coefficient used to benchmark model to actual data
  - Determined primarily by rack design
  - Determined secondarily by temperature and degradation level

RACKLIFE Benchmarking

- RACKLIFE predicted silica concentrations matched to actual plant data throughout life of Boraflex SFP racks
- Statepoints run at all BADGER test dates to benchmark model to BADGER test data
  - Escape coefficient adjusted to attempt to bound all BADGER data
  - Escape coefficient increases over time
  - RACKLIFE over predicts degradation compared to BADGER (RACKLIFE has a positive bias)
  - RACKLIFE over prediction increases as degradation level increases

BADGER/RACKLIFE comparison



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BADGER Testing

- Performed to benchmark RACKLIFE model and validate assumptions used for other Boraflex degradation mechanisms
  - Panel average areal density (RACKLIFE benchmark)
  - Individual gap size
  - Cumulative gap size
  - Gap locations
  - Panel shrinkage
  - Local dissolution
- Cells selected to get representative sample of SFP, but biased toward higher dose (and higher degraded) panels
- Results compared to previous campaigns

BADGER and RACKLIFE Frequencies

- Dependent on site specific commitments
- BADGER required every 3-4 years in each SFP with Boraflex credited as neutron absorber
  - Cells declared inoperable if measured areal density falls below criticality analysis limit
  - Cells declared inoperable if gap size exceeds criticality analysis limit
- RACKLIFE update required every 6-12 months
  - Current state reanalyzed
  - Projections updated
  - RACKLIFE is the “official” record of cell operability throughout the pool
  - Cells declared inoperable based on areal density data from next projected time step (so cells are taken out of service *prior* to falling below the required areal density)
- Additional testing and updates scheduled as required

BADGER and RACKLIFE Uncertainties

- BADGER and RACKLIFE contain uncertainties just like any other testing and code package
- Without any detailed data on what these uncertainties are, it is difficult to perform a systematic evaluation of each uncertainty
- Since RACKLIFE is the “official” mechanism for determining areal density throughout the pool, a validation of the RACKLIFE code can be performed using experimental (BADGER) data using the same 95/95 methodology described in NUREG /CR-6698.
  - Specific to SFP racks analyzed
  - Results in positive (conservative) bias
  - Results in 30-45% bias uncertainty – similar magnitude to September 2012 TLR, “Boraflex, RACKLIFE, and BADGER Description and Uncertainties”

Criticality Analysis

- Each Boraflex degradation mechanism modeled or evaluated separately
  - Overall panel thinning
  - Gap size based on BADGER data
  - Gaps modeled as co-located
  - Allowance added for undetected cracks (BADGER may not be able to distinguish from local dissolution, so assuming small cracks is conservative)
  - Panel shrinkage
  - Particle self-shielding
  - Local dissolution
  - Any potential seismic effects
- BADGER/RACKLIFE uncertainties included
  - Substantial impact on result ~2% Δk (total uncertainty ~2.3% Δk)
  - Bias conservatively ignored (15%), equivalent to ~1% Δk

Conclusions

- RACKLIFE model developed to perform conservative calculation of panel density for each individual panel
- BADGER used to benchmark model and validate other degradation mechanisms
- Uncertainties are present in both BADGER and RACKLIFE, but can be accounted for using 95/95 methodology
- Criticality analysis methodology results in conservative calculation of k_{eff}