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Boral Performance in Dry Storage and Transportation

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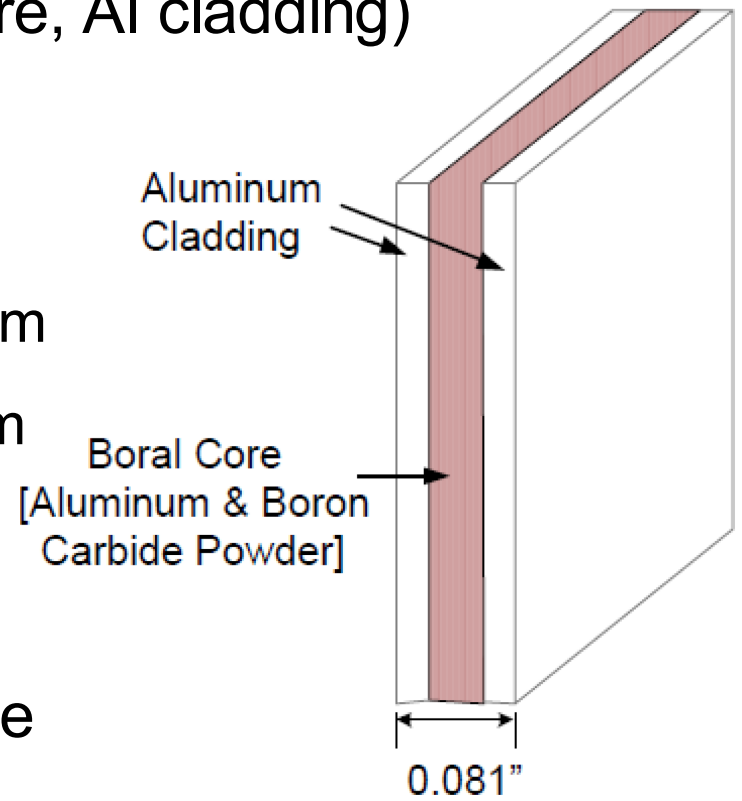
Boral®

- Cermet laminate plate (B_4C/Al core, Al cladding)
  - B_4C content: 35 – 65 wt.%
  - Core porosity: 1 – 10 %
  - Laminate thickness: 1.9 – 11.1 mm
  - Cladding thickness: 250 – 380 µm
- Subcriticality control during cask loading operations
- Moderator exclusion in dry storage



Pertinent Regulations

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- 10 CFR 72.124(a): *Spent fuel handling, packaging, transfer, and storage systems must be designed to be maintained subcritical and to ensure that, before a nuclear criticality accident is possible, at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety.*
- 10 CFR 72.236(c): *The spent fuel storage cask must be designed and fabricated so that the spent fuel is maintained in a subcritical condition under credible conditions.*

Background
Generic Safety Issue 196

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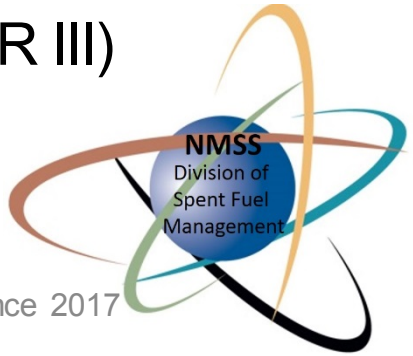
- Concerned with criticality safety as a result of blistered Boral in dry storage systems (DSSs) in the event of water intrusion (e.g., cask reflood)
- ORNL conducted a literature review and criticality assessment, which concluded that blistered Boral would remain an effective neutron absorber
  - Noted lack of comprehensive testing of older Boral (i.e., pre-manufacturing improvement program)
- GSI closed in 2006 with direction to monitor domestic and international programs (IAEA SPAR-II, SPAR III)



Differing Professional Opinion

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- NRC's organizational culture encourages, supports, and respects differing views.
  - June 29, 2016 – A former NRC staff member submitted a DPO concerning the evaluation and communication of Boral degradation effects in loaded DSSs.
  - July 19, 2016 – NRC's Office of Enforcement established an Ad Hoc Review Panel for evaluating the DPO concerns.
  - September 14, 2016 – DPO Panel issued a memorandum with conclusions and recommendations to the NMSS Office Director.

DPO Concerns

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- DSS and transportation package stakeholders have not been adequately informed by the NRC of safety and operational problems that may result from Boral degradation.
  - e.g., erosion of subcriticality margins, hydrogen generation, higher occupational doses due to bound fuel assemblies
- GSI-196 closure did not account for testing of older Boral.
  - DPO older Boral = material fabricated circa 2001 or prior
  - Potential blistering of older Boral should be investigated.

DPO Panel Conclusions

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- Subcriticality margins in DSSs and transportation packages with Boral are not sufficiently eroded by degradation observed to date to constitute a significant safety concern.
  - Uncertainty exists with older Boral due to lack of data.
- Concerns of retrievability and increased radiation exposure due to bound fuel assemblies are adequately addressed by current staff guidance.
- Communications to DSS users on precautions for hydrogen generation and combustion are adequate.

DPO Panel Recommendations

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- Communicate to stakeholders that degradation of Boral has been observed under simulated cask loading conditions, and repeated cycles may cause a licensee to be outside of its licensing basis for subcritical margin.
- Conduct an investigation of older Boral material, as recommended in the closure of GSI-196.
  - Consider testing Zion Boral material previously obtained under a separate EPRI-NRC cooperative research program.

NMSS Director Tasking Memo

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1. Staff to conduct operating experience assessment of DSSs and transportation packages that incorporated older Boral and have been subjected to re-flooding operations.
   - Determine whether any indications of potential degradation of Boral have been observed.
   - Compare assessment findings to the results and conclusions of ORNL's final letter report on GSI-196.
   - Make a recommendation as to whether further testing is warranted.

NMSS Director Tasking Memo

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2. Staff to determine if testing of Zion Boral samples can be performed on simulated dry storage environments and the associated expense for such testing.
3. Staff to document assessment findings and test feasibility in a position paper that considers the safety benefits and associated costs, and provide a recommendation for a path forward.

Operating Experience Assessment

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- Staff conducted special inspections at NAC International, TN Americas, and Holtec International, to gather:
  - Operating experience (transportation / dry storage)
  - Vendor-specific proprietary test programs
  - Inventory of loaded DSS designs
- Staff also reviewed pertinent proprietary results on EPRI's test program on older Boral.

Operating Experience Assessment – Findings

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- No spent fuel transportation packages incorporating older Boral have been shipped in the United States.
- No operating experience has been recorded by the vendors on degradation or re-flooding operations of DSSs that incorporate older Boral.

Operating Experience Assessment – Findings

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- Vendors are aware of Spain's operating experience with blistering of older Boral.
- Two vendors have conducted proprietary testing to demonstrate that blistering, deformation and delamination of older Boral is not credible in their DSS designs.
- Approximately 241 DSSs have been loaded with older Boral, which represents approximately 9% of the current inventory of in-service DSSs.

DSS Designs with Older Boral

- NAC International
  - MPC: Connecticut Yankee, Yankee Rowe
  - UMS: Maine Yankee
  - I-28: Surry
- TN Americas
  - TN-40: Prairie Island
  - NUHOMS-7P: H.B. Robinson
  - NUMOMS-24PT: Rancho Seco
- Holtec
  - MPC-68 (HI-STAR 100, HI-STORM 100): Hatch, Dresden, J.A. Fitzpatrick, Columbia Generating Station

Completed/Ongoing Activities

- Two draft reports (inspection findings/ position paper) being routed for internal review
- Test Program Planning:
  - Staff to propose independent test program per design-bases loading conditions for in-service DSS designs
  - Staff exploring options for obtaining as-fabricated older Boral material (not previously in wet storage, as Zion material)
  - Staff to engage with industry during test planning
  - Issued Pre-Solicitation Notice; Drafted Statement of Work, Government Cost Estimate, Open-Competition Request for Proposal

References

- DPO Case File for DPO-2016-002, Evaluation and Communication of Boral Degradation Effects in Deployed Spent Fuel Casks, Agencywide Documents Access and Management System Accession No. ML17069A437.

Acronyms

U.S.NRC
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- μm: micrometer
- Al: aluminum
- B_4C: boron carbide
- DPO: Differing Professional Opinion
- DSS: dry storage system
- GSI: Generic Safety Issue
- IAEA: International Atomic Energy Agency
- mm: millimeter
- NRC: Nuclear Regulatory Commission
- SPAR: Spent Fuel Assessment and Research