ADVANCED REACTOR SAFEGUARDS

MC&A for Pebble Bed Reactors

May 2022 Program Review

PRESENTED BY

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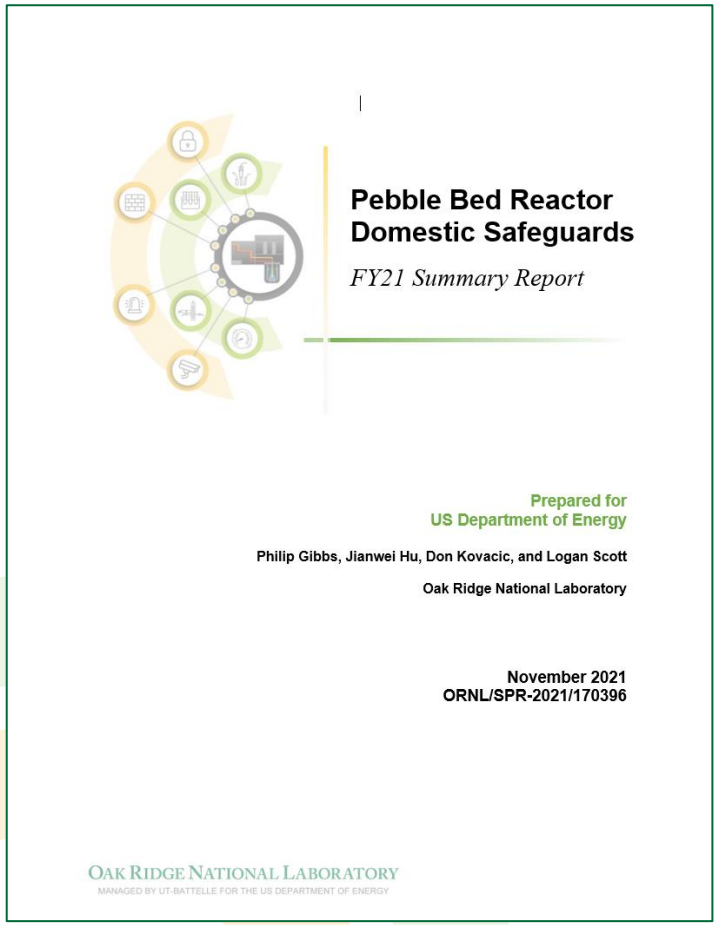
OAK RIDGE National Laboratory | Sandia National Laboratories | U.S. DEPARTMENT OF ENERGY

Fiscal Year 2022 Two New Focus Areas

1. Material Control and Accounting (MC&A) System Requirements
2. Accounting and Statistical Approach for Burnup and Production – Special Nuclear Material (SNM) Calculations

< Year End Report to summarize work on MC&A to date >

MC&A System for Pebble Bed Reactors (PBRs)



- U.S. commercial market dominated by 2 products:
  - SNMtrac® by Standish Technologies International
  - TRACWORKS ® by Westinghouse
    - *Note: Neither directly applicable to PBRs*
- FY21 Report highlights PBR differences from light water reactors (Section 2.4 and Appendix A)
  - Key challenge is rounding from large numbers of small items in differing group sizes
- Expect system to be commercially developed

Example Reactor Key Requirement Areas

- DOE/NRC reporting formats
- Generation of DOE/NRC Forms 741, 742, and 742C
- Electronic fuel receipts and movements – interface to fuel handling system
- Concept of “piece counting” – hybrid item/bulk concept
- Fuel groupings, un-groupings, movements, and inserts
- Multi-region fuel
- Obligation tracking
- Fresh, core, and spent fuel storage maps
- Extraction of burnup and isotopic data (e.g., *SNM Calculations)*

SNM Calculations - Reference

Material Control Systems for Nuclear Power Plants (ANSI N15.8-2009) Section 9.0

- ***Methods of computation*** *shall be established and utilized for determining the total element and isotopic composition of SNM in irradiated nuclear fuel assemblies and fuel components. The computed values are the basis for shipment documents, as required in 10 CFR 74.15, and material status reports, as required in 10 CFR 74.13.*
- ***Refinement of the element and isotopic computations*** *used in determining the SNM content of irradiated fuel should be considered as new technologies evolve. For reprocessed fuel, this may include a collection and comparison of reprocessing plant measurement data with computed data for fuel assemblies.*

Why is this important?

- Around 70% of the U.S. historical inventory difference (or MUF) is due to incorrectly handling this
- Incorrect handling is a significant contributor to shipper/receiver differences if/when fuel is processed

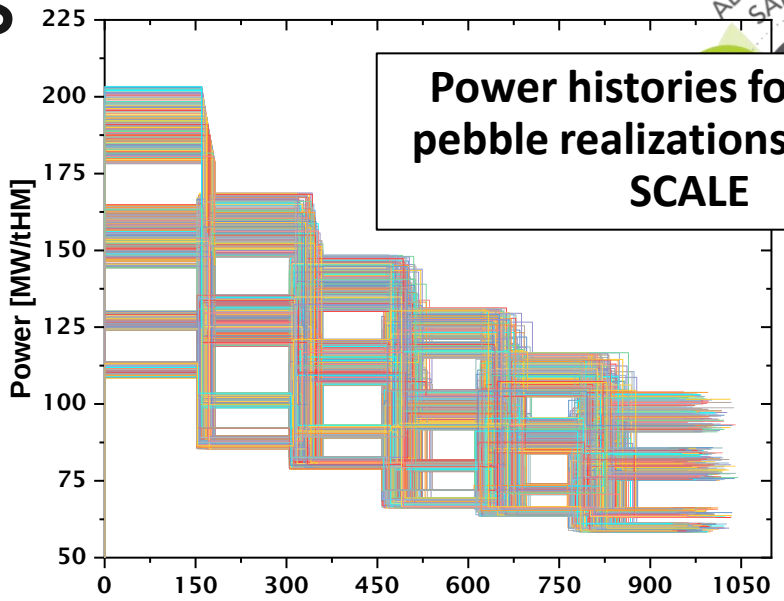
Accounting and Statistical Approach for Burnup and Production SNM Calculations

William Wieselquist

Pebble Inventory Characteristics

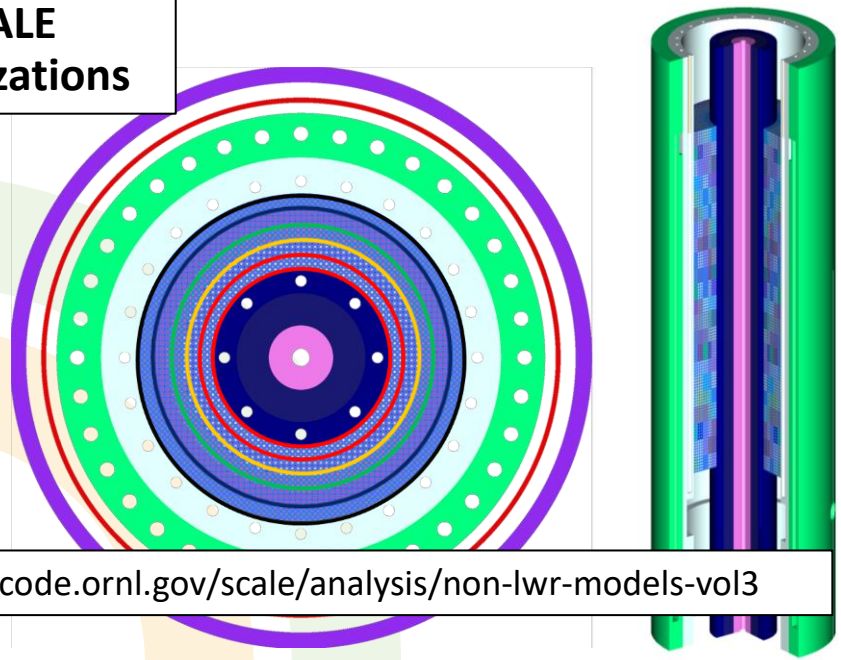
Demonstration using SCALE/ORIGAMI based on PBMR-400 benchmark

- Core is divided into several flow zones→ probability entering a flow zone equals the zone's volume ratio
- Pebbles near the inner/outer reflector have 5-20% reduced flow speed due to additional wall drag/friction

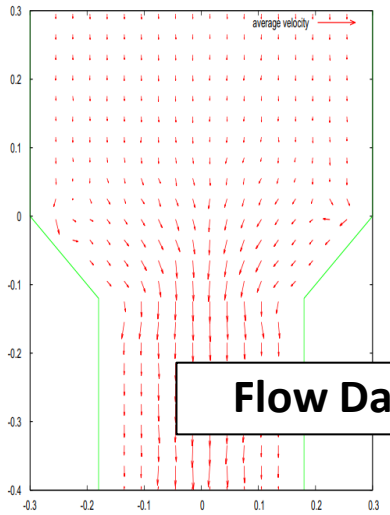


Power histories for 10,000 pebble realizations run with SCALE

SCALE visualizations



https://code.ornl.gov/scale/analysis/non-lwr-models-vol3



Flow Data

Figure 6. Flow field representation (arrow lengths are proportional to local average pebbles velocity)

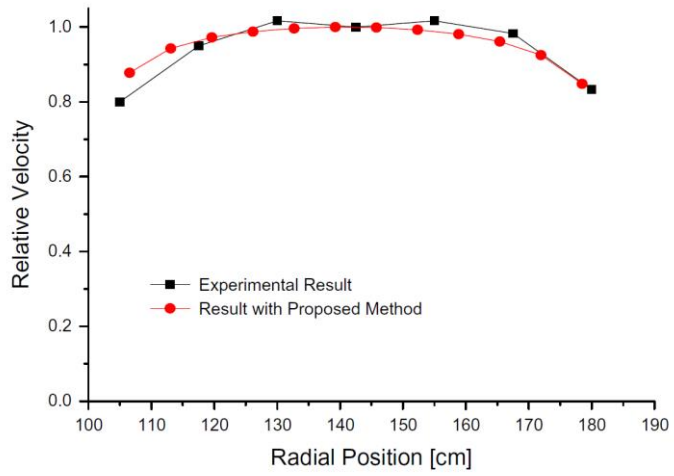
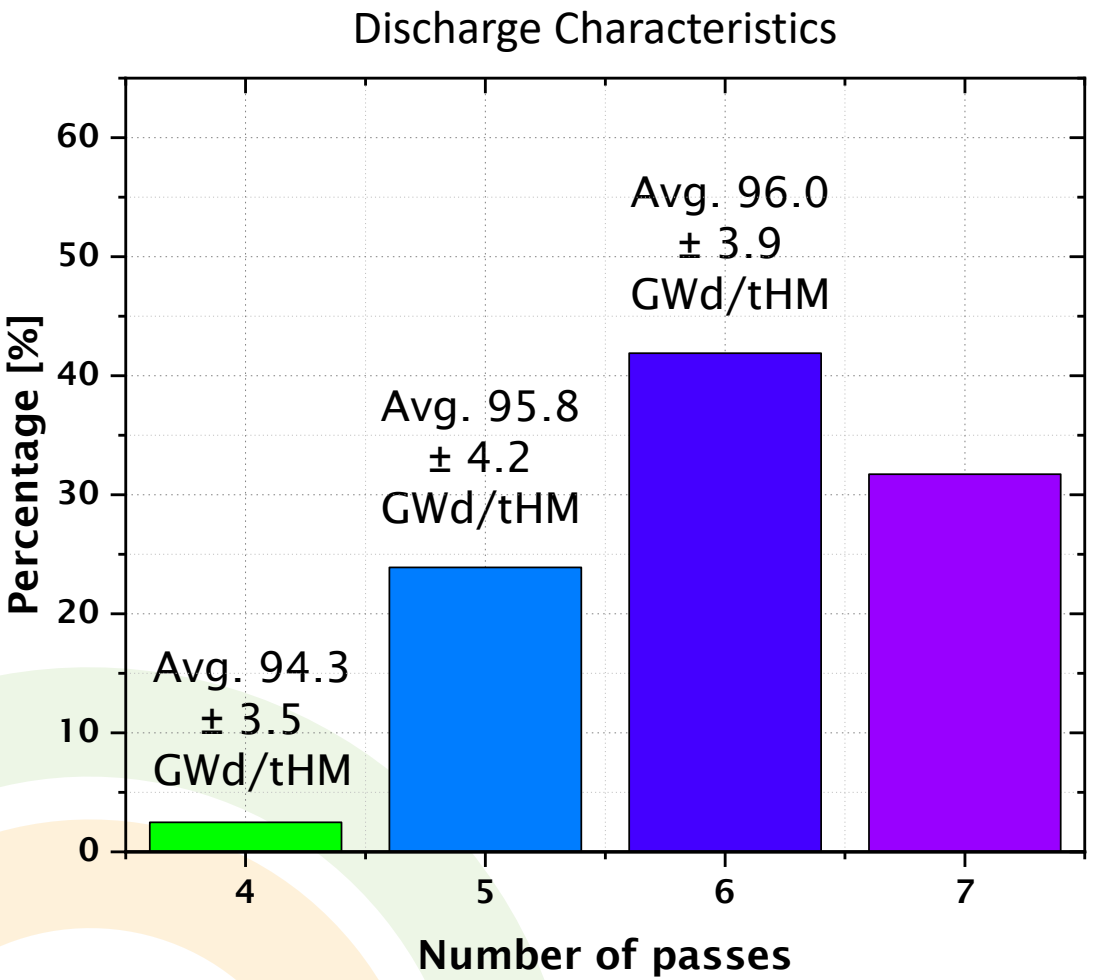


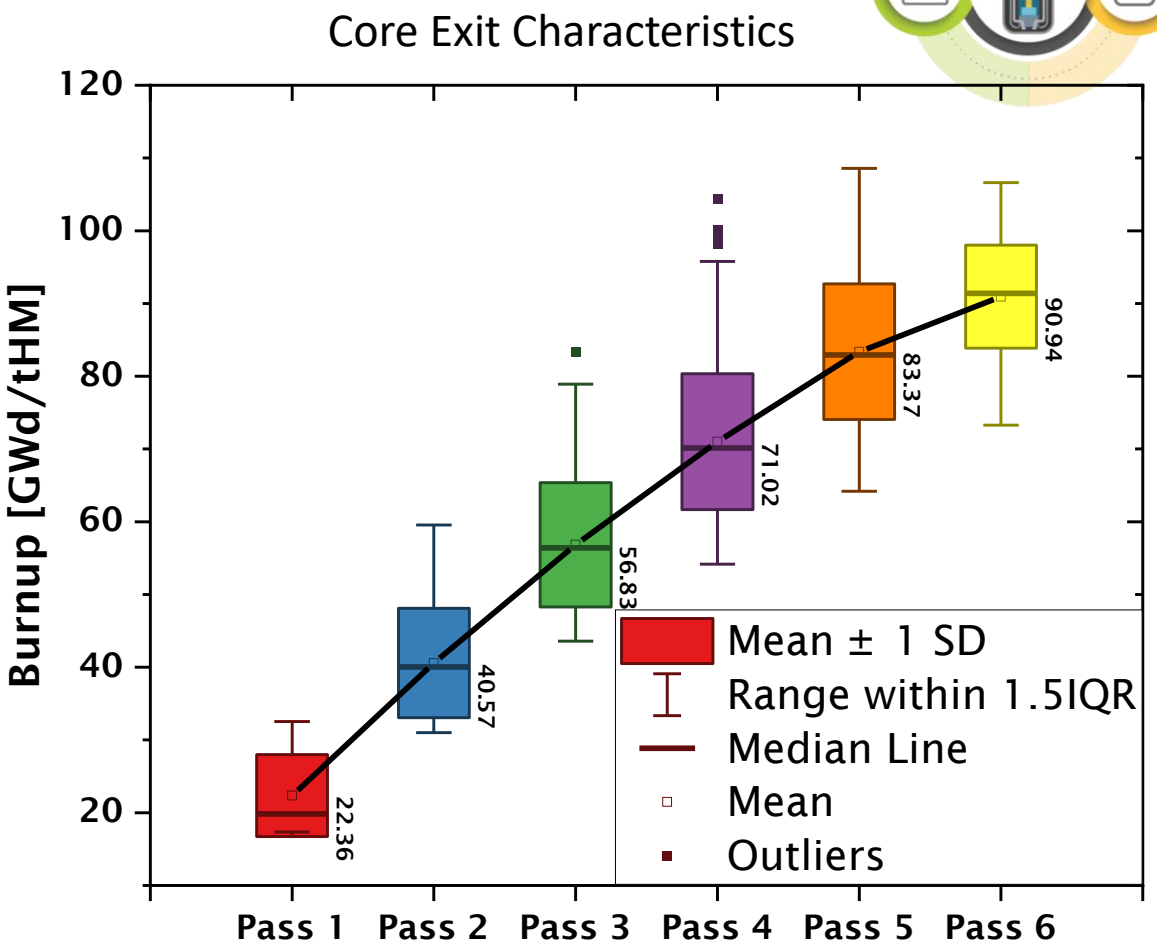
Fig. 9. Comparison of the PBMR pebble velocity results from the experiment and the proposed model.

Cogliati, J.J. and Ougag, A.M., Pebbles: A Computer Code for Modeling Packing, Flow and Re-circulation of Pebbles in a Pebble Bed Reactor Proceedings of HTR-2006, 2006.

Pebble Inventory Results



Target discharge burnup is 90 GWd/MTU achieved for about 65% of pebbles in 6 passes.



Outliers are those pebbles outside of the 1.5 Inter-Quartile Range (IQR). For a normal distribution, this would be outside approx. +/- 3σ.

Summary

- Provided highlights on MC&A systems
- Discussed SNM calculations as applied to PBRs
- FY22 concludes with a summary report covering all things MC&A researched to date
- Next steps likely to be burnup measurements and their impact on SNM calculations and spent fuel handling