Reevaluation of Room Return Corrections for Two ORCEF HEU-Metal-Cylinder Benchmark Evaluations

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- Yevgeniy Rozhikin – IPPE
  - Recommendation to reevaluate room return effects and subsequent review of results
- Scientists, engineers, and administrative support from 20 countries collaborating in the ICSBEP
Outline

- Background
  - Previous Work
- Experiments
  - History
  - Benchmarks
- Analysis
  - Room Return
  - Method

- Results
  - Summary
  - Comparison of Revised Data
- Conclusion
Conclusions from NCSD 2013

Comparison of 46 bare HEU benchmark experiments

- Basic spherical, slab, and cylindrical geometries are within $3\sigma$ of the benchmark values
  - When accounting for variations in correlated experiments with increased uncertainties
- Reasonable results for spheres and slabs
- Cylindrical system calculations appear low
  - Even for complex systems with cylinders
  - Need to investigate scatter in ORCEF cylinders
Spheres, Slabs, and Cylinders

- Consolidate data for basic geometries
- Combined correlated experiments
  - Variance-weighted average
  - Standard deviation
ORCEF Experiments

- 1960s and 1970s
- Critical experiments to support Y-12 storage, casting, and handling limits
- Verification of calculations methods and cross-sections for criticality safety
- HEU metal Oak Ridge alloy (oralloy)
ORCEF Measurement Uncertainties

- Very precise measurement capabilities at Y-12
  - Dimensions
    - ±0.0001 in.
  - Mass
    - ±0.01 g
  - Isotopics
    - ±1% $^{234}$U
    - < ±0.02 wt.% $^{235}$U & $^{236}$U
  - Impurities
    - ~500 ppm average content

- John T. Mihalczo
  - Experimenter still available for collaboration

- Further information available
  - ORNL/TM-2012/32
Existing Oralloy Series and Benchmarks

- Bare Cylinders
  - HEU-MET-FAST-051
- Beryllium Reflected
  - HEU-MET-FAST-059
  - HEU-MET-FAST-069
- Thin Graphite Reflected
  - HEU-MET-FAST-071
- Poly Reflected
  - HEU-MET-FAST-076
- GROTESQUE
  - HEU-MET-FAST-081
- ORSPHERE
  - HEU-MET-FAST-100
- Potassium Worth
- Complex Annuli
- Bare Annuli
- Interacting Cylinders
- Thick Graphite Reflected
Bare Cylinders (HEU-MET-FAST-051) revised
Beryllium Reflected
(HEU-MET-FAST-059, -069)
Thin Graphite Reflected (1” and 2”)
(HEU-MET-FAST-071) revised

<table>
<thead>
<tr>
<th>Region (nominal)</th>
<th>Height (cm)</th>
<th>Average Gap (cm)</th>
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</thead>
<tbody>
<tr>
<td>Fuel height, 22.84 cm ID, 27.84 cm OD region</td>
<td>8.537322</td>
<td>0.00150358</td>
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<tr>
<td>Fuel height, 27.84 cm ID, 32.02 cm OD region</td>
<td>8.646289</td>
<td>0.00194518</td>
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<td>Fuel height, 32.02 cm ID, 38.10 cm OD region</td>
<td>8.050022</td>
<td>0.00067810</td>
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<td>Graphite stack, 43.18 cm OD, 38.10 cm ID</td>
<td>18.179236</td>
<td>0.02656418</td>
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<td>Graphite stack, 48.26 cm OD, 43.18 cm ID</td>
<td>18.158034</td>
<td>0.04451750</td>
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<td>Graphite core</td>
<td>7.987312</td>
<td>0.00980420</td>
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</tbody>
</table>

Thick Variants To Be Investigated
Polyethylene Reflected (HEU-MET-FAST-076)
GROTESQUE (HEU-MET-FAST-081)
ORSHERE (HEU-MET-FAST-100)
Potassium Worth Measurement (In Progress)
Complex Annuli (In Progress)
Bare Annuli (To Be Evaluated)

Prompt Neutron Decay Constant Measurements Were Performed on Bare Cylinders and Annuli
More Interacting Cylinders (To Be Evaluated)
Room Return Effects – Previous Treatment

- HMF-051 & -071
- Treated as -3 ¢ and -2 ¢, respectively
  - Based on GODIVA room return measurements
- Room return effects varied among other oralloy benchmark experiments
Room Return Effects
– Evaluated

- 35 × 35 × 30 ft
- 5 ft or 2 ft thick concrete
- 11.7 ft from West
- 12.7 ft from North
- Concrete were prepared with crushed limestone

Calculations:
- MCNP6.1
- ENDF/B-VII.1
Results

- **Calculated Results**
  - Between -3.5 ¢ and -12 ¢
  - Greater than initial assumptions

- **Increases as diameter of cylinder increases**
  - -3.5 ¢ for 7” Ø
  - -11 ¢ for 15” Ø

- **Increases as distance between interacting cylinders increases**
  - More mass/volume

- **Thin graphite reflectors dampened room return effects**

- **Uncertainty ±0.42 ¢ (1σ)**
HMF-051 Results

The chart illustrates the comparison of (C-E)/E% for different cases. The x-axis represents the case number, ranging from 1 to 18. The y-axis shows the variation of (C-E)/E% from -0.5 to 0.2.

- **Current Benchmark Data**: Represented by black dots, displaying the original benchmark data points.
- **Mean Value using Current Benchmark Data**: Shown as a black dashed line, indicating the average trend for the current benchmark data.
- **Revised Room Return Corrections**: Depicted by blue squares, highlighting the corrected data points.
- **Mean Value using Revised Room Return Corrections**: Illustrated by a blue dashed line, showing the average trend for the revised corrections.

The chart indicates that the revised room return corrections have a slightly different distribution compared to the current benchmark data. Notably, the values approach zero towards the higher range of the y-axis, suggesting improved accuracy in the corrected data.

**Key Observations**:
- The revised corrections seem to align closer to the mean value, reducing the variation.
- This suggests that the revised corrections may provide a more accurate representation of the benchmark data.

**Values**:
- The mean values calculated for current benchmark data vary slightly, with a general trend around 0.19.
- The revised room return corrections show a mean value closer to 0.22, indicating a potential improvement.

**Conclusion**:
- The chart effectively visualizes the impact of revised room return corrections on the benchmark data, highlighting a slight increase in accuracy compared to the original data.

**Technical Note**:
- The HMF-051 results are presented using standard statistical methods, ensuring a clear comparison between the current and revised data sets.

**Further Analysis**:
- Additional statistical analysis could provide deeper insights into the significance of these corrections and their implications for future benchmarking efforts.
<table>
<thead>
<tr>
<th>Case Number</th>
<th>Current Benchmark Data</th>
<th>Revised Room Return Corrections</th>
<th>Revised Room Return Corrections</th>
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Conclusions

- Room return corrections revised
  - HEU-MET-FAST-051
  - HEU-MET-FAST-071
- Improvement in comparison between calculated and benchmark values
- Bare cylinders still calculate low

Future work

- Evaluate additional ORCEF oralloy critical experiments
  - Potassium
  - Bare/Complex annuli
  - Thick graphite reflectors
  - Interacting cylinders
- Evaluate non-critical measurements
Questions?
Extra Slides
The Benchmark Evaluation Process

**INTERNATIONAL BENCHMARK PROGRAMS**

**Benchmark Evaluation Process**
- Evaluation Process
  - Identify
  - Verify
  - Evaluate
  - Compile
  - Calculate
  - Document

**Peer Review** (National and International Experts)

**Comprehensive Source of Externally Peer Reviewed Integral Benchmark Data**

- Advanced Modeling and Simulation
- Analytical Methods Development, Validation, and Verification
- Reactor Design and Licensing
- Training
- Criticality and Reactor Safety Analysis
- Fuel Cycle and Related Activities
- Range of Applicability and Experiment Design
- Nuclear Data Refinement

**Future Use**

**Internal Benchmark Programs**
- Benchmark Experiment Data
- Externally Available Technical Journals & Reports
- Internal Reports Letters & Memos
- Logbooks
- Drawings
- Experimenter’s Annotated Copy of Published Reports
- Experimenter’s (Retired or Working on Other Projects)
- Facilities Awaiting D&D

**Short-term Preservation**
Cross Section Library Comparison

- CENDL-3.1
- ENDF/B-VII.0
- ENDF/B-VII.1
- JEFF-3.1
- JENDL-3.3
- JENDL-4.0
- TENDL-2012

(C-E)/E %

"Lady Godiva"
COMET
VNIITF Sphere
VNIITF Cylinder
VNIIF Cylinder
VNIIF Sphere
ORCEF Slab
ORCEF Cylinder
GROTESQUE
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Eigenvalue Calculations

- Monte-Carlo N-Particle (MCNP) 5-1.60
  - 1050 cycles, skipped 50, 1E6 histories/cycle =1E9
  - Statistical uncertainty 0.00002 \( \Delta k \)

- ENDF/B-VII.0 neutron data
  - ENDF/B-VII.1 has ENDF/B-VI.8 delayed neutron data for uranium isotopes and covariance data
    - Negligible impact on \( k_{\text{eff}} \)

- Compared against benchmark experiment eigenvalue and uncertainty