#### The Case For and Against a Gadolinium Bias in SCALE: Opening Arguments

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#### • HST-014 and HST-016

- Brief description and ICSBEP sample results
- SCALE 6.1 validation report, including S/U analysis
- SCALE 6.2.2 validation report
- MST-007 & HTC Phase 2 results
- Where are we and where are we going?



## HST-014 and HST-016

- HST-014 through HST-019 are experiments from IPPE (Russia)
- Uranyl nitrate of varying uranium concentration
- Three cases for each uranium concentration with no Gd, some Gd, and more Gd dissolved in solution
- ICSBEP sample results show discrepancy between calculated and expected values (C/E ratio) increasing with Gd concentration
- Models were built in SCALE 6 and added to VALID in July, 2009
- HST-016-003 identified as outlier in Sedat's paper on CE KENO validation in 2010



#### **Sample results from ICSBEP Handbook**





## **SCALE 6.1 Validation Report**

- Strong bias as a function of Gd concentration identified in SCALE 6.1 validation report (Marshall and Rearden)
- No other cases in VALID at the time contained soluble Gd
- Is it the code, the data, or the experiments?
- Calculated  $k_{eff}$  sensitivities indicated an ~16% error in <sup>157</sup>Gd capture cross section to explain discrepancy
  - Estimated uncertainty is ~3% or less in SCALE 6.1 covariance library for energy range of <sup>157</sup>Gd sensitivity



# SCALE 6.1 HST Results (Fig. 4 from ORNL/TM-2011/450)





#### S/U data from SCALE 6.1 (Figs 5 and 6 from ORNL/TM-2011/450)



Integral  $(n,\gamma)$  sensitivity is -0.156 for HST-016-003, and uncertainty is less than 5% over energy range where all sensitivity resides.

A 2% change in cross section is therefore a -0.156 \*  $0.02 = 0.0031 \Delta k$ .

C/E however is 1.02428

Is cross section off by almost 8 sigma?



## **Adding SCALE 6.2.2 validation results**

- ENDF/B-VII.1 & VII.0 nearly identical despite new <sup>157</sup>Gd evaluation
- Can this many different codes and cross section sets show the same bad behavior?
- What about other experiments?





## MST-007 and HTC Phase 2

 MIX-SOL-THERM-007 has soluble gadolinium over a wider concentration range than HST-014 and HST-016

Possible that a Pu evaluation error could impact results

• HTC Phase 2 has several experiments with soluble gadolinium

- Lattices instead of solutions
- Proprietary experiments not in the ICSBEP Handbook
  - Available to US nationals under an NDA from ORNL for some purposes
- Not in VALID, but reviewed internally during development NUREG/CR-7109



## **All results now**

- SCALE 6.2.2 with CE KENO and ENDF/B-VII.1
- Uncertainties in Gd concentration also shown
- No clear bias in MST-007 results
- Maybe a slight negative bias in HTC results?





#### Where are we now?

 Two related experiment series indicate a large bias in <sup>157</sup>Gd capture cross section

- S/U analysis indicates that <sup>157</sup>Gd is an unlikely source of the bias
- Two other experiment series do not support existence of large positive bias
- Data adjustment analyses (e.g., TSURFER) consistently reject HST-014 and HST-016 as experiments with inconsistent results
- Data community has had discussions about what to do with these experiments



#### Where are we going?

ORNL would like to perform additional validation for soluble Gd systems

- More systems are available on the ICSBEP Handbook
- DICE says 172 cases have soluble gadolinium, of which 13 are in VALID

- Adding more just takes time, money, and people

- Can comparison of results from modern codes & cross sections be used to demonstrate that the experiment evaluation is the problem?
  - Current effort at IRSN



### That's it – any questions?

