#### Validation of KENO V.a and KENO-VI in SCALE 6.2.2 Using ENDF/B-VII.0 and ENDF/B-VII.1 Libraries

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#### Introduction

- Validation effort demonstrates the general performance of the KENO V.a and KENO-VI codes across a wide range of systems
  - 15 experiment categories, > 600 individual cases
- Benchmarks are all from ICSBEP Handbook and included in the VALID library maintained at ORNL
- Models are executed using
  - 238-group and continuous energy libraries based on ENDF/B-VII.0
  - 56-group, 252-group, 200-group, and continuous energy libraries based on ENDF/B-VII.1
- Comparison of KENO V.a to KENO-VI using ENDF/B-VII.1 continuous energy library



### Valid procedure and library contents

- <u>Verified</u>, <u>Archived</u> <u>Library of</u> <u>Inputs and</u> <u>Data</u> procedure is a SCALE project computational procedure at ORNL
- Quality behind VALID:
  - Independent preparation and review of models and documentation
  - Individuals must be certified as qualified for task assigned
  - Version control maintained on data
  - Data and documentation backed up and retrievable
- For more information on VALID, see NCSD 2013 presentation



# **Critical experiments used**

<ul> <li>Cases in blue are new since</li> </ul>	Sequence	Experiment class	ICSBEP case numbers	Number of configurations
	LE 6.1 ation report s in red ew since 2015	HEU-MET-FAST	15, 16, 17, 18, 19, 20, 21, 25, 30, 38, 40, <mark>52</mark> , 65	<b>19/23</b> <sup>a</sup>
<ul> <li>Cases in red</li> </ul>		HEU-SOL-THERM	1, 13, 14, 16, 28, 29, 30	52
		IEU-MET-FAST	2, 3, 4, 5, 6, 7, 8, 9	8/11 <sup>a</sup>
		LEU-COMP-THERM	1, 2, <mark>8</mark> , 10, 17, 42, 50, <mark>78, 80</mark>	140
		LEU-SOL-THERM	2, 3, 4	19
		MIX-MET-FAST	5, 6	2
are new since		MIX-COMP-THERM	1, 2, 4	21
		MIX-SOL-THERM	2,7	10
ICINC 2013		PU-MET-FAST	1, 2, 5, 6, 8, 10, 18, 22, 23, 24, <mark>25, 26</mark>	12
paper		PU-SOL-THERM	1, 2, 3, 4, 5, 6, 7, 11, 20	81
		U233-COMP-THERM	1	3
<ul> <li>561 cases with</li> </ul>		U233-MET-FAST	1, 2, 3, 4, 5, 6	10
KENO V.a		U233-SOL-INTER	1	29
		U233-SOL-MIXED	1, 2	8
		U233-SOL-THERM	1, 2, 3, 4, 5, 8, 9, 11, 12, 13, 15, 16, 17	140
<ul> <li>57 cases with KENO-VI</li> </ul>	CSAS6/KENO-VI	HEU-MET-FAST	5, 8, 9, 10, 11, 13, 24, 80, 86, 92, 93, 94	27
		IEU-MET-FAST	19	2
		MIX-COMP-THERM	8	28

<sup>a</sup>The larger number includes simplified cases that are duplicate cases for which detailed models are also available in the library.



#### **Results**

- Average calculated-to-expected ratio (C/E) determined for each category of experiments
  - Uncertainty in C/E accounts for uncertainty in expected  $k_{eff}$  value and computational uncertainty
  - Experimental uncertainty >> computational uncertainty, dominates C/E uncertainty
- Results compared
  - Among ENDF/B-VII.1 libraries,
  - Between ENDF/B-VII.0 and respective ENDF/B-VII.1 libraries,
  - C/E with EALF, and
  - C/E with experimental and data uncertainty



## Average C/E difference from unity (bias) – KENO V.a



 USI and USM results are consistently poor for all libraries (intermediate and mixed energy)



### **KENO V.a HST systems**



- Comparing results for 56-group, 252group, 200-group, and continuous energy libraries based on ENDF/B-VII.1
- Outliers are from HST-014 and -016



## **KENO V.a HST systems**



- Comparing results for ENDF/B-VII.0 libraries and related ENDF/B-VII.1 libraries
  - For more information, see Marshall's paper on Gadolinium bias from this morning's session



#### **KENO V.a HST systems**



- C/E values as a function of EALF
  - Only for ENDF/B-VII.1 252group and continuous energy libraries
- No clear evidence of trends



## Average C/E difference from unity (bias) – KENO-VI



 Biases in KENO-VI appear to be generally slightly larger than in KENO V.a (not considering USI and USM systems)

 Result of more complex geometries?



## **KENO V.a and KENO-VI comparison**

- Different biases for KENO V.a and KENO-VI for same experiment categories, but with different experiments
- All KENO V.a experiments converted to KENO-VI models using c5toc6 utility
- Only run/compared with ENDF/B-VII.1 continuous energy library
- Same model-to-model comparison
- 94.6% of cases are within 2 sigma
- Monte Carlo uncertainty ranges between ~0.00006 ~0.00049



# **Differences (KENO-VI – KENO V.a)**



 Histogram of all individual case differences with overlay of an imposed normal distribution with the same mean and standard deviation



## Conclusions

- Code bias for a wide range of systems is fairly small
  - Less than 2.2% when considering all of the cases in all of the categories
  - For KENO V.a, bias is less than 0.92% when removing the USI and USM systems from consideration and less than 0.5% for almost all of the categories
  - For KENO-VI, bias is less than 0.9%
- Data can be used to identify potential discrepancies which may indicate poor experiment descriptions, disagreements between multigroup and continuous energy libraries/treatments, and/or possible errors in cross section libraries – for example the energy range of the USI and USM systems
- Evidence that KENO V.a and KENO-VI calculate equivalent k<sub>eff</sub> values for identical systems



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