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Title: Excluding Benchmark Statistical Outliers in Nuclear Criticality Safety Validation

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ANS Annual Meeting

2019 THE VALUE OF NUCLEAR

Excluding Benchmark Statistical Outliers in Nuclear Criticality Safety Validation

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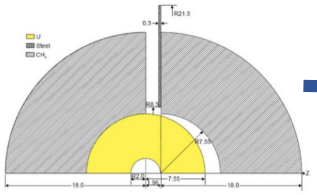
Rejection of Statistical Outliers

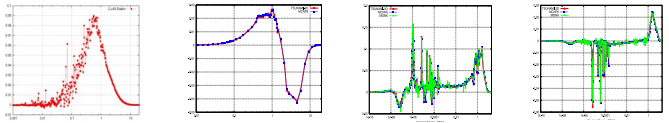
- ANSI/ANS-8.24-2007:
  - "*Rejection of data outliers shall be based on the inconsistency of the data with known physical behavior or on established statistical rejection methods.*"
- ANSI/ANS-8.24-2017:
  - "*Identification of data outliers may be based on established statistical rejection methods; rejection of outliers shall be based on the inconsistency of the data with known physical behavior in the experimental data.*"

– Determine impact of rejection of benchmark outliers on Nuclear Criticality Safety Validation
  – Pu and HEU Systems: metal, oxide, solution
  – Application parameter study models for use with MCNP6.2/Whisper-1.1



Application + Nuclear Data

Monte Carlo Criticality Calculation



Application Sensitivity Profile

SU-based Analysis
Pattern matching select similar benchmarks

Bias, Bias Uncertainty
Margin of Subcriticality
Upper Subcritical Limit

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Rejection of Statistical Outliers

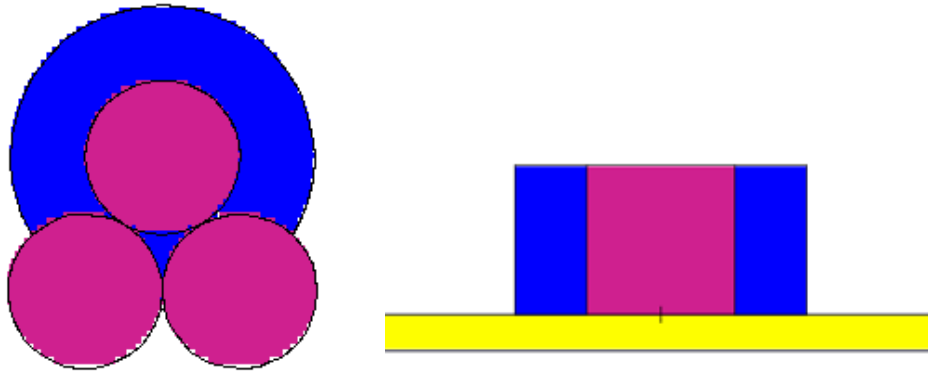
- Whisper Identification of Outliers
  - Generalized Linear Least Squares (GLLS)
    - Used to find the minimum chi-squared
    - Value of chi-squared per number of benchmarks = 1for perfect regression model
    - Rejected using iterative diagonal chi-squared method until $\chi^2 < 1.2$
    - 10% of Whisper-1.1 library identified as outliers using method
    - Whisper computed USL, user option to include identified outliers
    - Include or exclude identified outliers to determine impacts on USLs for Pu and HEU Systems

Benchmark Series	# Library	Rejected-ENDF/B-VII.1	% Library
HEU-COMP-THERM	25	5	20%
HEU-MET-FAST	251	29	12%
HEU-MET-INTER	4	2	50%
HEU-MET-THERM	4	2	50%
HEU-SOL-THERM	93	2	2%
LEU-COMP-THERM	182	4	2%
LEU-SOL-THERM	27	2	7%
MIX-MET-FAST	32	1	3%
MIX-SOL-THERM	21	9	43%
PU-COMP-MIXED	34	16	47%
PU-MET-FAST	68	3	4%
PU-SOL-THERM	158	15	9%
U233-MET-FAST	9	1	11%
U233-SOL-INTER	33	10	30%
U233-SOL-THERM	106	12	11%
OTHER	54	0	0%
TOTAL	1101	113	10%

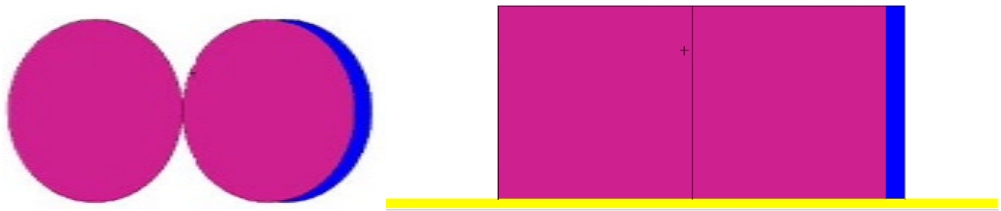
Determine Impact of Statistical Outliers on USL

- Application parameter study models for use with MCNP6.2/Whisper
  - Pu and HEU Systems: metal, oxide, solution

  - Metal and Oxide:
  - 3 right circular cylinders in close proximity
  - Water and steel reflection
  - Height-to-Diameter variation
  - Metal cases vary mass per cylinder
  - Oxide cases vary amount of water



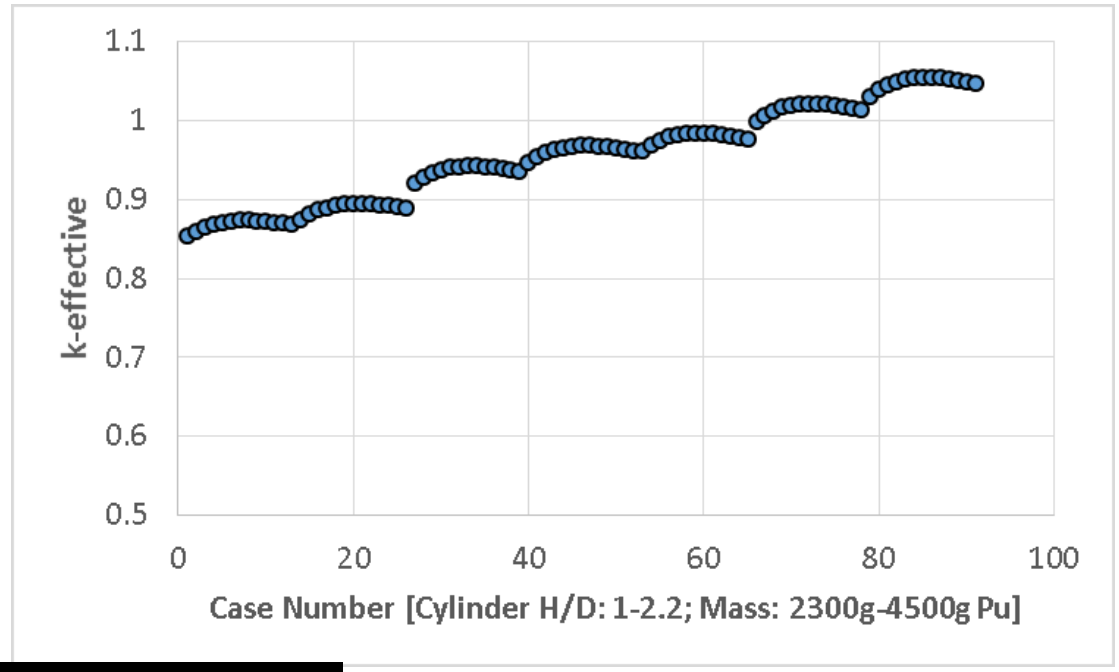
  - Solution (Metal-Water Mixture):
  - 2 right circular cylinders in close proximity
  - Water and steel reflection
  - Height-to-Diameter variation
  - Mixed with varying amount of water

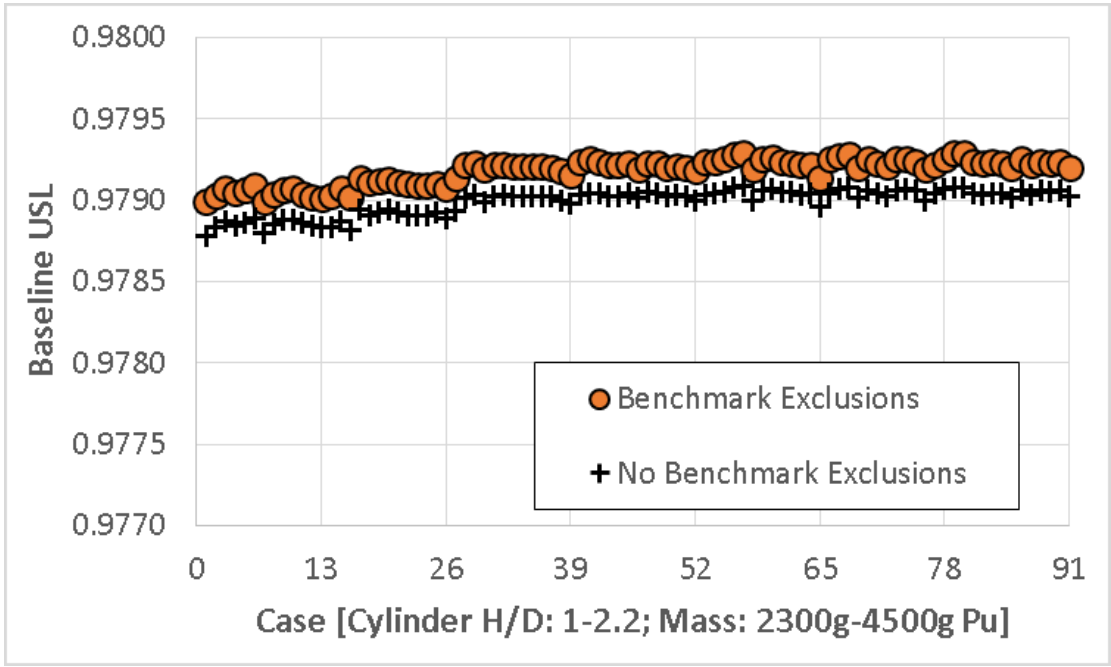


  - MCNP6.2 calculations → sensitivity profiles
  - Whisper → bias, bias uncertainty, nuclear data uncertainty margin

Results of Benchmark Rejection Study

- Pu metal results
  - Baseline USL slightly higher when benchmark outliers are excluded
  - Magnitude of difference in USL including vs. excluding outliers:
  - 0.00021





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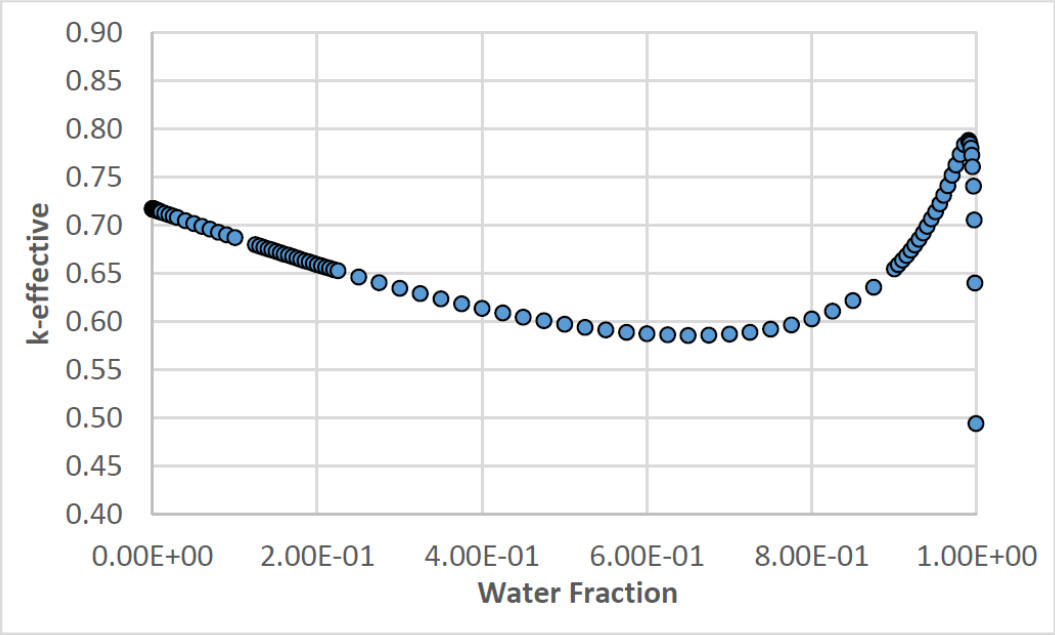
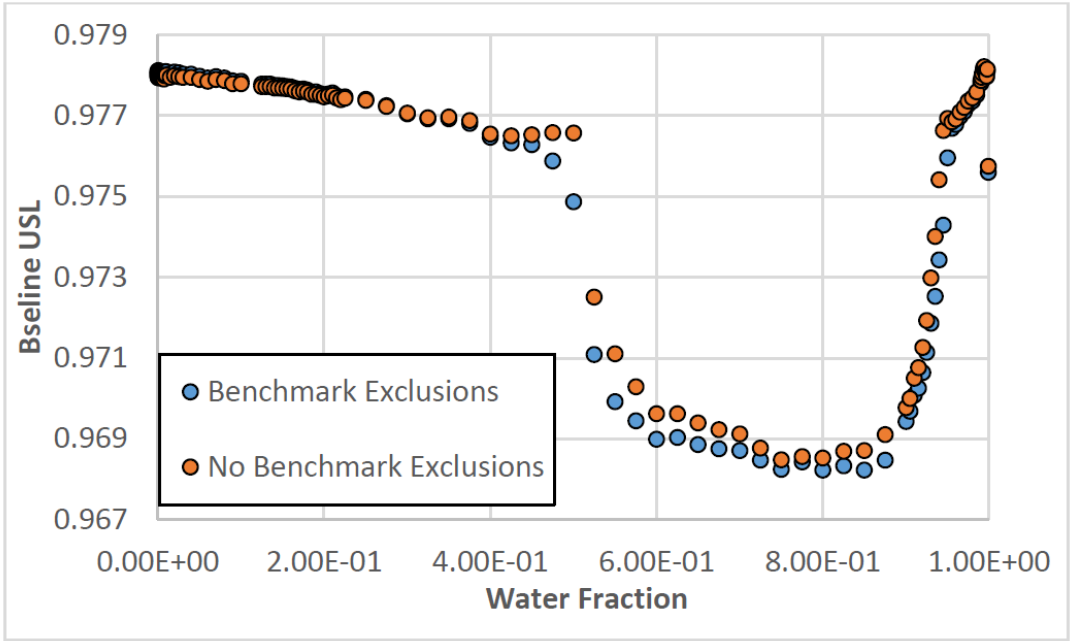
Results of Benchmark Rejection Study

- Pu oxide results
  - Baseline USL can be higher when benchmark outliers are NOT excluded
  - Magnitude of difference in USL including vs. excluding outliers:
  - 0.00234





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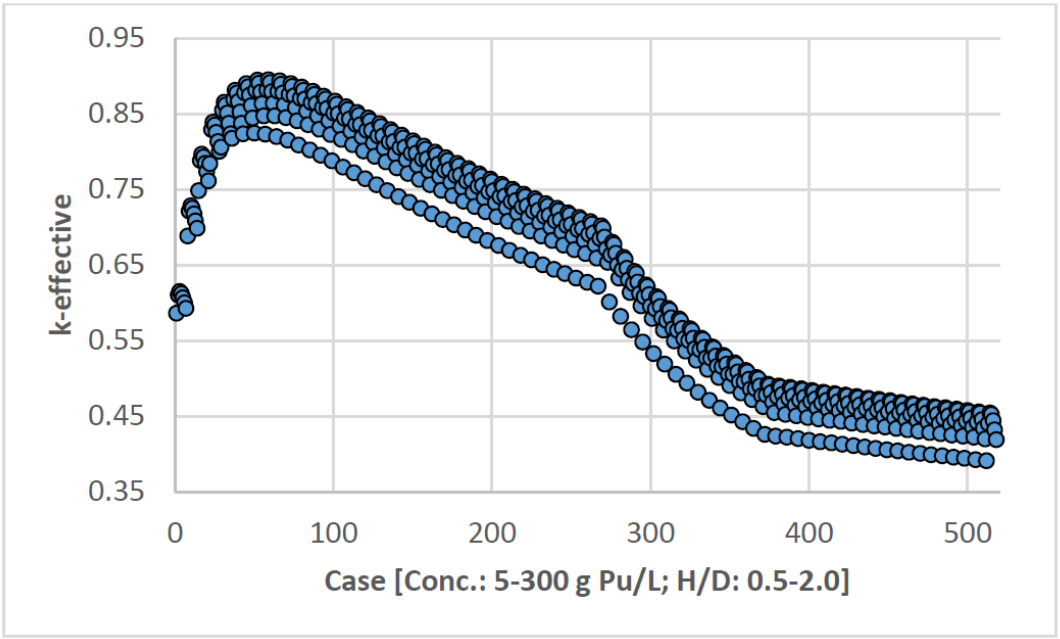
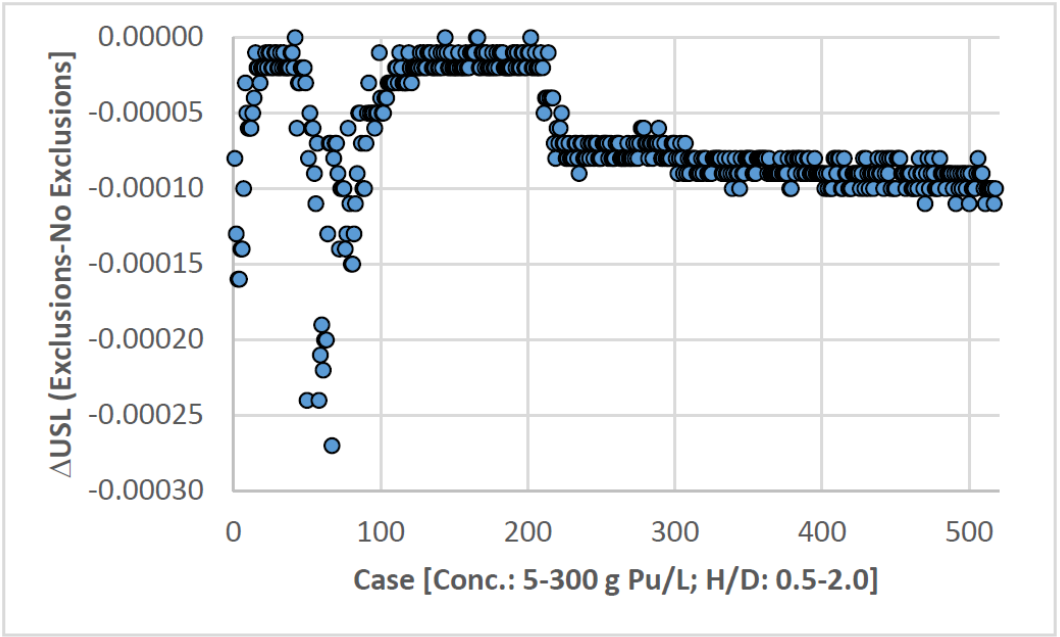
Results of Benchmark Rejection Study

- Pu solution results
  - Baseline USL can be higher when benchmark outliers are NOT excluded
  - Magnitude of difference in USL including vs. excluding outliers:
  - 0.00026





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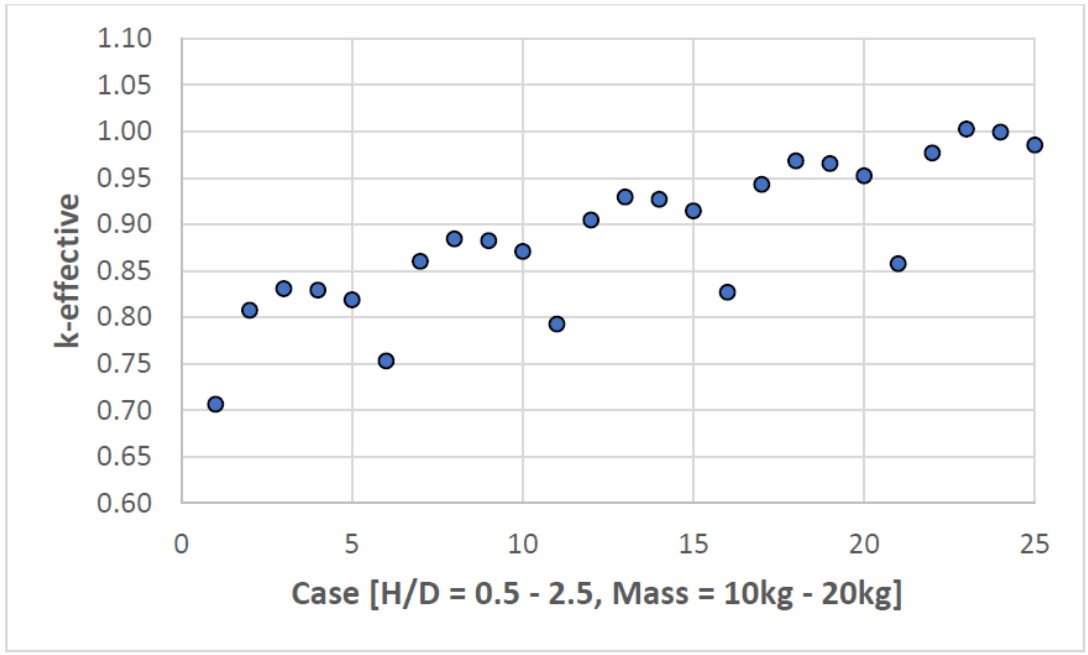
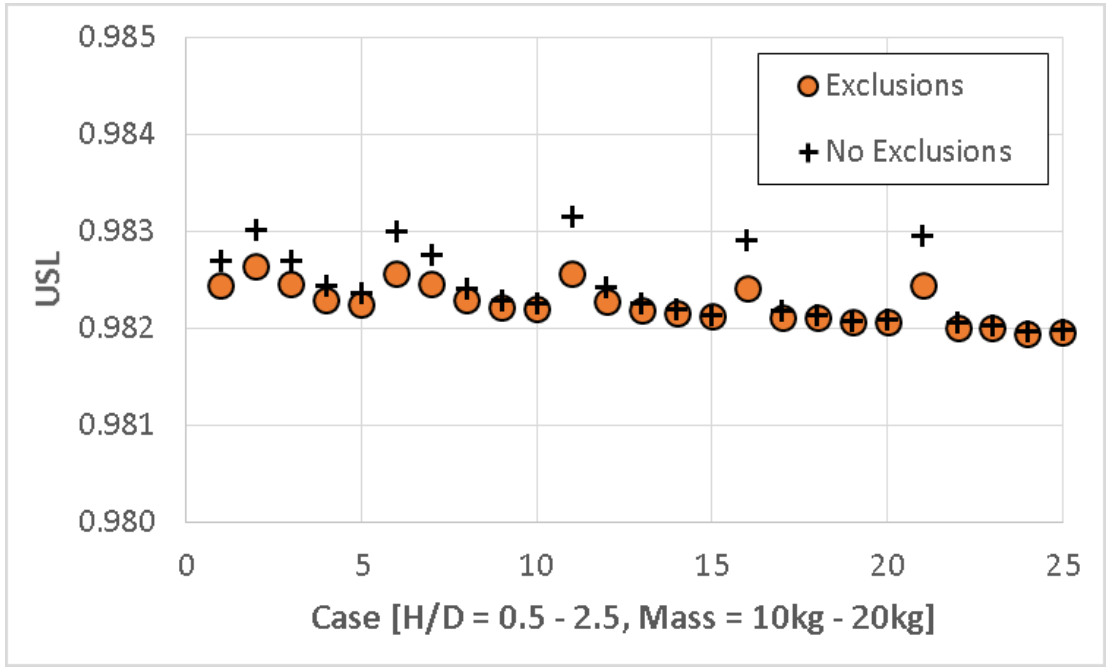
Results of Benchmark Rejection Study

- HEU metal results
  - Baseline USL can be higher when benchmark outliers are NOT excluded
  - Magnitude of difference in USL including vs. excluding outliers:
  - 0.00050





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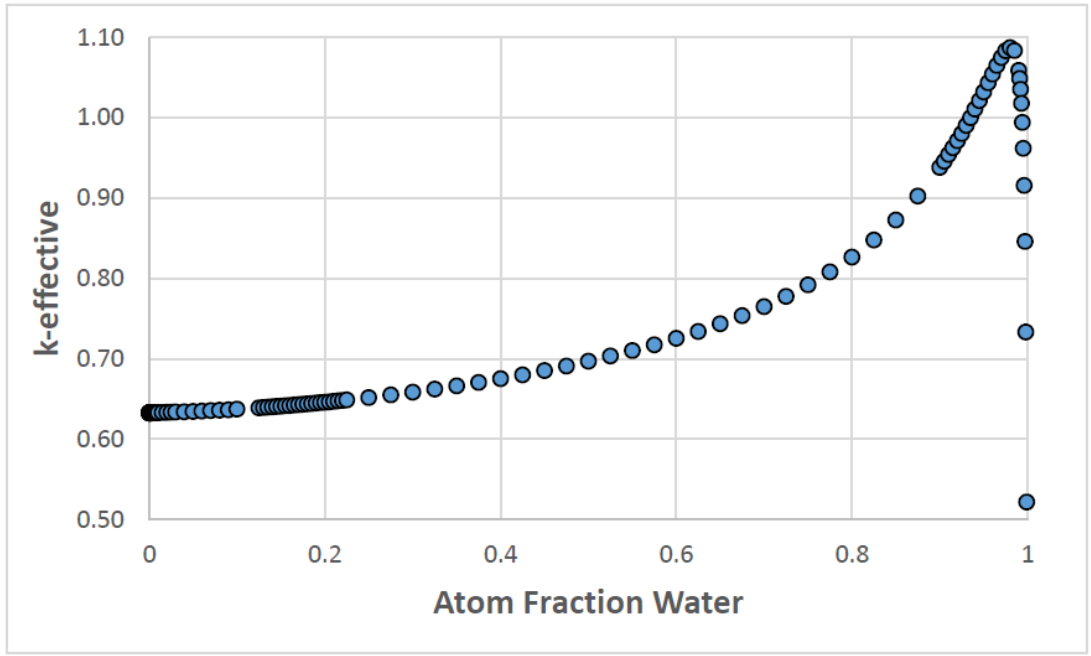
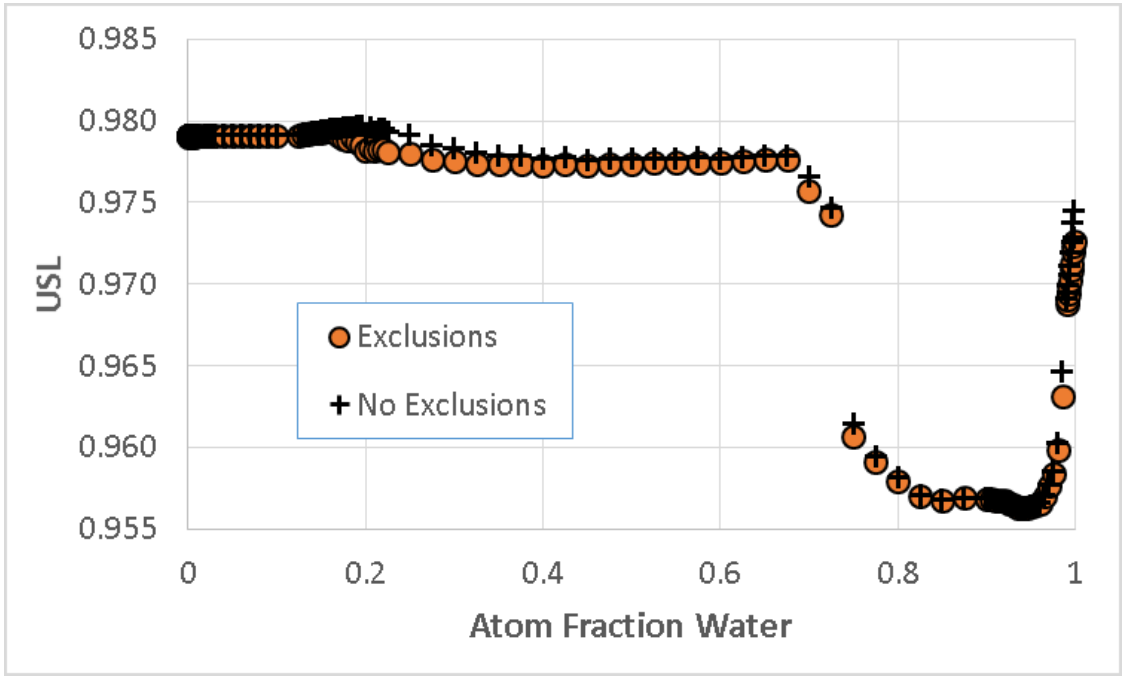
Results of Benchmark Rejection Study

- HEU oxide results
  - Baseline USL can be higher benchmark outliers are NOT excluded
  - Magnitude of difference in USL including vs. excluding outliers:
  - 0.00208





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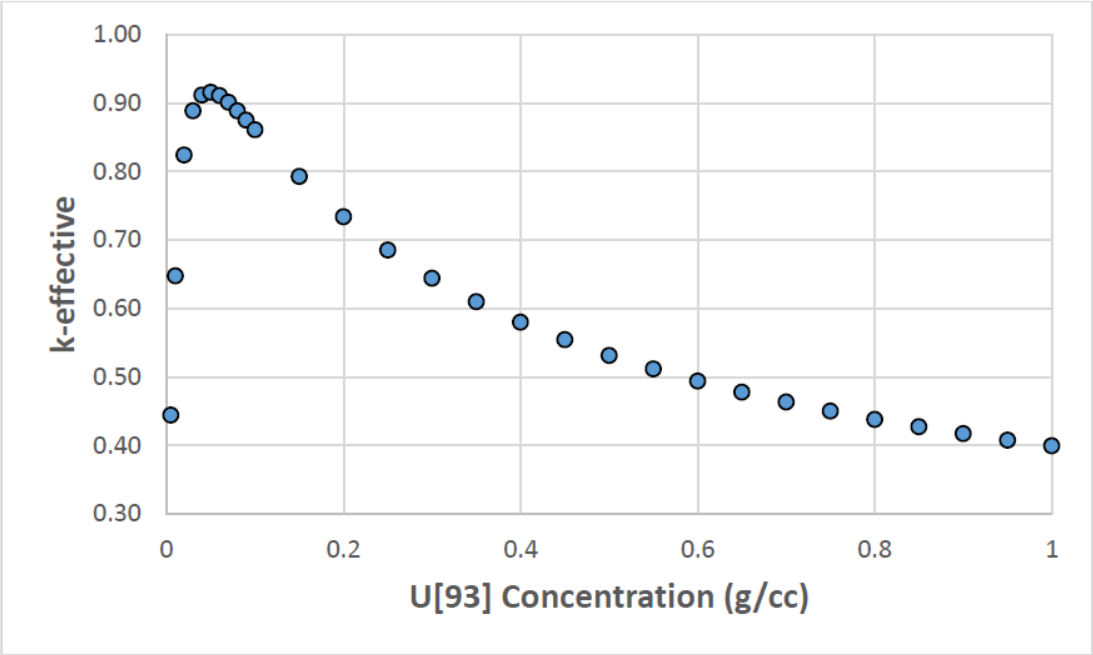
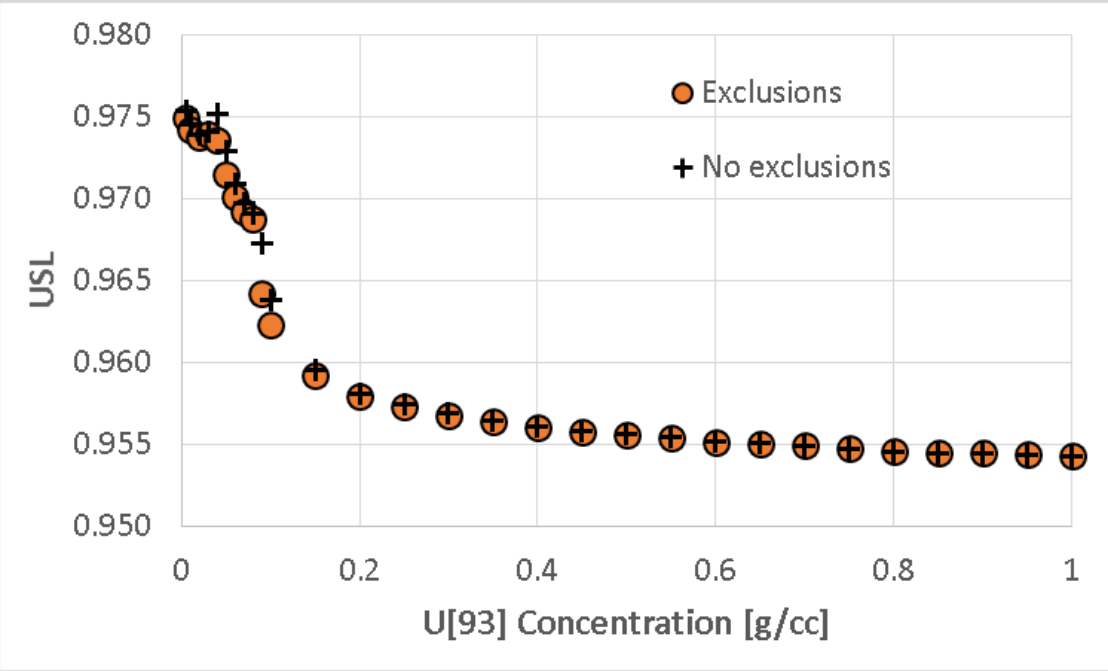
Results of Benchmark Rejection Study

- HEU solution results
  - Baseline USL can be higher when benchmark outliers are NOT excluded
  - Magnitude of difference in USL including vs. excluding outliers:
  - 0.00307





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Results of Benchmark Rejection Study

USL Differences

- Pu metal 0.00021
- Pu oxide 0.00234
- Pu solution 0.00026
- HEU metal 0.00050
- HEU oxide 0.00208
- HEU solution 0.00307

USL differences may be higher for other series