LA-UR-19-20048
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Intended for: ANS Annual Meeting, 2019-06-09 (Minneappolis, Minnesota, United States)
Web

Issued: 2019-01-08

Excluding Benchmark Experiment Statistical Outliers in Nuclear Criticality Safety Validation: A Comparison Study of Upper Subcritical Limits for Highly Enriched Uranium Systems

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Introduction

Neutron transport methods used to establish subcriticality require validation by comparison to critical experiments considered to be benchmarks. Whisper is a sensitivity/uncertainty analysis tool developed to assist with the task of validation in nuclear criticality safety. Details on the Whisper methodology can be found in References 1-3 on the MCNP® reference collection website at https://mcnp.lanl.gov. During the process of validation a benchmark experiment may be found to be a statistical outlier, in which the calculated k-effective value and the experiment k-effective value differ by an amount atypical for similar experiments. A methodology optionally employed by Whisper is the exclusion of statistical outliers based upon the iterative diagonal chi-squared statistical rejection technique. Alternatively, there is an option to include all benchmarks in the Whisper library collection, even those benchmarks found to be statistical outliers, when computing the bias, bias uncertainty and margin of subcriticality (MOS) leading to establishment of the baseline upper subcritical limit (USL). A comparison study has been done to compute USLs with and without statistical outliers in the Whisper benchmark collection to determine what effect rejection of statistical outliers has on the recommended baseline USL. The results show little overall difference in the recommended baseline USLs developed by Whisper when excluding statistical outliers. Additionally, there does not appear to be a clear trend in predicting whether the baseline USL will be higher or lower when rejecting statistical outliers from the benchmark critical experiment collection used for validation.

Whisper-1.0 was originally developed in 2014 and used for validation support at Los Alamos National Laboratory. Whisper was upgraded in 2016 to Whisper-1.1 and prepared for release with MCNP6.2 [References 3-5]. In December 2017 a revised ANSI/ANS-8.24-2017 *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations* [Reference 6] was approved. It included a modification to the language in the standard on the topic of rejection of statistical outliers stating:

"*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.*"

Previous to ANSI/ANS-8.24-2017 the language in ANSI/ANS-8.24-2007 [Reference 7] was:

"Rejection of data outliers shall be based on the inconsistency of the data with known physical behavior or on established statistical rejection methods."

This paper examines the effect of exclusion of benchmarks which are found to be statistical outliers from the collection of benchmarks used by Whisper-1.1. The focus of this study is on nuclear criticality safety validation for highly enriched uranium systems in which the weight fraction of ^{235}U is 0.93, referred to as U(93). The baseline recommended USL, calculational margin (CM) and margin of

subcriticality for nuclear data uncertainty ($MOS_{nuclear\ data}$) is presented for HEU application cases ranging from fast metal systems to intermediate moist oxide systems to thermal solution systems.

The USL, CM, and $MOS_{nuclear\ data}$ are shown as a function of the energy corresponding to the average neutron lethargy causing fission (EALF) and average neutron energy causing fission (ANECF) for U(93) systems in Figures 1 and 2.

Results show there is little difference in baseline USL when using a reduced benchmark collection due to statistical rejection of outliers. Overall maximum difference in baseline USL between the two methods:

$USL_{Benchmark\ Exclusions} - USL_{No\ Benchmark\ Exclusions} = -0.00058$ for U(93) metal systems,

$USL_{Benchmark\ Exclusions} - USL_{No\ Benchmark\ Exclusions} = -0.00208$ for U(93) oxide systems, and

$USL_{Benchmark\ Exclusions} - USL_{No\ Benchmark\ Exclusions} = -0.00307$ for U(93) solution systems.

There is slight nonconservatism, i.e., the baseline USL is greater, when including all the benchmarks in the Whisper-1.1 collection and not using the available statistical rejection technique to exclude benchmark outliers for U(93) systems.

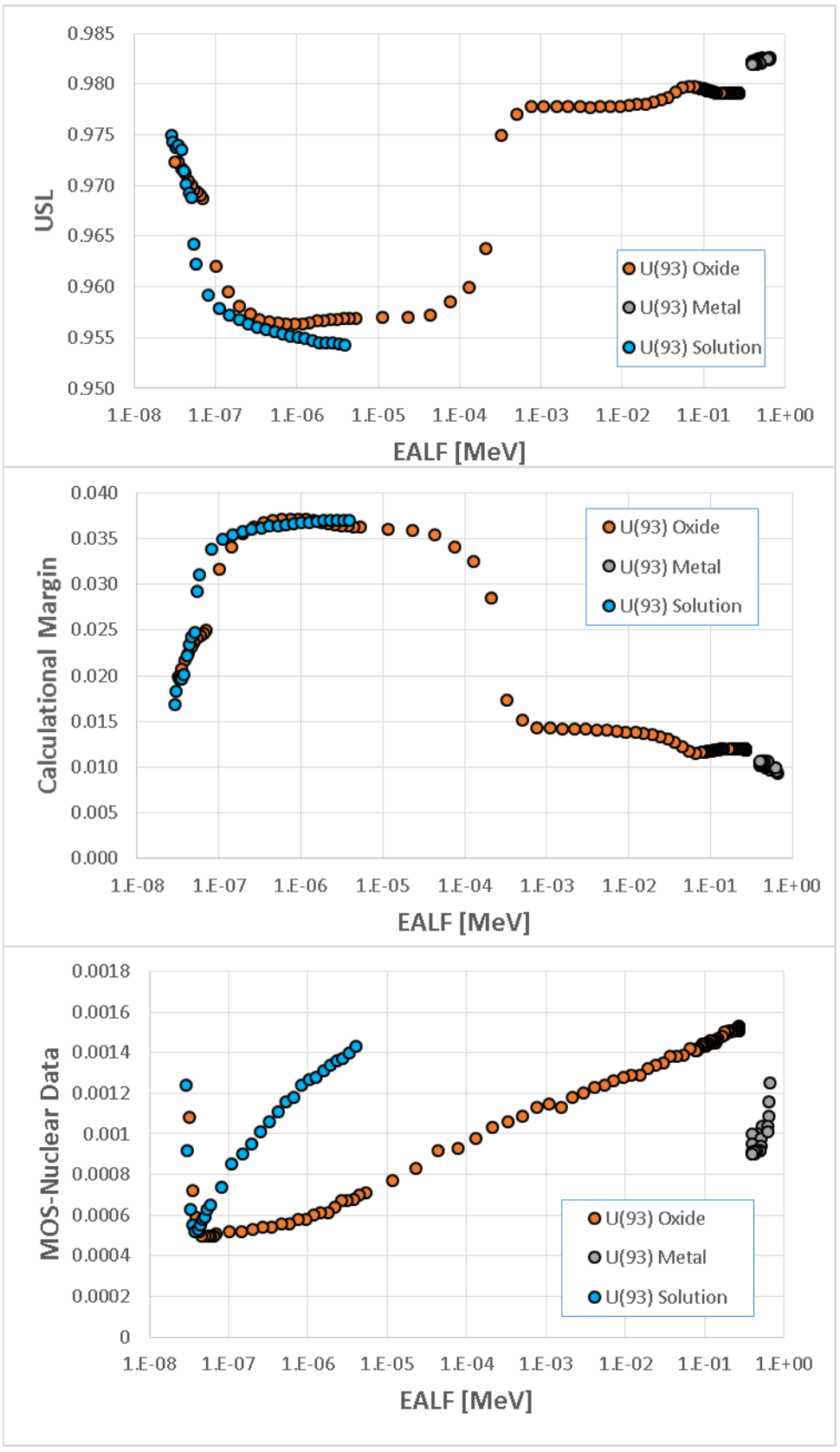

Figure 1. USL, CM, and MOS for nuclear data as a function of EALF.

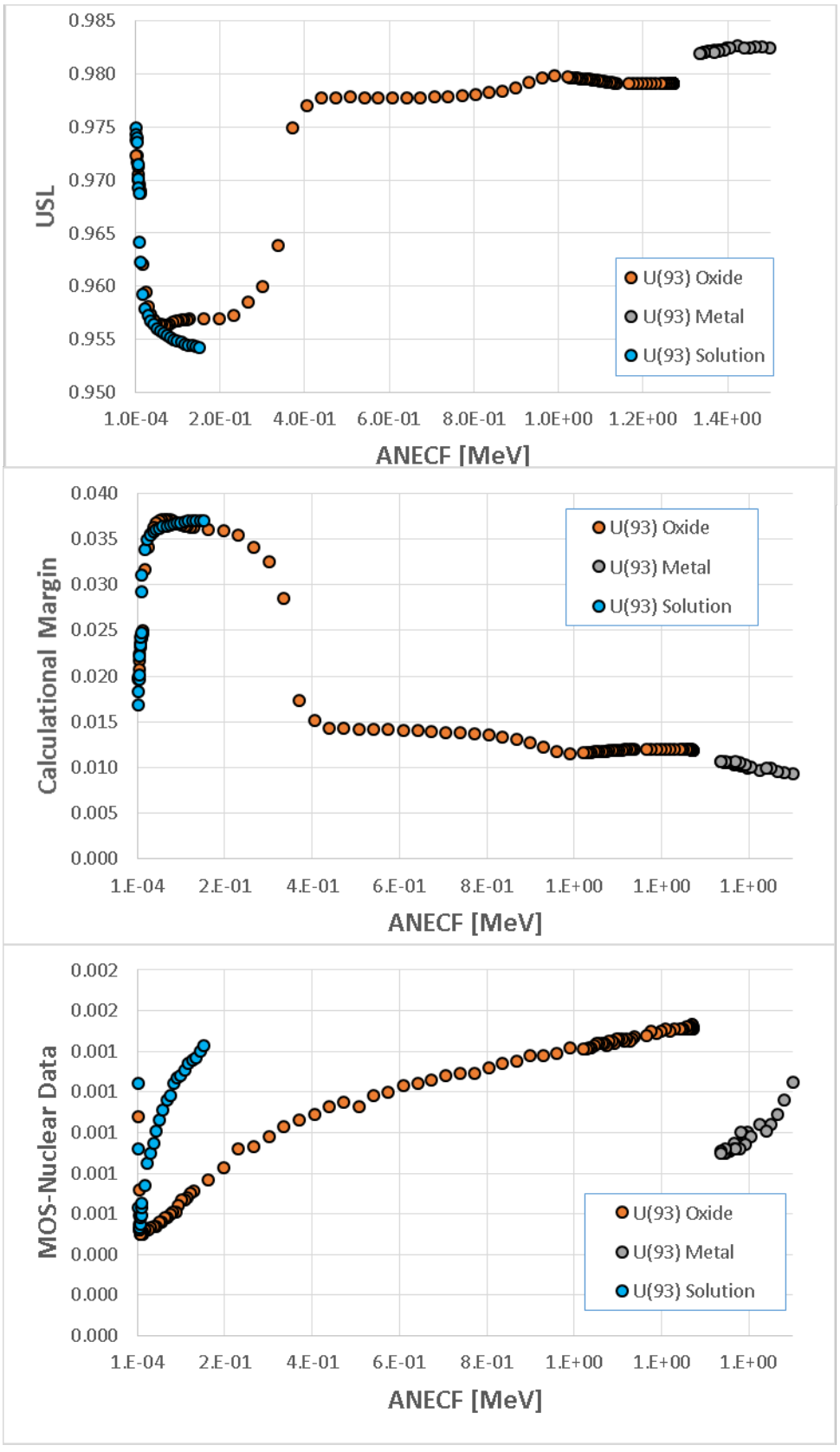

Figure 2. USL, CM, and MOS for nuclear data as a function of EALF.

HEU Study

Application models used for this study are described below, along with illustrations from MCNP6.2. Results were computed on the Los Alamos National Laboratory High Performance Computing (HPC) platform Snow. This platform is based on Linux OS with Intel Xeon Broadwell processors and 36 CPU nodes per core. The MCNP6.2 calculations were done using 18 Slurm tasks.

HEU Metal cases

The U(93) metal cases were conducted as a parameter study to cover a range of applicable process models. The process models consisted of three HEU-metal right circular cylinders on a stainless steel floor reflected radially by 1-inch thick water to represent personnel and incidental reflection. The three identical cylinders were placed touching in a triangular pattern with their bases sitting on the ½-inch thick stainless steel floor. The HEU was modeled as 93% ^{235}U by weight and 7% ^{238}U at a density of 18.75 g/cm^3. Various masses of HEU in the cylinders and height-to-diameter (H/D) ratio of the cylinders were modeled. The HEU mass modeled in each cylinder was 10000, 12500, 15000, 17500, and 20000 grams per cylinder. The H/D ratios varied from 0.5 to 2.5 in increments of 0.5. Parameterizing the mass per cylinder and H/D ratio as described resulted in 25 different cases. Internal to each individual case the cylinder mass and H/D were identical to one another; there was no variation amongst cylinders in an individual case and therefore the total mass in cases varied from 30000 to 60000 g Pu. The model geometry is shown below in Figure 3.

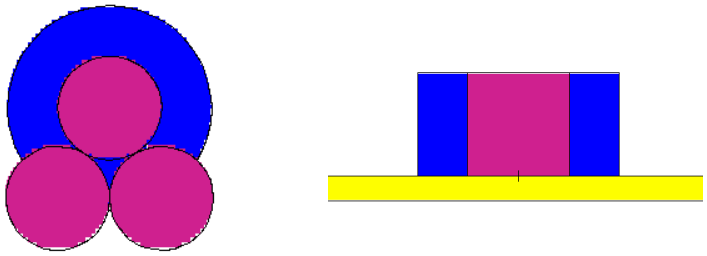

Figure 3.MCNP6.2 top and side view illustrations, respectively, of model geometry. HEU metal is shown in magenta; water in blue and steel in yellow.

MCNP6.2 was used to determine k-effective, the average energy of neutrons causing fission, the energy of the average lethargy of neutrons causing fission, and sensitivity profiles for each of the 25 process model cases. Whisper was used to find benchmarks neutronically similar to each process model case using sensitivity profiles, determine the calculational margin and portions of the margin of subcriticality leading to the baseline USL.

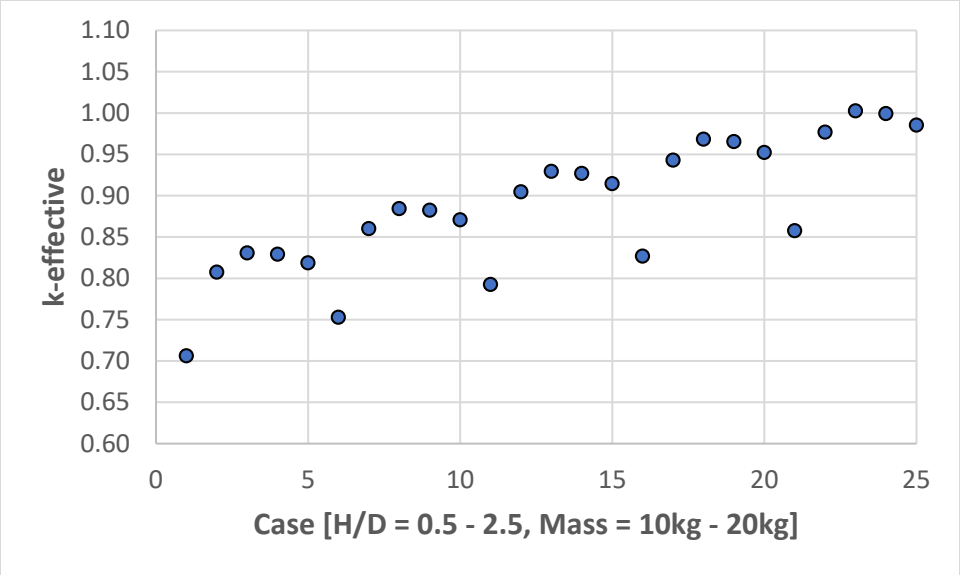

Figure 4. MCNP6.2 k-effective results for HEU metal cases.

Whisper-1.1 baseline USL results are reported below in Figure 5. A separate USL was computed for each application case using a benchmark collection reduced due to exclusions based upon the iterative diagonal chi-squared rejection method. In addition, the USL was computed for each process model case using a benchmark collection consisting of all 1101 benchmark experiments contained in the Whisper-1.1 library. When calculating the baseline USL and excluding benchmarks based upon statistical rejection the lowest baseline USL = 0.98194 and the highest 0.98264. When including all benchmarks the lowest baseline USL = 0.98196 and the highest = 0.98315.

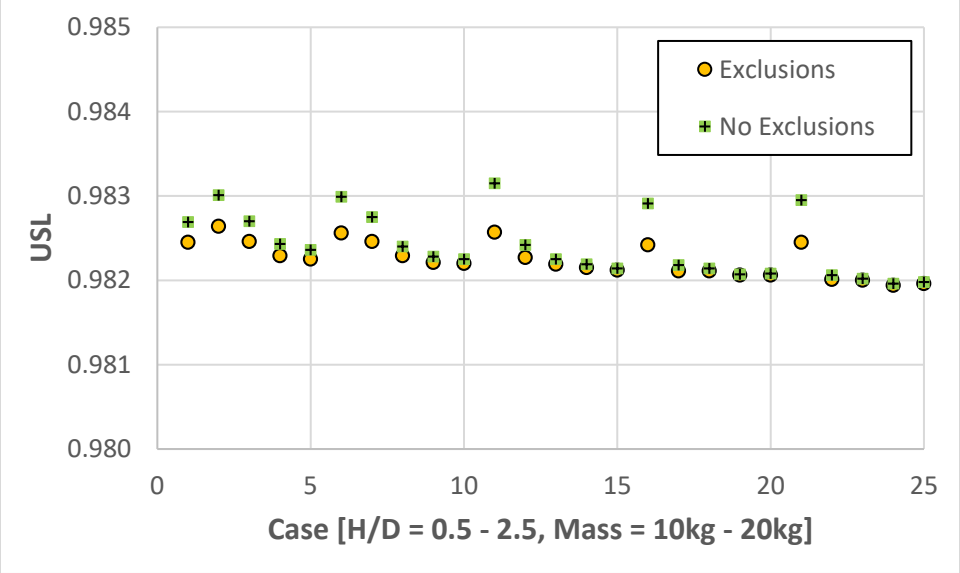

Figure 5. Whisper baseline USL for HEU metal cases.

The baseline USL is slightly higher when not excluding benchmarks. The difference between the baseline USL when including all benchmarks and the baseline USL when excluding some benchmarks in the

library ranges from 0.00001 to 0.00058, results are shown in Figure 6. The magnitude of USL difference is greatest for case 11, H/D = 0.5 and HEU mass of 15000.

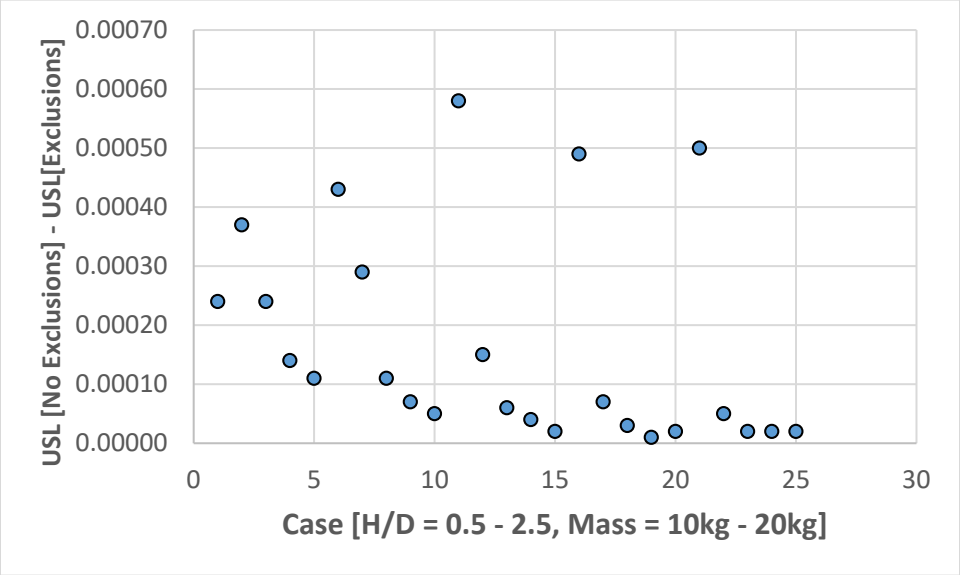

Figure 6. The difference between USL when using all benchmarks in the Whisper library vs. exclusing some benchmarks found to be statistical outliers.

The calculational margin calculated by Whisper is shown below in Figure 7. The difference between the CM when including all benchmarks and the CM when excluding some benchmarks in the library ranges from -0.00001 to -0.00058. The magnitude of the difference in the baseline USL computed by Whisper when using all benchmarks versus the baseline USL computed by Whisper when excluding outliers is due to the calculational margin (bias and bias uncertainty) and not due to the margin of subcriticality for nuclear data.

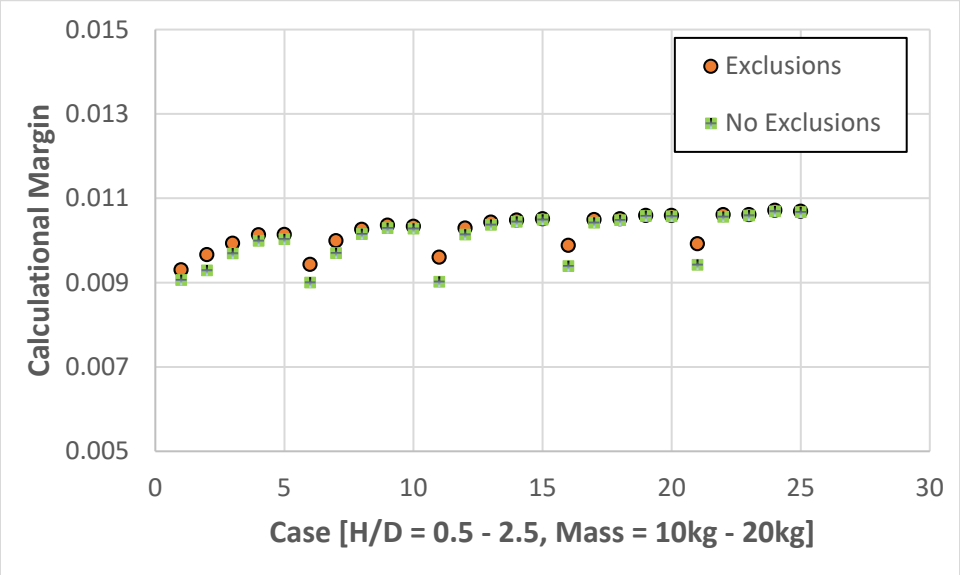

Figure 7. Whisper CM for HEU metal cases.

The margin of subcriticality due to nuclear data uncertainty is shown below. The $MOS_{nuclear\ data}$ is calculated from the sensitivity profile created by MCNP6.2 and the nuclear data covariances. GLLS adjustment of nuclear data covariances may be influenced by the benchmark collection. In Reference 8 two studies of nuclear data covariance adjustment were done. The initial study was conducted using the reduced benchmark set that does not include rejected outliers. In the subsequent study, Whisper nuclear data covariance adjustment was also done using the entire benchmark suite, keeping the benchmarks that were found to be outliers in the set. It was found that there are insignificant differences in the $MOS_{nuclear\ data}$ computed by Whisper whether or not the benchmark collection excludes outliers. For this reason the $MOS_{nuclear\ data}$ is the same for the case in which all benchmarks in the library are used versus the case in which benchmarks may be excluded based upon statistical rejection. Differences in the Whisper USLs generated when using a benchmark suite that excludes outliers versus the Whisper USLs generated when using a benchmark suite containing the entire library of 1101 benchmarks is due to differences in the Whisper calculational margin and not the $MOS_{nuclear\ data}$.

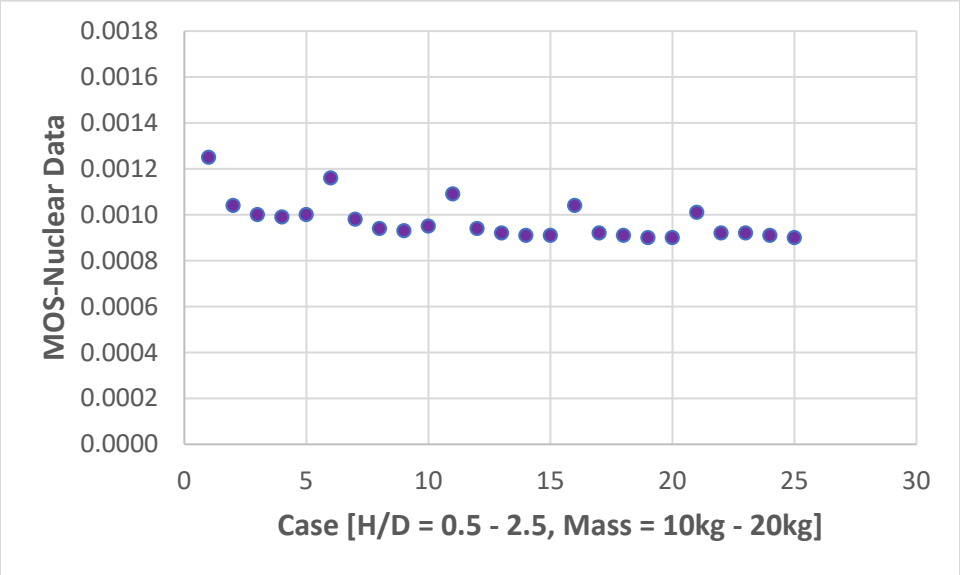

Figure 8. MOS for nuclear data for HEU metal cases.

It is important to note that only a subset of the benchmarks in the collection, enough found to be neutronically similar for valid statistical analysis in each case, are used to compute the baseline USL. For the HEU metal cases are in the fast energy spectrum, and the series of relevant benchmark experiments are those from HEU-MET-FAST (displayed in Table 7 in the Appendix). From that set of experiments there are 29 benchmark experiments which were found to be statistical outliers, 7 of which were found to be neutronically similar to case 11 shown in bold in Table 1, with each correlation coefficient, c_k. A c_k = 1 implies perfect correlation and many of the benchmarks are found to be highly correlated, or to have high neutronic similarity, to the HEU metal application cases.

The maximum magnitude of the USL difference, $USL_{\text{Benchmark Exclusions}} - USL_{\text{No Benchmark Exclusions}} = 0.98257 - 0.98315 = -0.00058$ occurred in Case 11, H/D = 0.5 and HEU mass of 15000. A comparison table for Case 11 is shown below in Table 1, with benchmarks which would have been excluded based upon the statistical rejection method shown in bold text.

Table 1. Comparison of Whisper results when using all benchmarks in the Whisper library vs. excluding some benchmarks found to be statistical outliers for case 11, chosen because it had the largest difference in USL for HEU metal cases.

Benchmark Exclusions			**No Benchmark Exclusions**		
Baseline USL = 0.98257			Baseline USL = 0.98315		
Bias = 0.00559			Bias = 0.00535		
Bias Uncertainty = 0.00401			Bias Uncertainty = 0.00367		
Nuclear Data Uncertainty = 0.00109			Nuclear Data Uncertainty = 0.00109		
Benchmark	**C_k**	**Weight**	**Benchmark**	**C_k**	**Weight**
heu-met-fast-084-019.i	0.9848	1.0000	heu-met-fast-084-019.i	0.9848	1.0000
			heu-met-fast-051-015.i	**0.9845**	**0.9655**
			heu-met-fast-051-001.i	**0.9845**	**0.9564**
heu-met-fast-051-002.i	0.9844	0.9644	heu-met-fast-051-002.i	0.9844	0.9542
			heu-met-fast-051-003.i	**0.9843**	**0.9405**
			heu-met-fast-051-016.i	**0.9842**	**0.9186**
heu-met-fast-051-004.i	0.9838	0.8965	heu-met-fast-051-004.i	0.9838	0.8669
			heu-met-fast-051-014.i	**0.9838**	**0.8658**
			heu-met-fast-051-017.i	**0.9833**	**0.8005**
heu-met-fast-100-002.i	0.9832	0.8391	heu-met-fast-100-002.i	0.9832	0.7932
			heu-met-fast-051-009.i	0.9831	0.7781
heu-met-fast-100-001.i	0.9828	0.8005	heu-met-fast-100-001.i	0.9828	0.7436
heu-met-fast-084-017.i	0.9825	0.7608	heu-met-fast-084-017.i	0.9825	0.6926
heu-met-fast-084-001.i	0.9824	0.7515	heu-met-fast-084-001.i	0.9824	0.6806
			heu-met-fast-051-018.i	**0.9822**	**0.6640**
heu-met-fast-043-001.i	0.9822	0.7343	heu-met-fast-043-001.i	0.9822	0.6584
heu-met-fast-084-015.i	0.9821	0.7217	heu-met-fast-084-015.i	0.9821	0.6423
heu-met-fast-001-001.i	0.9820	0.7172	heu-met-fast-001-001.i	0.9820	0.6365
heu-met-fast-043-002.i	0.9819	0.7061	heu-met-fast-043-002.i	0.9819	0.6222
heu-met-fast-078-041.i	0.9819	0.7000	heu-met-fast-078-041.i	0.9819	0.6144
heu-met-fast-084-023.i	0.9818	0.6951	heu-met-fast-084-023.i	0.9818	0.6080
heu-met-fast-084-004.i	0.9815	0.6640	heu-met-fast-084-004.i	0.9815	0.5682
heu-met-fast-043-003.i	0.9810	0.6120	heu-met-fast-043-003.i	0.9810	0.5012
heu-met-fast-007-019.i	0.9810	0.6119	heu-met-fast-007-019.i	0.9810	0.5012
heu-met-fast-007-001.i	0.9808	0.5872	heu-met-fast-007-001.i	0.9808	0.4695
heu-met-fast-008-001.i	0.9807	0.5754	heu-met-fast-008-001.i	0.9807	0.4542
heu-met-fast-018-002.i	0.9806	0.5695	heu-met-fast-018-002.i	0.9806	0.4466
heu-met-fast-087-001.i	0.9806	0.5693	heu-met-fast-087-001.i	0.9806	0.4464
heu-met-fast-012-001.i	0.9805	0.5588	heu-met-fast-012-001.i	0.9805	0.4330
heu-met-fast-044-001.i	0.9801	0.5207	heu-met-fast-044-001.i	0.9801	0.3839
heu-met-fast-084-007.i	0.9801	0.5171	heu-met-fast-084-007.i	0.9801	0.3793
heu-met-fast-044-002.i	0.9800	0.5123	heu-met-fast-044-002.i	0.9800	0.3731
heu-met-fast-022-002.i	0.9800	0.5076	heu-met-fast-022-002.i	0.9800	0.3670
heu-met-fast-015-001.i	0.9800	0.5052	heu-met-fast-015-001.i	0.9800	0.3640
heu-met-fast-079-001.i	0.9799	0.4983	heu-met-fast-079-001.i	0.9799	0.3552
heu-met-fast-044-003.i	0.9799	0.4947	heu-met-fast-044-003.i	0.9799	0.3505
heu-met-fast-078-023.i	0.9797	0.4827	heu-met-fast-078-023.i	0.9797	0.3351
heu-met-fast-065-002.i	0.9796	0.4712	heu-met-fast-065-002.i	0.9796	0.3203

heu-met-fast-089-001.i	0.9796	0.4644	heu-met-fast-089-001.i	0.9796	0.3116
heu-met-fast-044-005.i	0.9795	0.4618	heu-met-fast-044-005.i	0.9795	0.3082
heu-met-fast-043-004.i	0.9795	0.4587	heu-met-fast-043-004.i	0.9795	0.3042
heu-met-fast-020-002.i	0.9794	0.4493	heu-met-fast-020-002.i	0.9794	0.2922
heu-met-fast-043-005.i	0.9794	0.4461	heu-met-fast-043-005.i	0.9794	0.2881
heu-met-fast-084-022.i	0.9794	0.4449	heu-met-fast-084-022.i	0.9794	0.2865
heu-met-fast-084-005.i	0.9793	0.4347	heu-met-fast-084-005.i	0.9793	0.2734
heu-met-fast-044-004.i	0.9791	0.4201	heu-met-fast-044-004.i	0.9791	0.2546
heu-met-fast-079-002.i	0.9788	0.3884	heu-met-fast-079-002.i	0.9788	0.2139
heu-met-fast-078-025.i	0.9783	0.3384	heu-met-fast-078-025.i	0.9783	0.1496
heu-met-fast-084-026.i	0.9782	0.3190	heu-met-fast-084-026.i	0.9782	0.1247
heu-met-fast-063-001.i	0.9779	0.2914	heu-met-fast-063-001.i	0.9779	0.0893
heu-met-fast-084-016.i	0.9778	0.2866	heu-met-fast-084-016.i	0.9778	0.0830
heu-met-fast-041-003.i	0.9777	0.2683	heu-met-fast-041-003.i	0.9777	0.0595
heu-met-fast-084-002.i	0.9774	0.2468	heu-met-fast-084-002.i	0.9774	0.0318
heu-met-fast-019-001.i	0.9773	0.2351	heu-met-fast-019-001.i	0.9773	0.0169
heu-met-fast-084-027.i	0.9768	0.1762			
heu-met-fast-063-002.i	0.9766	0.1645			
heu-met-fast-078-003.i	0.9765	0.1516			
heu-met-fast-079-003.i	0.9763	0.1303			
heu-met-fast-078-043.i	0.9763	0.1280			
heu-met-fast-027-001.i	0.9763	0.1267			
heu-met-fast-010-002.i	0.9762	0.1207			
heu-met-fast-010-001.i	0.9754	0.0370			

Table 2. Whisper results for benchmark outliers that were chosen as neutronically similar for HEU metal cases.

Benchmark Outlier	Times Benchmark is Neutronically Similar to Application	Maximum c_k
heu-met-fast-007-006	6	0.9832
heu-met-fast-007-032	18	0.9827
heu-met-fast-007-033	0	n/a
heu-met-fast-007-034	0	n/a
heu-met-fast-007-036	0	n/a
heu-met-fast-007-037	0	n/a
heu-met-fast-007-039	0	n/a
heu-met-fast-007-040	0	n/a
heu-met-fast-025-005	0	n/a
heu-met-fast-038-001	0	n/a
heu-met-fast-040-001	0	n/a
heu-met-fast-051-001	23	0.9864
heu-met-fast-051-003	23	0.9862
heu-met-fast-051-009	19	0.9854
heu-met-fast-051-014	23	0.9862
heu-met-fast-051-015	23	0.9862
heu-met-fast-051-016	23	0.9861

heu-met-fast-051-017	19	0.9855
heu-met-fast-051-018	11	0.9845
heu-met-fast-057-001	0	n/a
heu-met-fast-057-003	0	n/a
heu-met-fast-057-005	0	n/a
heu-met-fast-064-001	0	n/a
heu-met-fast-064-003	0	n/a
heu-met-fast-090-001	0	n/a
heu-met-fast-090-002	0	n/a
heu-met-fast-092-003	0	n/a
heu-met-fast-093-001	0	n/a
heu-met-fast-094-002	0	n/a
	Total Times Similar = 188	**Overall Max. C_k = 0.9864**

HEU "Solution" cases

The U(93) "solution" cases were modeled as an metal-water mixture and conducted as a parameter study to cover a range of concentration. The process models consisted of two right circular cylinders of U(93) metal-water mixture on a stainless steel floor reflected radially with a ½-inch thick offset water on one cylinder to represent personnel and incidental reflection. The two metal-water mixture cylinders were placed touching one another with their bases sitting on the ½-inch thick stainless steel floor. The HEU was modeled as 93% ^{235}U by weight and 7% ^{238}U. The mass of HEU in each metal-water mixture cylinder was set at 1,000 g U. The cylinder height-to-diameter (H/D) ratio was set to 1.6. The HEU concentration modeled in each cylinder ranged from 0.005 g U/cm^3 to 1 g U/cm^3, with overall mixture density calculated by combining the metal at 18.75 g/cm^3 and the water at 1 g/cm^3 in a mechanical mixture. Parameterizing the concentration resulted in 29 different cases. Internal to each individual case the cylinder mass and H/D were identical to one another; there was no variation amongst cylinders in an individual case.

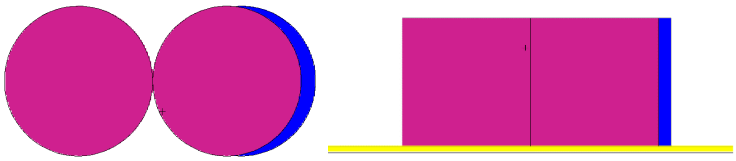

Figure 9. MCNP6.2 top and side view illustrations, respectively, of model geometry. HEU "solution" is shown in magenta; water in blue and steel in yellow.

MCNP6.2 was used to determine k-effective, the average energy of neutrons causing fission, the energy of the average lethargy of neutrons causing fission, and sensitivity profiles for each of the 29 process model cases. Whisper was used to find benchmarks neutronically similar to each process model case using sensitivity profiles, determine the calculational margin and portions of the margin of subcriticality leading to the baseline USL.

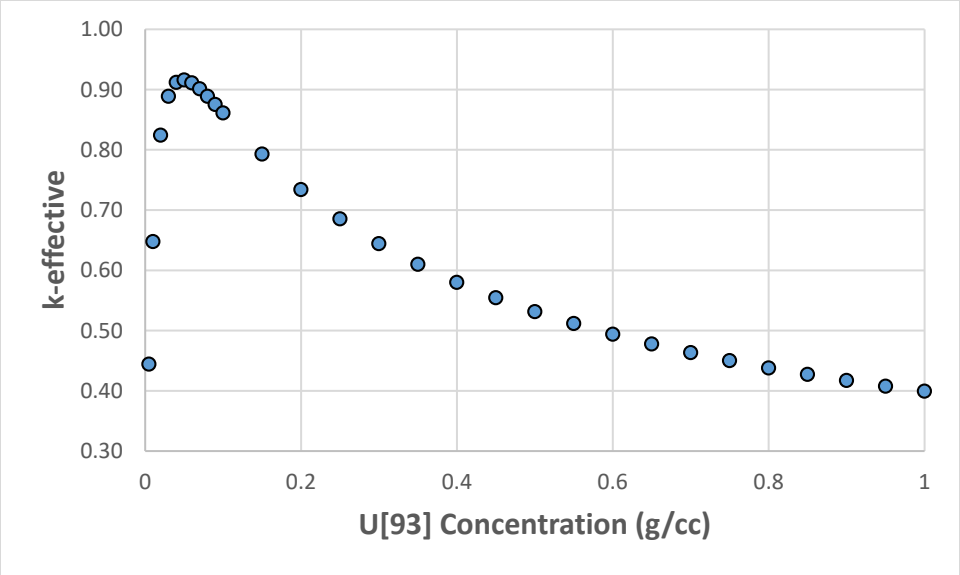

Figure 10. MCNP6.2 k-effective results for HEU "Solution" cases.

Whisper-1.1 baseline USL results are reported below in Figure 11. A separate USL was computed for each application case using a benchmark collection reduced due to exclusions based upon the iterative diagonal chi-squared rejection method. In addition, the USL was computed for each process model case using a benchmark collection consisting of all 1101 benchmark experiments contained in the Whisper-1.1 library. When calculating the baseline USL and excluding benchmarks based upon statistical rejection the lowest baseline USL = 0.95427 and the highest 0.97494. When including all benchmarks the lowest baseline USL = 0.95427 and the highest = 0.97538.

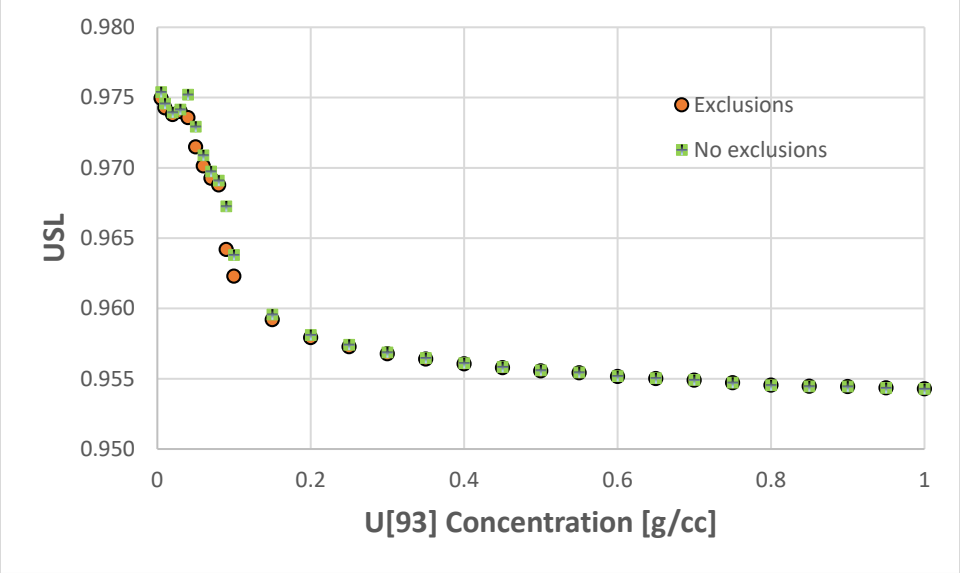

Figure 11. Whisper baseline USL results for HEU "Solution" cases.

The baseline USL is slightly higher when not excluding benchmarks. The difference between the baseline USL when including all benchmarks and the baseline USL when excluding some benchmarks in the

library ranges from 0 to 0.00307, results are shown in Figure 12. The magnitude of USL difference is greatest for case 10, HEU oxide concentration of 0.09 g/cm^3.

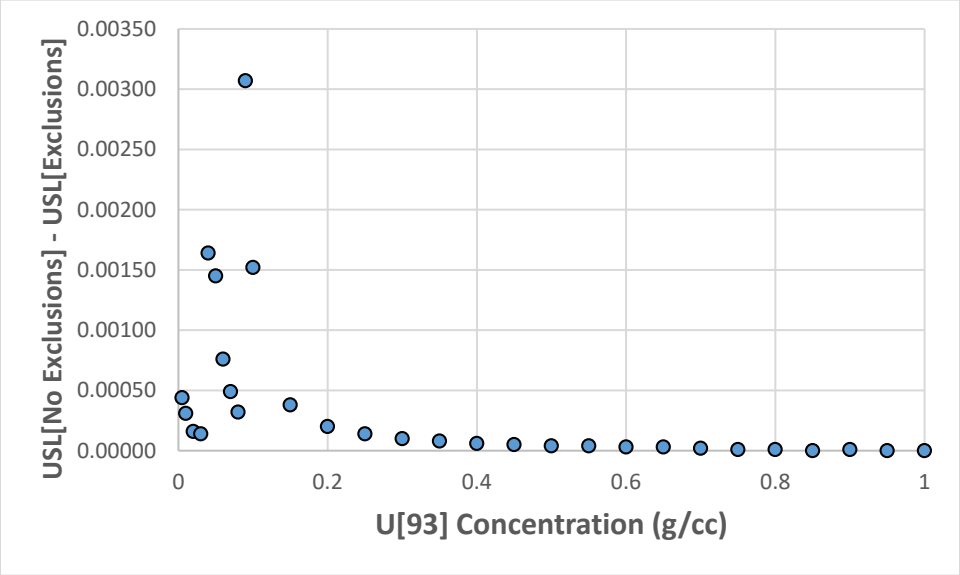

Figure 12. The difference between USL when using all benchmarks in the Whisper library vs. exclusing some benchmarks found to be statistical outliers for HEU "Solution" cases.

The calculational margin calculated by Whisper is shown below in Figure 13. The difference between the CM when including all benchmarks and the CM when excluding some benchmarks in the library ranges from 0 to -0.00307. The magnitude of the difference in the baseline USL computed by Whisper when using all benchmarks versus the baseline USL computed by Whisper when excluding outliers is due to the calculational margin (bias and bias uncertainty) and not due to the margin of subcriticality for nuclear data.

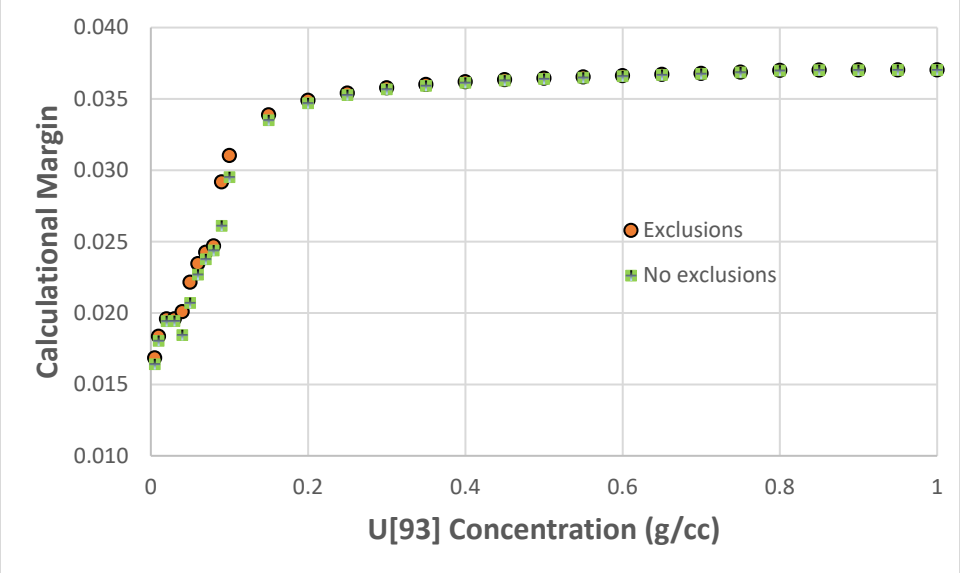

Figure 13. CM for HEU "Solution" cases.

The margin of subcriticality due to nuclear data uncertainty is shown below. The $MOS_{nuclear\ data}$ is calculated from the sensitivity profile created by MCNP6.2 and the nuclear data covariances. GLLS adjustment of nuclear data covariances may be influenced by the benchmark collection. In Reference 8 two studies of nuclear data covariance adjustment were done. The initial study was conducted using the reduced benchmark set that does not include rejected outliers. In the subsequent study, Whisper nuclear data covariance adjustment was also done using the entire benchmark suite, keeping the benchmarks that were found to be outliers in the set. It was found that there are insignificant differences in the $MOS_{nuclear\ data}$ computed by Whisper whether or not the benchmark collection excludes outliers. For this reason the $MOS_{nuclear\ data}$ is the same for the case in which all benchmarks in the library are used versus the case in which benchmarks may be excluded based upon statistical rejection. Differences in the Whisper USLs generated when using a benchmark suite that excludes outliers versus the Whisper USLs generated when using a benchmark suite containing the entire library of 1101 benchmarks is due to differences in the Whisper calculational margin and not the $MOS_{nuclear\ data}$.

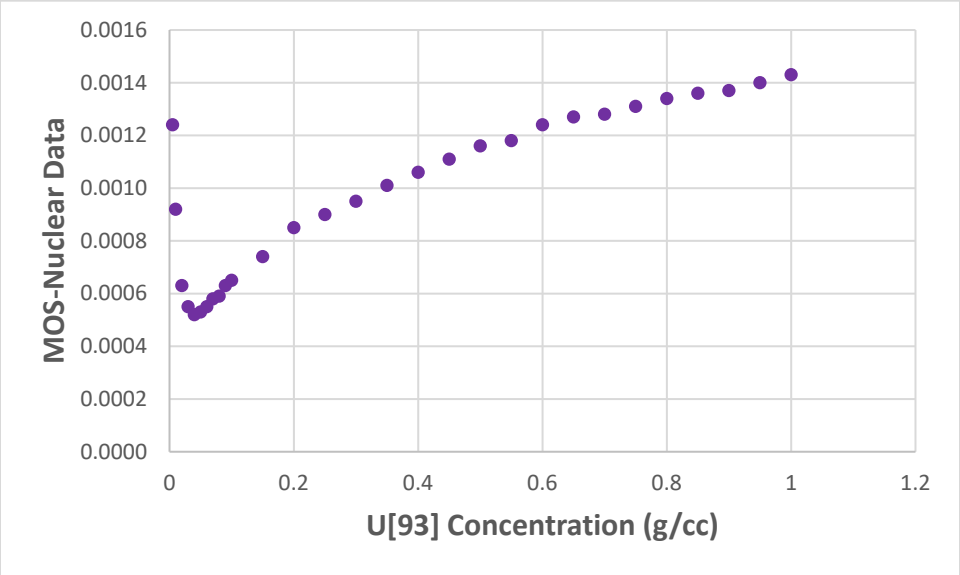

Figure 14. MOs for nuclear data for HEU "Solution" cases.

It is important to note that only a subset of the benchmarks in the collection, enough found to be neutronically similar for valid statistical analysis in each case, are used to compute the baseline USL. The HEU solution cases are in the thermal energy spectrum and the series of relevant benchmark experiments are those from HEU-MET-THERM, HEU-COMP-THERM, and HEU-SOL-THERM. From those sets of experiments there are 9 benchmark experiments which were found to be statistical outliers (shown in Table 7 in the Appendix), 4 of which were found to be neutronically similar to HEU solution case 10 below, with each correlation coefficient, c_k. A $c_k = 1$ implies perfect correlation and many of the benchmarks are found to be highly correlated, or to have high neutronic similarity, to the HEU solution application cases.

The maximum magnitude of the USL difference, $USL_{\text{Benchmark Exclusions}} - USL_{\text{No Benchmark Exclusions}} = 0.96419 - 0.96726 = -0.00307$ occurred in Case 10, HEU concentration of 0.09 g/cm^3. A comparison table for Case 10 is shown below in Table 3, with benchmarks which would have been excluded based upon the statistical rejection method shown in bold text.

Table 3. Comparison of Whisper results when using all benchmarks in the Whisper library vs. excluding some benchmarks found to be statistical outliers for case 10, chosen because it had the largest difference in USL for HEU "Solution" cases.

Benchmark Exclusions			**No Benchmark Exclusions**		
Baseline USL = 0.96419			Baseline USL = 0.96726		
Bias = 0.01035			Bias = 0.01056		
Bias Uncertainty = 0.0183			Bias Uncertainty = 0.01555		
Nuclear Data Uncertainty = 0.00063			Nuclear Data Uncertainty = 0.00063		
Benchmark	**C_k**	**Weight**	**Benchmark**	**C_k**	**Weight**
heu-sol-therm-043-001	0.9991	1.0000	heu-sol-therm-043-001	0.9991	1.0000
heu-sol-therm-001-007	0.9988	0.9903	heu-sol-therm-001-007	0.9988	0.9895
heu-sol-therm-001-003	0.9987	0.9884	heu-sol-therm-001-003	0.9987	0.9874
heu-sol-therm-001-008	0.9987	0.9864	heu-sol-therm-001-008	0.9987	0.9852
heu-sol-therm-001-001	0.9986	0.9862	heu-sol-therm-001-001	0.9986	0.9851
heu-sol-therm-010-001	0.9974	0.9461	heu-sol-therm-010-001	0.9974	0.9415
			heu-sol-therm-001-010	**0.9962**	**0.9013**
heu-sol-therm-001-006	0.9961	0.9066	heu-sol-therm-001-006	0.9961	0.8987
heu-sol-therm-001-005	0.9948	0.8648	heu-sol-therm-001-005	0.9948	0.8533
heu-sol-therm-009-003	0.9937	0.8315	heu-sol-therm-009-003	0.9937	0.8172
heu-comp-therm-002-023	0.9925	0.7916	heu-comp-therm-002-023	0.9925	0.7739
heu-comp-therm-002-019	0.9907	0.7364	heu-comp-therm-002-019	0.9907	0.7139
heu-sol-therm-025-005	0.9906	0.7307	heu-sol-therm-025-005	0.9906	0.7078
heu-sol-therm-050-005	0.9899	0.7092	heu-sol-therm-050-005	0.9899	0.6845
heu-sol-therm-011-002	0.9898	0.7065	heu-sol-therm-011-002	0.9898	0.6815
heu-sol-therm-011-001	0.9896	0.7018	heu-sol-therm-011-001	0.9896	0.6764
heu-sol-therm-050-011	0.9895	0.6969	heu-sol-therm-050-011	0.9895	0.6711
heu-comp-therm-002-018	0.9886	0.6700	heu-comp-therm-002-018	0.9886	0.6419
heu-sol-therm-001-002	0.9885	0.6649	heu-sol-therm-001-002	0.9885	0.6364
heu-sol-therm-001-004	0.9878	0.6450	heu-sol-therm-001-004	0.9878	0.6148
			heu-sol-therm-001-009	**0.9878**	**0.6119**
heu-comp-therm-002-024	0.9874	0.6316	heu-comp-therm-002-024	0.9874	0.6002
heu-sol-therm-025-004	0.9857	0.5773	heu-sol-therm-025-004	0.9857	0.5412
heu-sol-therm-025-001	0.9850	0.5559	heu-sol-therm-025-001	0.9850	0.5181
heu-comp-therm-002-002	0.9848	0.5485	heu-comp-therm-002-002	0.9848	0.5101
heu-sol-therm-025-002	0.9847	0.5452	heu-sol-therm-025-002	0.9847	0.5065
heu-comp-therm-002-003	0.9845	0.5397	heu-comp-therm-002-003	0.9845	0.5005
heu-comp-therm-002-011	0.9838	0.5178	heu-comp-therm-002-011	0.9838	0.4767
heu-comp-therm-002-012	0.9837	0.5136	heu-comp-therm-002-012	0.9837	0.4721
heu-sol-therm-009-002	0.9835	0.5081	heu-sol-therm-009-002	0.9835	0.4661
heu-comp-therm-002-020	0.9831	0.4967	heu-comp-therm-002-020	0.9831	0.4538
heu-comp-therm-002-004	0.9829	0.4891	heu-comp-therm-002-004	0.9829	0.4455
heu-sol-therm-019-002	0.9812	0.4347	heu-sol-therm-019-002	0.9812	0.3865
heu-sol-therm-019-001	0.9808	0.4244	heu-sol-therm-019-001	0.9808	0.3753
			heu-met-therm-014-001	**0.9802**	**0.3530**
heu-comp-therm-002-025	0.9788	0.3589	heu-comp-therm-002-025	0.9788	0.3043
heu-comp-therm-002-013	0.9784	0.3469	heu-comp-therm-002-013	0.9784	0.2912
heu-comp-therm-002-001	0.9782	0.3408	heu-comp-therm-002-001	0.9782	0.2846

heu-comp-therm-002-005	0.9776	0.3230	heu-comp-therm-002-005	0.9776	0.2653
heu-sol-therm-019-003	0.9756	0.2575	heu-sol-therm-019-003	0.9756	0.1943
			heu-comp-therm-002-021	**0.9716**	**0.0595**
heu-sol-therm-050-004	0.9714	0.1258	heu-sol-therm-050-004	0.9714	0.0513
heu-sol-therm-050-006	0.9712	0.1212	heu-sol-therm-050-006	0.9712	0.0464
heu-sol-therm-009-001	0.9712	0.1186	heu-sol-therm-009-001	0.9712	0.0435
heu-comp-therm-002-006	0.9711	0.1175	heu-comp-therm-002-006	0.9711	0.0422
heu-sol-therm-050-008	0.9711	0.1168	heu-sol-therm-050-008	0.9711	0.0415
heu-sol-therm-050-002	0.9709	0.1095	heu-sol-therm-050-002	0.9709	0.0336
heu-sol-therm-050-001	0.9706	0.1009	heu-sol-therm-050-001	0.9706	0.0243
heu-sol-therm-050-010	0.9706	0.0999	heu-sol-therm-050-010	0.9706	0.0232
heu-comp-therm-002-014	0.9703	0.0918	heu-comp-therm-002-014	0.9703	0.0144
heu-sol-therm-038-012	0.9691	0.0523			
heu-sol-therm-038-011	0.9690	0.0495			
heu-sol-therm-038-001	0.9682	0.0263			

Table 4. Whisper results for benchmark outliers that were chosen as neutronically similar for HEU "Solution" cases.

Benchmark Outlier	Times Benchmark is Neutronically Similar to Application	Maximum c_k
heu-met-therm-012-001	0	n/a
heu-met-therm-014-001	27	0.9830
heu-comp-therm-002-015	6	0.9903
heu-comp-therm-002-016	3	0.9820
heu-comp-therm-002-017	3	0.9737
heu-comp-therm-002-021	10	0.9943
heu-comp-therm-002-022	4	0.9893
heu-sol-therm-001-009	24	0.9922
heu-sol-therm-001-010	27	0.9995
	Total Times Similar = 104	**Overall Max. C_k = 0.9995**

HEU Oxide cases

The U(93) oxide cases were conducted as a parameter study to cover a range of water moisture within the oxide. The process models consisted of three HEU oxide right circular cylinders on a stainless steel floor reflected radially by 1-inch thick water to represent personnel and incidental reflection. The three identical cylinders were placed touching in a triangular pattern with their bases sitting on a 1-inch thick stainless steel floor. The HEU oxide was modeled as 93% ^{235}U by weight and 7% ^{238}U at a density of 18 g/cm^3. The HEU oxide mass modeled in each cylinder was 10000 grams per cylinder. The H/D ratios of all cylinders was set at 1.6. Parameterizing the atom fraction water per cylinder from 1e-6 to 0.999 resulted in 106 different cases. Internal to each individual case the cylinder mass and H/D were identical to one another; there was no variation amongst cylinders in an individual case. The model geometry is shown below in Figure 16.

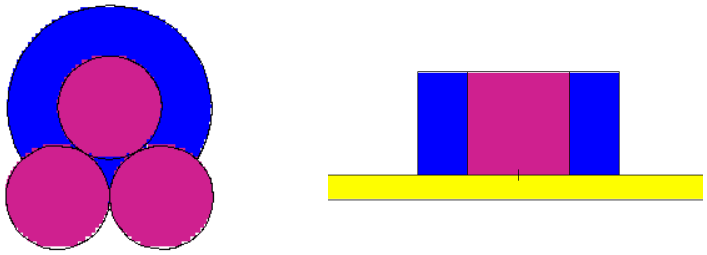

Figure 16. MCNP6.2 top and side view illustrations, respectively, of model geometry. HEU oxide is shown in magenta; water in blue and steel in yellow.

MCNP6.2 was used to determine k-effective, the average energy of neutrons causing fission, the energy of the average lethargy of neutrons causing fission, and sensitivity profiles for each of the 106 process model cases. Whisper was used to find benchmarks neutronically similar to each process model case using sensitivity profiles, determine the calculational margin and portions of the margin of subcriticality leading to the baseline USL.

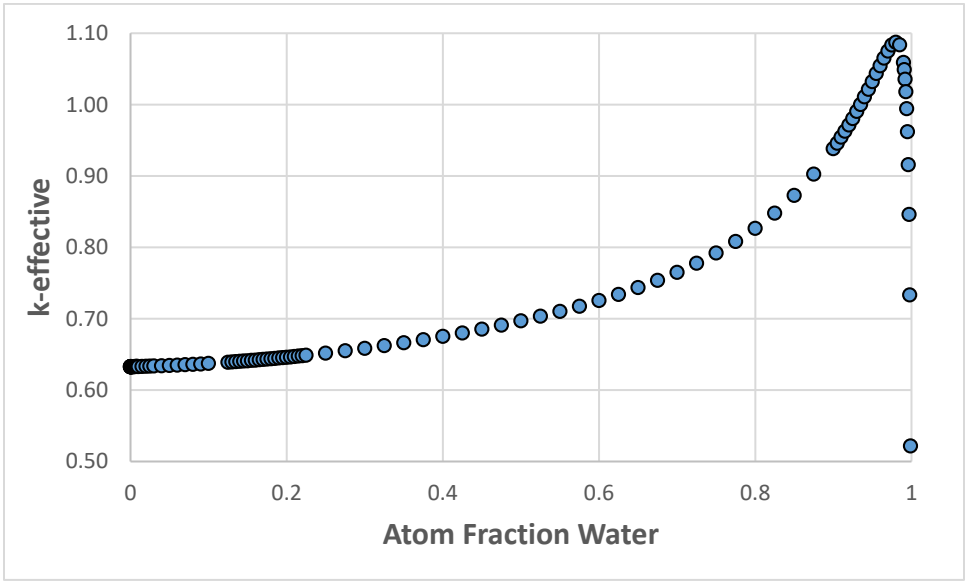

Figure 17. MCNP6.2 k-effective results for HEU oxide cases.

Whisper-1.1 baseline USL results are reported below in Figure 18. A separate USL was computed for each application case using a benchmark collection reduced due to exclusions based upon the iterative diagonal chi-squared rejection method. In addition, the USL was computed for each process model case using a benchmark collection consisting of all 1101 benchmark experiments contained in the Whisper-1.1 library. When calculating the baseline USL and excluding benchmarks based upon statistical rejection the lowest baseline USL = 0.95633 and the highest 0.97940. When including all benchmarks the lowest baseline USL = 0.95633 and the highest = 0.97970.

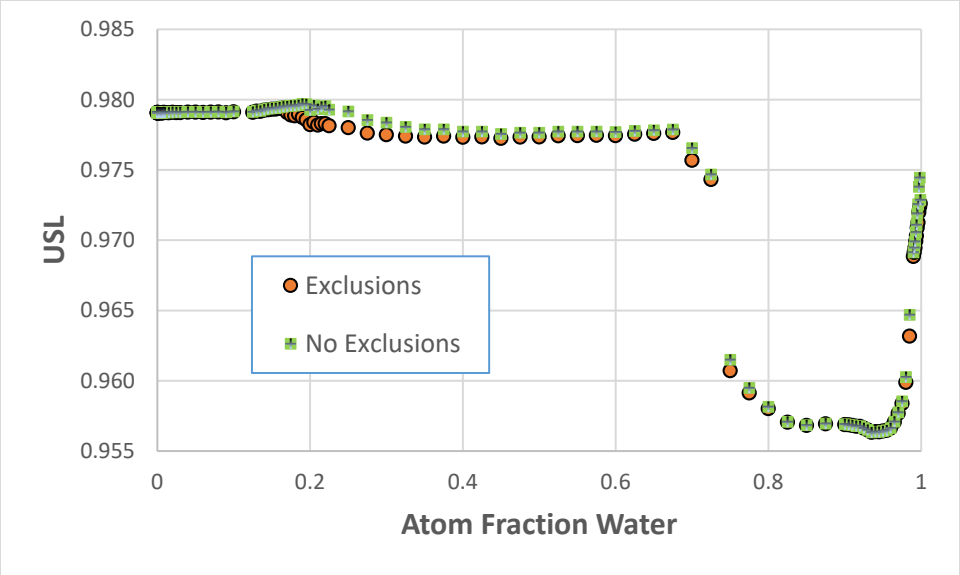

Figure 18. Whisper baseline USL for HEU oxide cases.

The baseline USL is slightly higher when not excluding benchmarks. The difference between the baseline USL when including all benchmarks and the baseline USL when excluding some benchmarks in the library ranges from 0 to 0.00208, results are shown in Figure 19. The magnitude of USL difference is greatest for case 105, water fraction = 0.98. Case 105 is more indicative of a solution system than an oxide system. The case more reflective of an oxide system with the next highest difference in USLs is case 52, water fraction = 0.22 with a difference between USLs of 0.00125.

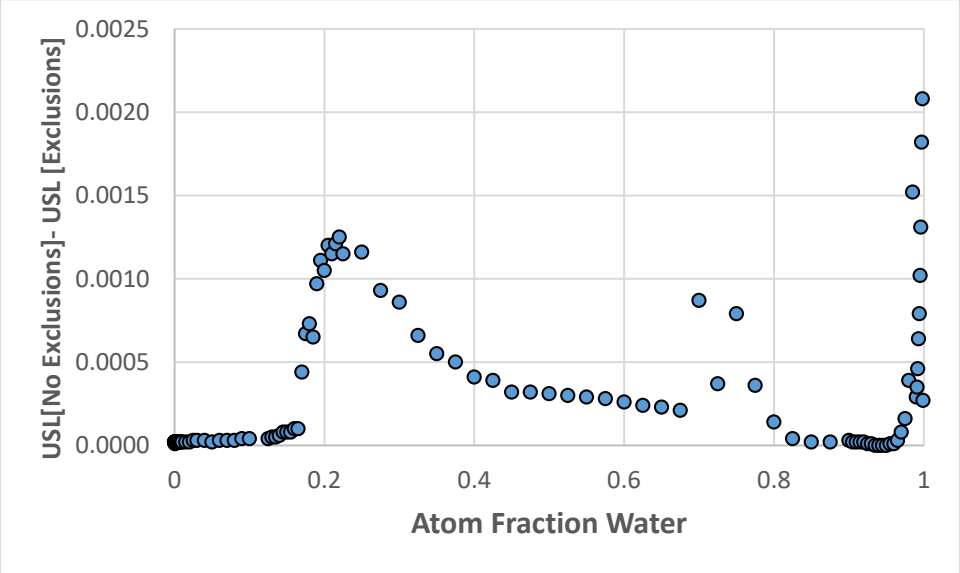

Figure 19. The difference between USL when using all benchmarks in the Whisper library vs. exclusing some benchmarks found to be statistical outliers for HEU oxide cases.

The calculational margin calculated by Whisper is shown below in Figure 20. The difference between the CM when including all benchmarks and the CM when excluding some benchmarks in the library ranges from 0 to -0.00208. The magnitude of the difference in the baseline USL computed by Whisper when

using all benchmarks versus the baseline USL computed by Whisper when excluding outliers is due to the calculational margin (bias and bias uncertainty) and not due to the margin of subcriticality for nuclear data.

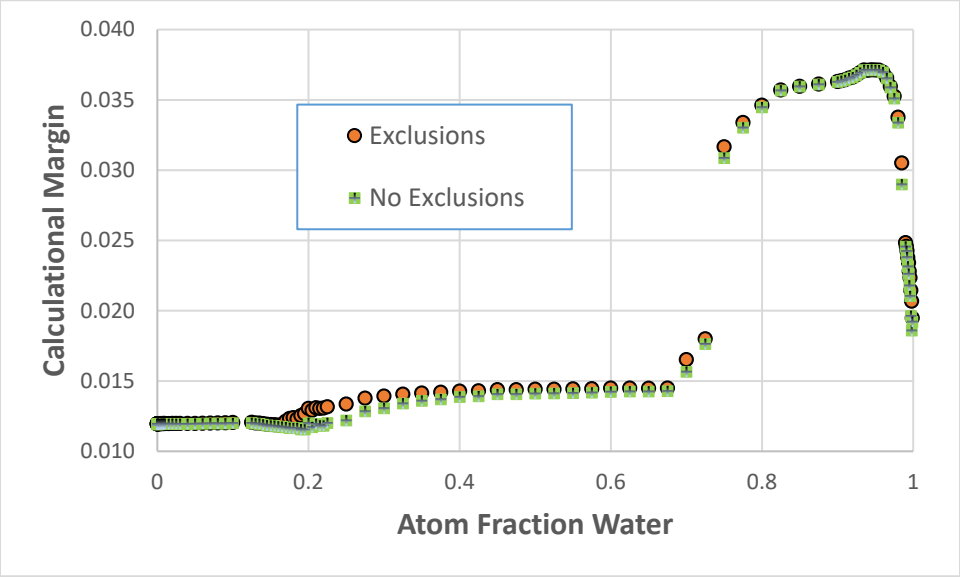

Figure 20. Whisper CM for HEU oxide cases.

The margin of subcriticality due to nuclear data uncertainty is shown below. The $MOS_{nuclear\ data}$ is calculated from the sensitivity profile created by MCNP6.2 and the nuclear data covariances. GLLS adjustment of nuclear data covariances may be influenced by the benchmark collection. In Reference 8 two studies of nuclear data covariance adjustment were done. The initial study was conducted using the reduced benchmark set that does not include rejected outliers. In the subsequent study, Whisper nuclear data covariance adjustment was also done using the entire benchmark suite, keeping the benchmarks that were found to be outliers in the set. It was found that there are insignificant differences in the $MOS_{nuclear\ data}$ computed by Whisper whether or not the benchmark collection excludes outliers. For this reason the $MOS_{nuclear\ data}$ is the same for the case in which all benchmarks in the library are used versus the case in which benchmarks may be excluded based upon statistical rejection. Differences in the Whisper USLs generated when using a benchmark suite that excludes outliers versus the Whisper USLs generated when using a benchmark suite containing the entire library of 1101 benchmarks is due to differences in the Whisper calculational margin and not the $MOS_{nuclear\ data}$.

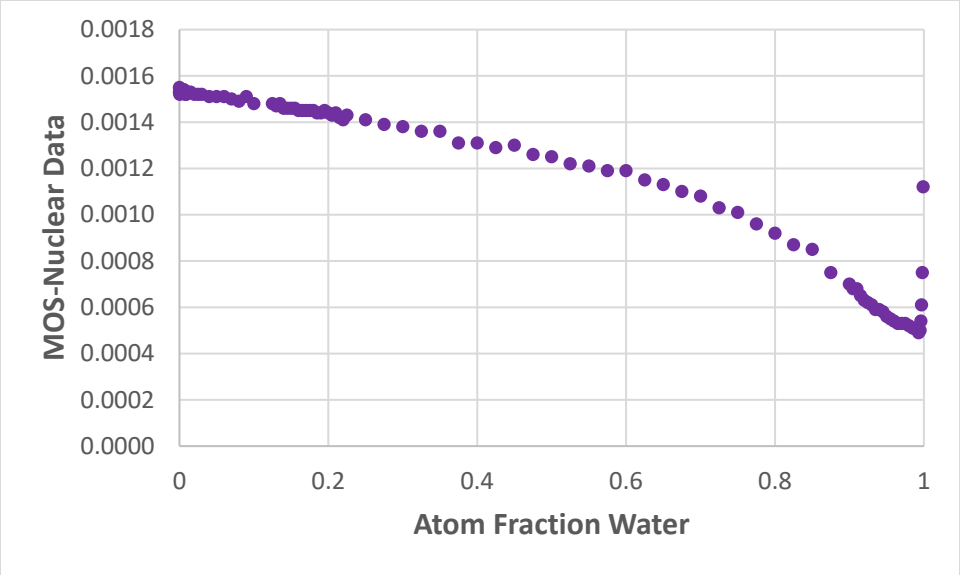

Figure 21. MOS for nuclear data for HEU oxide cases.

It is important to note that only a subset of the benchmarks in the collection, enough found to be neutronically similar for valid statistical analysis in each case, are used to compute the baseline USL. The HEU oxide cases with variable water content are in the fast, intermediate and thermal energy spectrums, and the series of relevant benchmark experiments are those from HEU-MET-FAST, HEU-MET-MIXED, HEU-COMP-THERM, HEU-COMP-INTER, HEU-SOL-THERM. From those sets of experiments there are 36 benchmark experiments which were found to be statistical outliers (displayed in Table 7 in the Appendix), many were found to be neutronically similar to the HEU oxide cases as shown in Table 6, with each correlation coefficient, c_k. A $c_k = 1$ implies perfect correlation and many of the benchmarks are found to be highly correlated, or to have high neutronic similarity, to the HEU oxide application cases.

Case 52 was chosen for further study because it has one of the largest differences in USLs, as shown in Figure 19. There are other cases with slightly higher USL differences, however they were not chosen for further study because they have a water fraction near 1 and rather "solution-like" and therefore studied further in the solution cases. The magnitude of the USL difference, $USL_{\text{Benchmark Exclusions}} - USL_{\text{No Benchmark Exclusions}} = 0.97813 - 0.97928 = -0.00125$ in Case 52, atom fraction water = 0.22. A comparison table for Case 52 is shown below in Table 5, with benchmarks which would have been excluded based upon the statistical rejection method shown in bold text.

Table 5. Comparison of Whisper results when using all benchmarks in the Whisper library vs. excluding some benchmarks found to be statistical outliers for case 52, chosen because it had the largest difference in USL for HEU oxide cases.

Benchmark Exclusions			**No Benchmark Exclusions**		
Baseline USL = 0.97813			Baseline USL = 0.97928		
Bias = 0.00609			Bias = 0.00538		
Bias Uncertainty = 0.00707			Bias Uncertainty = 0.00663		
Nuclear Data Uncertainty = 0.00143			Nuclear Data Uncertainty = 0.00143		
Benchmark	**C_k**	**Weight**	**Benchmark**	**C_k**	**Weight**
heu-met-fast-007-030.i	0.9783	1.0000	heu-met-fast-007-030.i	0.9783	1.0000
heu-met-fast-007-031.i	0.9729	0.8578	heu-met-fast-007-031.i	0.9729	0.8309

heu-met-fast-007-025.i	0.9720	0.8329	heu-met-fast-007-025.i	0.9720	0.8011
heu-met-fast-007-010.i	0.9720	0.8328	heu-met-fast-007-010.i	0.9720	0.8010
heu-met-fast-007-026.i	0.9719	0.8321	heu-met-fast-007-026.i	0.9719	0.8002
heu-met-fast-007-011.i	0.9717	0.8246	heu-met-fast-007-011.i	0.9717	0.7913
heu-met-fast-034-002.i	0.9713	0.8158	heu-met-fast-034-002.i	0.9713	0.7809
heu-met-fast-033-001.i	0.9713	0.8144	heu-met-fast-033-001.i	0.9713	0.7791
heu-met-fast-007-012.i	0.9709	0.8048	heu-met-fast-007-012.i	0.9709	0.7678
heu-met-fast-007-015.i	0.9708	0.8027	heu-met-fast-007-015.i	0.9708	0.7652
heu-met-fast-007-016.i	0.9708	0.8011	heu-met-fast-007-016.i	0.9708	0.7634
heu-met-fast-007-014.i	0.9706	0.7971	heu-met-fast-007-014.i	0.9706	0.7586
heu-met-fast-007-013.i	0.9704	0.7903	heu-met-fast-007-013.i	0.9704	0.7505
			heu-met-fast-007-037.i	**0.9687**	**0.6997**
heu-met-fast-007-038.i	0.9686	0.7443	heu-met-fast-007-038.i	0.9686	0.6957
			heu-met-fast-007-040.i	**0.9685**	**0.6914**
			heu-met-fast-007-036.i	**0.9682**	**0.6815**
			heu-met-fast-007-039.i	**0.9681**	**0.6809**
heu-met-fast-033-002.i	0.9680	0.7275	heu-met-fast-033-002.i	0.9680	0.6758
heu-met-fast-007-024.i	0.9679	0.7263	heu-met-fast-007-024.i	0.9679	0.6743
heu-met-fast-034-001.i	0.9677	0.7194	heu-met-fast-034-001.i	0.9677	0.6662
heu-met-fast-007-023.i	0.9675	0.7144	heu-met-fast-007-023.i	0.9675	0.6602
heu-met-fast-031-001.i	0.9659	0.6725	heu-met-fast-031-001.i	0.9659	0.6104
heu-met-fast-007-029.i	0.9657	0.6677	heu-met-fast-007-029.i	0.9657	0.6046
heu-met-fast-034-003.i	0.9647	0.6422	heu-met-fast-034-003.i	0.9647	0.5743
heu-met-fast-078-007.i	0.9625	0.5838	heu-met-fast-078-007.i	0.9625	0.5048
heu-met-fast-004-001.i	0.9620	0.5705	heu-met-fast-004-001.i	0.9620	0.4890
heu-met-mixed-002-001.i	0.9614	0.5531	heu-met-mixed-002-001.i	0.9614	0.4683
heu-met-mixed-003-001.i	0.9609	0.5399	heu-met-mixed-003-001.i	0.9609	0.4525
heu-met-fast-007-022.i	0.9609	0.5398	heu-met-fast-007-022.i	0.9609	0.4525
			heu-met-fast-090-002.i	**0.9607**	**0.4460**
heu-met-fast-007-007.i	0.9604	0.5285	heu-met-fast-007-007.i	0.9604	0.4390
heu-met-fast-007-009.i	0.9603	0.5262	heu-met-fast-007-009.i	0.9603	0.4362
heu-met-fast-007-008.i	0.9603	0.5249	heu-met-fast-007-008.i	0.9603	0.4347
			heu-met-fast-007-006.i	**0.9602**	**0.4315**
heu-met-fast-007-021.i	0.9602	0.5222	heu-met-fast-007-021.i	0.9602	0.4315
heu-met-fast-007-028.i	0.9595	0.5034	heu-met-fast-007-028.i	0.9595	0.4091
heu-met-fast-091-001.i	0.9592	0.4954	heu-met-fast-091-001.i	0.9592	0.3996
heu-met-fast-007-020.i	0.9591	0.4925	heu-met-fast-007-020.i	0.9591	0.3962
heu-met-fast-007-035.i	0.9589	0.4892	heu-met-fast-007-035.i	0.9589	0.3923
heu-met-fast-007-005.i	0.9584	0.4748	heu-met-fast-007-005.i	0.9584	0.3751
			heu-met-fast-090-001.i	**0.9570**	**0.3317**
heu-met-mixed-001-001.i	0.9565	0.4242	heu-met-mixed-001-001.i	0.9565	0.3149
heu-met-fast-007-041.i	0.9561	0.4151	heu-met-fast-007-041.i	0.9561	0.3041
heu-met-fast-007-042.i	0.9554	0.3945	heu-met-fast-007-042.i	0.9554	0.2796
heu-met-fast-078-001.i	0.9544	0.3705	heu-met-fast-078-001.i	0.9544	0.2510
heu-met-fast-007-004.i	0.9529	0.3302	heu-met-fast-007-004.i	0.9529	0.2030
heu-comp-inter-003-006.i	0.9487	0.2193	heu-comp-inter-003-006.i	0.9487	0.0711

heu-met-fast-007-003.i	0.9486	0.2174	heu-met-fast-007-003.i	0.9486	0.0688
heu-met-fast-016-002.i	0.9486	0.2171	heu-met-fast-016-002.i	0.9486	0.0685
heu-met-fast-007-027.i	0.9469	0.1719	heu-met-fast-007-027.i	0.9469	0.0147
heu-met-fast-007-017.i	0.9437	0.0863			
heu-met-fast-088-001.i	0.9435	0.0818			
heu-met-fast-011-001.i	0.9432	0.0728			
heu-met-fast-007-002.i	0.9430	0.0677			
heu-met-fast-007-018.i	0.9428	0.0620			
heu-met-fast-078-033.i	0.9427	0.0601			
heu-met-fast-078-011.i	0.9422	0.0484			
heu-met-fast-078-029.i	0.9420	0.0417			
heu-met-fast-084-011.i	0.9419	0.0407			
heu-met-fast-078-009.i	0.9415	0.0294			
heu-met-fast-078-017.i	0.9413	0.0244			
heu-met-fast-078-013.i	0.9411	0.0194			
heu-met-fast-078-015.i	0.9410	0.0159			
heu-met-fast-078-005.i	0.9404	0.0011			

Table 6. Whisper results for benchmark outliers that were chosen as neutronically similar for HEU oxide cases.

Benchmark Outlier	Times Benchmark is Neutronically Similar to Application	Maximum c_k
heu-met-fast-007-006	73	0.9622
heu-met-fast-007-032	25	0.9295
heu-met-fast-007-033	25	0.9283
heu-met-fast-007-034	0	n/a
heu-met-fast-007-036	75	0.9699
heu-met-fast-007-037	70	0.9740
heu-met-fast-007-039	56	0.9743
heu-met-fast-007-040	63	0.9741
heu-met-fast-025-005	0	n/a
heu-met-fast-038-001	0	n/a
heu-met-fast-040-001	0	n/a
heu-met-fast-051-001	0	n/a
heu-met-fast-051-003	0	n/a
heu-met-fast-051-009	0	n/a
heu-met-fast-051-014	19	0.9244
heu-met-fast-051-015	8	0.9217
heu-met-fast-051-016	0	n/a
heu-met-fast-051-017	0	n/a
heu-met-fast-051-018	0	n/a
heu-met-fast-057-001	0	n/a
heu-met-fast-057-003	0	n/a
heu-met-fast-057-005	0	n/a
heu-met-fast-064-001	0	n/a
heu-met-fast-064-003	0	n/a

heu-met-fast-090-001	75	0.9584
heu-met-fast-090-002	60	0.9663
heu-met-fast-092-003	0	n/a
heu-met-fast-093-001	0	n/a
heu-met-fast-094-002	0	n/a
heu-comp-therm-002-015	4	0.9804
heu-comp-therm-002-016	1	0.9508
heu-comp-therm-002-017	0	n/a
heu-comp-therm-002-021	10	0.9881
heu-comp-therm-002-022	2	0.9670
heu-sol-therm-001-009	30	0.9977
heu-sol-therm-001-010	15	0.9997
	Total Times Similar = 611	**Overall Max. C_k = 0.9997**

Summary

A comparison study has been done to compute USLs with and without statistical outliers in the Whisper-1.1 benchmark collection to determine what effect rejection of statistical outliers has on the recommended USL. The effect of exclusion of benchmarks which are found to be statistical outliers from the collection of benchmarks used by Whisper-1.1 on nuclear criticality safety validation for HEU systems is found to be small. The results show little overall difference in the recommended baseline USLs developed by Whisper when excluding statistical outliers. Additionally, there does not appear to be a clear trend in predicting whether the baseline USL will be higher or lower when rejecting statistical outliers from the benchmark critical experiment collection used for validation.

The baseline recommended USL, calculational margin and margin of subcriticality for nuclear data uncertainty was presented for many HEU application cases ranging from fast metal systems to intermediate moist oxide systems to thermal solution systems. Results show there is little difference in baseline USL when using a reduced benchmark collection due to statistical rejection of outliers. Overall maximum difference in baseline USL between the two methods:

$USL_{\text{Benchmark Exclusions}} - USL_{\text{No Benchmark Exclusions}} = -0.00058$ for U(93) metal systems,

$USL_{\text{Benchmark Exclusions}} - USL_{\text{No Benchmark Exclusions}} = -0.00208$ for U(93) oxide systems, and

$USL_{\text{Benchmark Exclusions}} - USL_{\text{No Benchmark Exclusions}} = -0.00307$ for U(93) solution systems.

There is slight nonconservatism, i.e., the baseline USL is greater, when including all the benchmarks in the Whisper-1.1 collection and not using the available statistical rejection technique to exclude benchmark outliers for U(93) systems.

Acknowledgements

This work was supported by the US DOE-NNSA Nuclear Criticality Safety Program.

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Appendix- Whisper-1.1 Benchmark Collection Relevant to Plutonium Systems

Table 7. Whisper HEU benchmarks. Bold indicates benchmark was found to be statistical outlier.

Benchmark	k_{exp}	σ_{exp}	k_{calc}	σ_{calc}	Bias	Bias uncert.
heu-comp-inter-003-006.i	1.00000	0.00470	0.99558	0.00011	0.00442	0.00470
heu-comp-therm-002-001.i	1.00110	0.00690	1.01150	0.00013	-0.01040	0.00690
heu-comp-therm-002-002.i	1.00110	0.00690	1.01385	0.00013	-0.01275	0.00690
heu-comp-therm-002-003.i	1.00110	0.00690	1.01666	0.00012	-0.01556	0.00690
heu-comp-therm-002-004.i	1.00110	0.00690	1.01599	0.00012	-0.01489	0.00690
heu-comp-therm-002-005.i	1.00110	0.00690	1.01700	0.00013	-0.01590	0.00690
heu-comp-therm-002-006.i	1.00110	0.00690	1.01718	0.00011	-0.01608	0.00690
heu-comp-therm-002-007.i	1.00110	0.00690	1.01738	0.00011	-0.01628	0.00690
heu-comp-therm-002-008.i	1.00110	0.00690	1.01748	0.00011	-0.01638	0.00690
heu-comp-therm-002-009.i	1.00110	0.00690	1.01882	0.00010	-0.01772	0.00690
heu-comp-therm-002-010.i	1.00110	0.00690	1.01562	0.00010	-0.01452	0.00690
heu-comp-therm-002-011.i	1.00110	0.00530	1.01446	0.00013	-0.01336	0.00530
heu-comp-therm-002-012.i	1.00110	0.00550	1.01370	0.00012	-0.01260	0.00550
heu-comp-therm-002-013.i	1.00110	0.00550	1.01791	0.00012	-0.01681	0.00550
heu-comp-therm-002-014.i	1.00110	0.00550	1.01767	0.00011	-0.01657	0.00550
heu-comp-therm-002-015.i	**1.00110**	**0.00550**	**1.01916**	**0.00011**	**-0.01806**	**0.00550**
heu-comp-therm-002-016.i	**1.00110**	**0.00530**	**1.01879**	**0.00010**	**-0.01769**	**0.00530**
heu-comp-therm-002-017.i	**1.00110**	**0.00530**	**1.02344**	**0.00010**	**-0.02234**	**0.00530**
heu-comp-therm-002-018.i	1.00200	0.00430	1.01569	0.00013	-0.01369	0.00430
heu-comp-therm-002-019.i	1.00200	0.00430	1.01291	0.00012	-0.01091	0.00430
heu-comp-therm-002-020.i	1.00200	0.00430	1.01552	0.00011	-0.01352	0.00430
heu-comp-therm-002-021.i	**1.00200**	**0.00430**	**1.01677**	**0.00012**	**-0.01477**	**0.00430**
heu-comp-therm-002-022.i	**1.00200**	**0.00430**	**1.01724**	**0.00011**	**-0.01524**	**0.00430**
heu-comp-therm-002-023.i	1.00080	0.00850	1.01438	0.00012	-0.01358	0.00850
heu-comp-therm-002-024.i	1.00080	0.00850	1.01501	0.00012	-0.01421	0.00850
heu-comp-therm-002-025.i	1.00080	0.00850	1.01358	0.00012	-0.01278	0.00850
heu-met-fast-001-001.i	1.00000	0.00100	1.00000	0.00008	0.00000	0.00100
heu-met-fast-002-001.i	1.00000	0.00300	1.00150	0.00009	-0.00150	0.00300
heu-met-fast-002-002.i	1.00000	0.00300	1.00193	0.00009	-0.00193	0.00300
heu-met-fast-002-003.i	1.00000	0.00300	1.00037	0.00009	-0.00037	0.00300
heu-met-fast-002-004.i	1.00000	0.00300	0.99946	0.00009	0.00054	0.00300
heu-met-fast-002-005.i	1.00000	0.00300	1.00000	0.00009	0.00000	0.00300
heu-met-fast-002-006.i	1.00000	0.00300	1.00129	0.00009	-0.00129	0.00300
heu-met-fast-003-001.i	1.00000	0.00500	0.99492	0.00009	0.00508	0.00500
heu-met-fast-003-002.i	1.00000	0.00500	0.99434	0.00009	0.00566	0.00500
heu-met-fast-003-003.i	1.00000	0.00500	0.99916	0.00009	0.00084	0.00500
heu-met-fast-003-004.i	1.00000	0.00300	0.99718	0.00009	0.00282	0.00300
heu-met-fast-003-005.i	1.00000	0.00300	1.00158	0.00009	-0.00158	0.00300

heu-met-fast-003-006.i	1.00000	0.00300	1.00150	0.00009	-0.00150	0.00300
heu-met-fast-003-007.i	1.00000	0.00300	1.00199	0.00009	-0.00199	0.00300
heu-comp-inter-003-006.i	1.00000	0.00500	1.00220	0.00009	-0.00220	0.00500
heu-met-fast-003-008.i	1.00000	0.00500	1.00267	0.00009	-0.00267	0.00500
heu-met-fast-003-009.i	1.00000	0.00500	1.00491	0.00009	-0.00491	0.00500
heu-met-fast-003-010.i	1.00000	0.00500	1.00875	0.00009	-0.00875	0.00500
heu-met-fast-003-011.i	1.00000	0.00470	0.99558	0.00011	0.00442	0.00470
heu-met-fast-003-012.i	1.00000	0.00300	1.00864	0.00009	-0.00864	0.00300
heu-met-fast-004-001.i	0.99850	0.00300	0.99406	0.00011	0.00444	0.00300
heu-met-fast-005-001.i	1.00000	0.00360	0.99510	0.00009	0.00490	0.00360
heu-met-fast-005-002.i	1.00070	0.00360	0.99795	0.00010	0.00275	0.00360
heu-met-fast-005-003.i	0.99960	0.00360	1.00046	0.00010	-0.00086	0.00360
heu-met-fast-005-004.i	0.99890	0.00360	0.99438	0.00011	0.00452	0.00360
heu-met-fast-005-005.i	0.99800	0.00360	0.99909	0.00010	-0.00109	0.00360
heu-met-fast-005-006.i	0.99870	0.00360	0.99792	0.00009	0.00078	0.00360
heu-met-fast-007-001.i	0.99500	0.00240	0.99245	0.00009	0.00255	0.00240
heu-met-fast-007-002.i	0.99640	0.00140	0.99832	0.00009	-0.00192	0.00140
heu-met-fast-007-003.i	0.99900	0.00130	0.99976	0.00010	-0.00076	0.00130
heu-met-fast-007-004.i	0.99480	0.00130	0.99766	0.00010	-0.00286	0.00130
heu-met-fast-007-005.i	0.99780	0.00180	0.99971	0.00010	-0.00191	0.00180
heu-met-fast-007-006.i	**1.00060**	**0.00130**	**1.00560**	**0.00009**	**-0.00500**	**0.00130**
heu-met-fast-007-007.i	0.99740	0.00140	1.00118	0.00010	-0.00378	0.00140
heu-met-fast-007-008.i	0.99730	0.00130	0.99925	0.00010	-0.00195	0.00130
heu-met-fast-007-009.i	0.99950	0.00560	1.00209	0.00010	-0.00259	0.00560
heu-met-fast-007-010.i	0.99810	0.00120	0.99901	0.00011	-0.00091	0.00121
heu-met-fast-007-011.i	0.99580	0.00130	0.99725	0.00011	-0.00145	0.00130
heu-met-fast-007-012.i	0.99320	0.00120	0.99280	0.00012	0.00040	0.00121
heu-met-fast-007-013.i	0.99900	0.00120	1.00088	0.00013	-0.00188	0.00121
heu-met-fast-007-014.i	0.99640	0.00120	0.99703	0.00012	-0.00063	0.00121
heu-met-fast-007-015.i	0.99590	0.00120	0.99671	0.00012	-0.00081	0.00121
heu-met-fast-007-016.i	0.99690	0.00120	0.99723	0.00012	-0.00033	0.00121
heu-met-fast-007-017.i	0.99530	0.00120	0.99584	0.00013	-0.00054	0.00121
heu-met-fast-007-018.i	0.99720	0.00120	0.99818	0.00013	-0.00098	0.00121
heu-met-fast-007-019.i	0.99560	0.00150	0.99614	0.00009	-0.00054	0.00150
heu-met-fast-007-020.i	0.99500	0.00170	0.99776	0.00010	-0.00276	0.00170
heu-met-fast-007-021.i	0.99560	0.00180	0.99845	0.00010	-0.00285	0.00180
heu-met-fast-007-022.i	0.99630	0.00190	0.99926	0.00011	-0.00296	0.00190
heu-met-fast-007-023.i	0.99620	0.00170	0.99902	0.00010	-0.00282	0.00170
heu-met-fast-007-024.i	0.99700	0.00180	0.99954	0.00011	-0.00254	0.00180
heu-met-fast-007-025.i	0.99590	0.00180	0.99811	0.00011	-0.00221	0.00180
heu-met-fast-007-026.i	0.99660	0.00170	0.99837	0.00012	-0.00177	0.00170
heu-met-fast-007-027.i	0.99480	0.00140	0.99673	0.00010	-0.00193	0.00140
heu-met-fast-007-028.i	0.99700	0.00230	0.99804	0.00010	-0.00104	0.00230
heu-met-fast-007-029.i	0.99610	0.00140	0.99865	0.00011	-0.00255	0.00140
heu-met-fast-007-030.i	0.99640	0.00210	0.99730	0.00011	-0.00090	0.00210
heu-met-fast-007-031.i	0.99960	0.00220	1.00107	0.00012	-0.00147	0.00220

heu-met-fast-007-032.i	**0.99410**	**0.00120**	**1.00450**	**0.00009**	**-0.01040**	**0.00120**
heu-met-fast-007-033.i	**0.99770**	**0.00190**	**1.01394**	**0.00009**	**-0.01624**	**0.00190**
heu-met-fast-007-034.i	**0.99590**	**0.00170**	**1.01733**	**0.00010**	**-0.02143**	**0.00170**
heu-met-fast-007-035.i	1.00030	0.00180	0.99489	0.00011	0.00541	0.00180
heu-met-fast-007-036.i	**0.99990**	**0.00070**	**1.00354**	**0.00012**	**-0.00364**	**0.00071**
heu-met-fast-007-037.i	**0.99880**	**0.00080**	**1.00182**	**0.00012**	**-0.00302**	**0.00081**
heu-met-fast-007-038.i	1.00000	0.00080	1.00267	0.00011	-0.00267	0.00081
heu-met-fast-007-039.i	**1.00180**	**0.00140**	**1.00636**	**0.00011**	**-0.00456**	**0.00140**
heu-met-fast-007-040.i	**1.00130**	**0.00080**	**1.00598**	**0.00011**	**-0.00468**	**0.00081**
heu-met-fast-007-041.i	0.99940	0.00090	1.00093	0.00012	-0.00153	0.00091
heu-met-fast-007-042.i	1.00160	0.00090	1.00292	0.00012	-0.00132	0.00091
heu-met-fast-007-043.i	0.99980	0.00080	1.00040	0.00013	-0.00060	0.00081
heu-met-fast-008-001.i	0.99890	0.00160	0.99583	0.00008	0.00307	0.00160
heu-met-fast-009-001.i	0.99920	0.00150	0.99763	0.00009	0.00157	0.00150
heu-met-fast-009-002.i	0.99920	0.00150	0.99649	0.00009	0.00271	0.00150
heu-met-fast-010-001.i	0.99920	0.00150	0.99829	0.00009	0.00091	0.00150
heu-met-fast-010-002.i	0.99920	0.00150	0.99789	0.00009	0.00131	0.00150
heu-met-fast-011-001.i	0.99890	0.00150	0.99887	0.00011	0.00003	0.00150
heu-met-fast-012-001.i	0.99920	0.00180	0.99823	0.00009	0.00097	0.00180
heu-met-fast-013-001	0.99900	0.00150	0.99752	0.00009	0.00148	0.00150
heu-met-fast-014-001.i	0.99890	0.00170	0.99777	0.00009	0.00113	0.00170
heu-met-fast-015-001.i	0.99960	0.00170	0.99470	0.00009	0.00490	0.00170
heu-met-fast-016-001.i	0.99960	0.00180	1.00163	0.00009	-0.00203	0.00180
heu-met-fast-016-002.i	0.99960	0.00180	1.00263	0.00009	-0.00303	0.00180
heu-met-fast-017-001.i	0.99930	0.00140	1.00058	0.00010	-0.00128	0.00140
heu-met-fast-018-002.i	1.00000	0.00140	0.99971	0.00008	0.00029	0.00140
heu-met-fast-019-001.i	1.00000	0.00300	1.00708	0.00009	-0.00708	0.00300
heu-met-fast-020-002.i	1.00000	0.00280	1.00063	0.00010	-0.00063	0.00280
heu-met-fast-021-002.i	1.00000	0.00240	0.99760	0.00009	0.00240	0.00240
heu-met-fast-022-002.i	1.00000	0.00190	0.99763	0.00009	0.00237	0.00190
heu-met-fast-025-001.i	0.99870	0.00140	0.99907	0.00009	-0.00037	0.00140
heu-met-fast-025-002.i	0.99900	0.00160	1.00124	0.00009	-0.00224	0.00160
heu-met-fast-025-003.i	0.99910	0.00160	1.00369	0.00009	-0.00459	0.00160
heu-met-fast-025-004.i	0.99950	0.00160	1.00544	0.00009	-0.00594	0.00160
heu-met-fast-025-005.i	**0.99910**	**0.00160**	**1.00557**	**0.00009**	**-0.00647**	**0.00160**
heu-met-fast-026-011.i	1.00000	0.00380	1.00330	0.00011	-0.00330	0.00380
heu-met-fast-027-001.i	1.00000	0.00250	1.00058	0.00009	-0.00058	0.00250
heu-met-fast-028-001.i	1.00000	0.00300	1.00298	0.00009	-0.00298	0.00300
heu-met-fast-029-001.i	1.00000	0.00200	1.00572	0.00009	-0.00572	0.00200
heu-met-fast-030-001.i	1.00000	0.00090	1.00219	0.00010	-0.00219	0.00091
heu-met-fast-031-001.i	1.00000	0.00590	1.00487	0.00010	-0.00487	0.00590
heu-met-fast-032-001.i	1.00000	0.00160	1.00411	0.00009	-0.00411	0.00160
heu-met-fast-032-002.i	1.00000	0.00270	1.00487	0.00009	-0.00487	0.00270
heu-met-fast-032-003.i	1.00000	0.00170	1.00017	0.00009	-0.00017	0.00170
heu-met-fast-032-004.i	1.00000	0.00170	1.00100	0.00009	-0.00100	0.00170
heu-met-fast-033-001.i	0.99910	0.00140	0.99902	0.00011	0.00008	0.00140

heu-met-fast-033-002.i	0.99910	0.00140	0.99769	0.00011	0.00141	0.00140
heu-met-fast-034-001.i	0.99900	0.00120	0.99703	0.00011	0.00197	0.00121
heu-met-fast-034-002.i	0.99900	0.00120	0.99873	0.00011	0.00027	0.00121
heu-met-fast-034-003.i	0.99900	0.00120	0.99767	0.00011	0.00133	0.00121
heu-met-fast-036-001.i	0.99930	0.00150	0.99908	0.00011	0.00022	0.00150
heu-met-fast-036-002.i	0.99930	0.00130	0.99837	0.00010	0.00093	0.00130
heu-met-fast-037-001.i	0.99970	0.00110	1.00215	0.00011	-0.00245	0.00111
heu-met-fast-037-002.i	0.99970	0.00110	0.99779	0.00011	0.00191	0.00111
heu-met-fast-038-001.i	**0.99990**	**0.00070**	**1.00303**	**0.00010**	**-0.00313**	**0.00071**
heu-met-fast-038-002.i	0.99990	0.00090	1.00186	0.00010	-0.00196	0.00091
heu-met-fast-040-001.i	**0.99910**	**0.00110**	**1.00453**	**0.00009**	**-0.00543**	**0.00110**
heu-met-fast-041-001.i	1.00130	0.00300	1.00687	0.00009	-0.00557	0.00300
heu-met-fast-041-002.i	1.00220	0.00430	1.00517	0.00011	-0.00297	0.00430
heu-met-fast-041-003.i	1.00060	0.00290	1.00240	0.00009	-0.00180	0.00290
heu-met-fast-041-004.i	1.00060	0.00250	1.00725	0.00009	-0.00665	0.00250
heu-met-fast-041-005.i	1.00060	0.00310	1.00287	0.00009	-0.00227	0.00310
heu-met-fast-041-006.i	1.00060	0.00450	1.00434	0.00010	-0.00374	0.00450
heu-met-fast-043-001.i	0.99950	0.00180	0.99900	0.00008	0.00050	0.00180
heu-met-fast-043-002.i	0.99950	0.00190	0.99821	0.00009	0.00129	0.00190
heu-met-fast-043-003.i	0.99950	0.00210	0.99880	0.00009	0.00070	0.00210
heu-met-fast-043-004.i	0.99950	0.00150	0.99725	0.00009	0.00225	0.00150
heu-met-fast-043-005.i	0.99950	0.00150	0.99826	0.00009	0.00124	0.00150
heu-met-fast-044-001.i	0.99950	0.00190	1.00000	0.00008	-0.00050	0.00190
heu-met-fast-044-002.i	0.99950	0.00170	0.99962	0.00008	-0.00012	0.00170
heu-met-fast-044-003.i	0.99950	0.00190	0.99993	0.00009	-0.00043	0.00190
heu-met-fast-044-004.i	0.99950	0.00140	0.99931	0.00009	0.00019	0.00140
heu-met-fast-044-005.i	0.99950	0.00150	0.99989	0.00008	-0.00039	0.00150
heu-met-fast-049-001.i	0.99900	0.00160	0.99808	0.00009	0.00092	0.00160
heu-met-fast-049-002.i	0.99940	0.00150	0.99963	0.00009	-0.00023	0.00150
heu-met-fast-049-003.i	0.99940	0.00160	0.99886	0.00009	0.00054	0.00160
heu-met-fast-050-001.i	0.99900	0.00120	0.99803	0.00009	0.00097	0.00120
heu-met-fast-051-001.i	**0.99710**	**0.00050**	**0.99505**	**0.00009**	**0.00205**	**0.00051**
heu-met-fast-051-002.i	0.99680	0.00050	0.99546	0.00009	0.00134	0.00051
heu-met-fast-051-003.i	**0.99740**	**0.00050**	**0.99497**	**0.00009**	**0.00243**	**0.00051**
heu-met-fast-051-004.i	0.99690	0.00050	0.99517	0.00009	0.00173	0.00051
heu-met-fast-051-009.i	**0.99820**	**0.00020**	**0.99489**	**0.00009**	**0.00331**	**0.00022**
heu-met-fast-051-014.i	**0.99960**	**0.00020**	**0.99861**	**0.00008**	**0.00099**	**0.00022**
heu-met-fast-051-015.i	**0.99980**	**0.00010**	**0.99805**	**0.00008**	**0.00175**	**0.00013**
heu-met-fast-051-016.i	**0.99810**	**0.00010**	**0.99636**	**0.00009**	**0.00174**	**0.00013**
heu-met-fast-051-017.i	**0.99690**	**0.00010**	**0.99546**	**0.00008**	**0.00144**	**0.00013**
heu-met-fast-051-018.i	**0.99840**	**0.00020**	**0.99387**	**0.00009**	**0.00453**	**0.00022**
heu-met-fast-057-001.i	**1.00000**	**0.00200**	**0.98964**	**0.00009**	**0.01036**	**0.00200**
heu-met-fast-057-002.i	1.00000	0.00230	0.99824	0.00009	0.00176	0.00230
heu-met-fast-057-003.i	**1.00000**	**0.00320**	**1.01718**	**0.00010**	**-0.01718**	**0.00320**
heu-met-fast-057-004.i	1.00000	0.00400	0.98783	0.00009	0.01217	0.00400
heu-met-fast-057-005.i	**1.00000**	**0.00190**	**1.02180**	**0.00009**	**-0.02180**	**0.00190**

heu-met-fast-057-006.i	1.00000	0.00290	0.99667	0.00009	0.00333	0.00290
heu-met-fast-058-001.i	1.00000	0.00260	1.00323	0.00012	-0.00323	0.00260
heu-met-fast-058-002.i	1.00000	0.00350	1.00499	0.00010	-0.00499	0.00350
heu-met-fast-058-003.i	1.00000	0.00270	1.00285	0.00011	-0.00285	0.00270
heu-met-fast-058-004.i	1.00000	0.00210	1.00208	0.00009	-0.00208	0.00210
heu-met-fast-058-005.i	1.00000	0.00330	1.00098	0.00009	-0.00098	0.00330
heu-met-fast-063-001.i	0.99930	0.00490	1.00064	0.00009	-0.00134	0.00490
heu-met-fast-063-002.i	0.99880	0.00470	1.00094	0.00009	-0.00214	0.00470
heu-met-fast-064-001.i	**0.99960**	**0.00080**	**0.99537**	**0.00009**	**0.00423**	**0.00081**
heu-met-fast-064-002.i	0.99960	0.00100	0.99562	0.00009	0.00398	0.00100
heu-met-fast-064-003.i	**0.99960**	**0.00090**	**0.99360**	**0.00009**	**0.00600**	**0.00090**
heu-met-fast-065-002.i	0.99950	0.00130	0.99812	0.00009	0.00138	0.00130
heu-met-fast-066-001.i	1.00300	0.00330	1.00374	0.00010	-0.00074	0.00330
heu-met-fast-066-002.i	1.00230	0.00290	1.00192	0.00010	0.00038	0.00290
heu-met-fast-066-003.i	1.00230	0.00260	1.00466	0.00010	-0.00236	0.00260
heu-met-fast-066-004.i	1.00430	0.00430	1.00496	0.00011	-0.00066	0.00430
heu-met-fast-066-005.i	1.00300	0.00330	1.00431	0.00010	-0.00131	0.00330
heu-met-fast-066-006.i	1.00280	0.00300	1.00343	0.00010	-0.00063	0.00300
heu-met-fast-066-007.i	1.00480	0.00390	1.00578	0.00011	-0.00098	0.00390
heu-met-fast-066-008.i	1.00390	0.00400	1.00458	0.00011	-0.00068	0.00400
heu-met-fast-066-009.i	1.00270	0.00360	1.00289	0.00010	-0.00019	0.00360
heu-met-fast-067-001.i	1.00860	0.00040	1.00112	0.00008	0.00748	0.00041
heu-met-fast-067-002.i	0.99380	0.00240	0.99620	0.00008	-0.00240	0.00240
heu-met-fast-072-001.i	0.99910	0.00240	1.00867	0.00010	-0.00957	0.00240
heu-met-fast-072-003.i	1.00160	0.00690	1.01221	0.00009	-0.01061	0.00690
heu-met-fast-073-001.i	1.00040	0.00160	1.00806	0.00009	-0.00766	0.00160
heu-met-fast-077-001.i	1.00010	0.00310	1.00068	0.00010	-0.00058	0.00310
heu-met-fast-077-002.i	0.99950	0.00270	1.00068	0.00010	-0.00118	0.00270
heu-met-fast-077-003.i	0.99950	0.00400	0.99787	0.00011	0.00163	0.00400
heu-met-fast-077-004.i	0.99980	0.00320	0.99836	0.00010	0.00144	0.00320
heu-met-fast-077-005.i	0.99940	0.00270	1.00012	0.00009	-0.00072	0.00270
heu-met-fast-077-006.i	0.99960	0.00330	0.99969	0.00010	-0.00009	0.00330
heu-met-fast-077-007.i	0.99940	0.00560	1.00057	0.00010	-0.00117	0.00560
heu-met-fast-077-008.i	0.99940	0.00350	0.99833	0.00010	0.00107	0.00350
heu-met-fast-078-001.i	0.99950	0.00180	0.99457	0.00011	0.00493	0.00180
heu-met-fast-078-003.i	0.99940	0.00220	0.99591	0.00010	0.00349	0.00220
heu-met-fast-078-005.i	0.99910	0.00190	0.99636	0.00010	0.00274	0.00190
heu-met-fast-078-007.i	1.00000	0.00190	0.99845	0.00011	0.00155	0.00190
heu-met-fast-078-009.i	0.99970	0.00220	0.99568	0.00010	0.00402	0.00220
heu-met-fast-078-011.i	0.99950	0.00150	0.99582	0.00010	0.00368	0.00150
heu-met-fast-078-013.i	1.00000	0.00170	0.99727	0.00010	0.00273	0.00170
heu-met-fast-078-015.i	0.99910	0.00180	0.99655	0.00010	0.00255	0.00180
heu-met-fast-078-017.i	0.99950	0.00180	0.99657	0.00010	0.00293	0.00180
heu-met-fast-078-023.i	0.99920	0.00220	0.99824	0.00009	0.00096	0.00220
heu-met-fast-078-025.i	0.99920	0.00250	0.99742	0.00010	0.00178	0.00250
heu-met-fast-078-027.i	0.99920	0.00210	0.99595	0.00009	0.00325	0.00210

heu-met-fast-078-029.i	1.00000	0.00250	1.00212	0.00010	-0.00212	0.00250
heu-met-fast-078-031.i	0.99940	0.00200	0.99519	0.00010	0.00421	0.00200
heu-met-fast-078-033.i	0.99960	0.00260	0.99588	0.00009	0.00372	0.00260
heu-met-fast-078-035.i	0.99910	0.00220	0.99445	0.00010	0.00465	0.00220
heu-met-fast-078-037.i	0.99860	0.00210	0.99620	0.00009	0.00240	0.00210
heu-met-fast-078-039.i	0.99890	0.00210	0.99694	0.00010	0.00196	0.00210
heu-met-fast-078-041.i	0.99920	0.00250	0.99664	0.00009	0.00256	0.00250
heu-met-fast-078-043.i	1.00000	0.00190	0.99765	0.00009	0.00235	0.00190
heu-met-fast-079-001.i	0.99960	0.00150	0.99984	0.00008	-0.00024	0.00150
heu-met-fast-079-002.i	0.99960	0.00140	0.99921	0.00009	0.00039	0.00140
heu-met-fast-079-003.i	0.99960	0.00150	1.00009	0.00009	-0.00049	0.00150
heu-met-fast-079-004.i	0.99960	0.00140	1.00113	0.00009	-0.00153	0.00140
heu-met-fast-079-005.i	0.99960	0.00150	0.99981	0.00009	-0.00021	0.00150
heu-met-fast-084-001.i	0.99940	0.00190	0.99881	0.00009	0.00059	0.00190
heu-met-fast-084-002.i	0.99940	0.00210	0.99948	0.00009	-0.00008	0.00210
heu-met-fast-084-003.i	0.99930	0.00210	0.99988	0.00009	-0.00058	0.00210
heu-met-fast-084-004.i	0.99940	0.00200	0.99868	0.00009	0.00072	0.00200
heu-met-fast-084-005.i	0.99930	0.00210	1.00497	0.00009	-0.00567	0.00210
heu-met-fast-084-006.i	0.99940	0.00240	0.99858	0.00008	0.00082	0.00240
heu-met-fast-084-007.i	0.99950	0.00200	0.99740	0.00009	0.00210	0.00200
heu-met-fast-084-008.i	0.99940	0.00340	1.00840	0.00009	-0.00900	0.00340
heu-met-fast-084-009.i	0.99930	0.00540	1.00246	0.00009	-0.00316	0.00540
heu-met-fast-084-010.i	0.99930	0.00220	1.00106	0.00009	-0.00176	0.00220
heu-met-fast-084-011.i	0.99950	0.00190	1.00146	0.00010	-0.00196	0.00190
heu-met-fast-084-012.i	0.99940	0.00200	0.99740	0.00009	0.00200	0.00200
heu-met-fast-084-013.i	0.99940	0.00220	0.99897	0.00009	0.00043	0.00220
heu-met-fast-084-014.i	0.99940	0.00190	0.99987	0.00009	-0.00047	0.00190
heu-met-fast-084-015.i	0.99950	0.00210	0.99790	0.00009	0.00160	0.00210
heu-met-fast-084-016.i	0.99940	0.00200	0.99912	0.00009	0.00028	0.00200
heu-met-fast-084-017.i	0.99950	0.00190	1.00036	0.00009	-0.00086	0.00190
heu-met-fast-084-018.i	0.99950	0.00220	0.99743	0.00008	0.00207	0.00220
heu-met-fast-084-019.i	0.99960	0.00190	0.99768	0.00009	0.00192	0.00190
heu-met-fast-084-020.i	0.99950	0.00250	1.00304	0.00009	-0.00354	0.00250
heu-met-fast-084-021.i	0.99950	0.00450	1.00023	0.00009	-0.00073	0.00450
heu-met-fast-084-022.i	0.99940	0.00200	0.99824	0.00009	0.00116	0.00200
heu-met-fast-084-023.i	0.99930	0.00240	0.99956	0.00010	-0.00026	0.00240
heu-met-fast-084-024.i	0.99960	0.00180	0.99862	0.00009	0.00098	0.00180
heu-met-fast-084-025.i	0.99950	0.00200	0.99808	0.00008	0.00142	0.00200
heu-met-fast-084-026.i	0.99930	0.00220	1.00039	0.00009	-0.00109	0.00220
heu-met-fast-084-027.i	0.99940	0.00200	0.99769	0.00009	0.00171	0.00200
heu-met-fast-087-001.i	0.99870	0.00130	0.99840	0.00009	0.00030	0.00130
heu-met-fast-088-001.i	0.99930	0.00080	0.99681	0.00010	0.00249	0.00081
heu-met-fast-088-002.i	0.99930	0.00070	0.99672	0.00011	0.00258	0.00071
heu-met-fast-089-001.i	0.99910	0.00140	1.00008	0.00009	-0.00098	0.00140
heu-met-fast-090-001.i	**0.99940**	**0.00070**	**1.00567**	**0.00011**	**-0.00627**	**0.00071**
heu-met-fast-090-002.i	**0.99930**	**0.00070**	**1.00226**	**0.00011**	**-0.00296**	**0.00071**

heu-met-fast-091-001.i	0.99960	0.00090	0.99957	0.00011	0.00003	0.00091
heu-met-fast-092-001.i	0.99860	0.00110	1.00105	0.00008	-0.00245	0.00110
heu-met-fast-092-002.i	0.99890	0.00130	1.00279	0.00009	-0.00389	0.00130
heu-met-fast-092-003.i	**0.99930**	**0.00120**	**1.00397**	**0.00009**	**-0.00467**	**0.00120**
heu-met-fast-092-004.i	0.99930	0.00130	1.00361	0.00009	-0.00431	0.00130
heu-met-fast-093-001.i	**0.99780**	**0.00120**	**1.00328**	**0.00008**	**-0.00548**	**0.00120**
heu-met-fast-094-001.i	0.99940	0.00120	1.00347	0.00010	-0.00407	0.00120
heu-met-fast-094-002.i	**0.99930**	**0.00100**	**1.00366**	**0.00010**	**-0.00436**	**0.00100**
heu-met-fast-100-001.i	1.00310	0.00070	1.00486	0.00008	-0.00176	0.00070
heu-met-fast-100-002.i	0.99660	0.00070	0.99878	0.00008	-0.00218	0.00070
heu-met-inter-006-001.i	**0.99770**	**0.00080**	**0.99293**	**0.00010**	**0.00477**	**0.00081**
heu-met-inter-006-002.i	1.00010	0.00080	0.99682	0.00011	0.00328	0.00081
heu-met-inter-006-003.i	1.00150	0.00090	1.00071	0.00011	0.00079	0.00091
heu-met-inter-006-004.i	**1.00160**	**0.00080**	**1.00728**	**0.00011**	**-0.00568**	**0.00081**
heu-met-mixed-001-001.i	0.99950	0.00130	1.00227	0.00011	-0.00277	0.00130
heu-met-mixed-002-001.i	1.00000	0.00370	1.00647	0.00012	-0.00647	0.00370
heu-met-mixed-003-001.i	1.00000	0.00380	1.00760	0.00011	-0.00760	0.00380
heu-met-mixed-004-001.i	0.99990	0.00090	1.00249	0.00009	-0.00259	0.00090
heu-met-mixed-015-001.i	0.99960	0.00080	0.99701	0.00012	0.00259	0.00081
heu-met-mixed-016-001.i	0.99950	0.00080	1.00156	0.00012	-0.00206	0.00081
heu-met-mixed-016-002.i	0.99950	0.00070	1.00250	0.00011	-0.00300	0.00071
heu-met-mixed-017-001.i	0.99950	0.00080	0.99547	0.00011	0.00403	0.00081
heu-met-therm-010-001.i	1.00650	0.00720	1.00875	0.00012	-0.00225	0.00720
heu-met-therm-012-001.i	**0.99710**	**0.00250**	**1.00919**	**0.00012**	**-0.01209**	**0.00250**
heu-met-therm-014-001.i	**0.99390**	**0.00150**	**1.00795**	**0.00013**	**-0.01405**	**0.00151**
heu-met-therm-031-001.i	1.00370	0.00240	1.00850	0.00011	-0.00480	0.00240
heu-sol-therm-001-001.i	1.00000	0.00250	0.99828	0.00016	0.00172	0.00251
heu-sol-therm-001-002.i	1.00000	0.00250	0.99603	0.00015	0.00397	0.00250
heu-sol-therm-001-003.i	1.00000	0.00250	1.00177	0.00016	-0.00177	0.00251
heu-sol-therm-001-004.i	1.00000	0.00250	0.99852	0.00015	0.00148	0.00250
heu-sol-therm-001-005.i	1.00000	0.00250	0.99868	0.00014	0.00132	0.00250
heu-sol-therm-001-006.i	1.00000	0.00250	1.00196	0.00013	-0.00196	0.00250
heu-sol-therm-001-007.i	1.00000	0.00250	0.99779	0.00014	0.00221	0.00250
heu-sol-therm-001-008	1.00000	0.00250	0.99823	0.00015	0.00177	0.00250
heu-sol-therm-001-009.i	**1.00000**	**0.00250**	**0.99435**	**0.00015**	**0.00565**	**0.00250**
heu-sol-therm-001-010.i	**1.00000**	**0.00250**	**0.99257**	**0.00013**	**0.00743**	**0.00250**
heu-sol-therm-009-001.i	0.99900	0.00430	1.00215	0.00014	-0.00315	0.00430
heu-sol-therm-009-002.i	1.00000	0.00390	1.00249	0.00014	-0.00249	0.00390
heu-sol-therm-009-003.i	1.00000	0.00360	1.00211	0.00013	-0.00211	0.00360
heu-sol-therm-010-001.i	1.00000	0.00290	1.00115	0.00012	-0.00115	0.00290
heu-sol-therm-011-001.i	1.00000	0.00230	1.00481	0.00012	-0.00481	0.00230
heu-sol-therm-011-002.i	1.00000	0.00230	1.00072	0.00011	-0.00072	0.00230
heu-sol-therm-012-001.i	0.99990	0.00580	1.00088	0.00008	-0.00098	0.00580
heu-sol-therm-013-001.i	1.00120	0.00260	0.99862	0.00008	0.00258	0.00260
heu-sol-therm-013-002.i	1.00070	0.00360	0.99781	0.00008	0.00289	0.00360
heu-sol-therm-013-003.i	1.00090	0.00360	0.99415	0.00010	0.00675	0.00360

heu-sol-therm-013-004.i	1.00030	0.00360	0.99600	0.00010	0.00430	0.00360
heu-sol-therm-019-001.i	0.99910	0.00410	0.99737	0.00014	0.00173	0.00410
heu-sol-therm-019-002.i	0.99910	0.00410	0.99895	0.00013	0.00015	0.00410
heu-sol-therm-019-003.i	0.99910	0.00670	0.99459	0.00013	0.00451	0.00670
heu-sol-therm-025-001.i	1.00020	0.00250	1.00093	0.00012	-0.00073	0.00250
heu-sol-therm-025-002.i	1.00070	0.00250	1.00048	0.00011	0.00022	0.00250
heu-sol-therm-025-003.i	1.00020	0.00640	0.99527	0.00010	0.00493	0.00640
heu-sol-therm-025-004.i	1.00030	0.00270	1.00083	0.00012	-0.00053	0.00270
heu-sol-therm-025-005.i	1.00130	0.00300	1.00309	0.00012	-0.00179	0.00300
heu-sol-therm-025-006.i	1.00020	0.00670	1.00858	0.00011	-0.00838	0.00670
heu-sol-therm-025-007.i	1.00090	0.00730	1.01263	0.00010	-0.01173	0.00730
heu-sol-therm-025-008.i	1.00000	0.00670	1.01005	0.00010	-0.01005	0.00670
heu-sol-therm-025-009.i	1.00020	0.00650	1.00398	0.00011	-0.00378	0.00650
heu-sol-therm-025-010.i	1.00030	0.00430	1.00818	0.00011	-0.00788	0.00430
heu-sol-therm-025-011.i	1.00020	0.00450	1.00745	0.00011	-0.00725	0.00450
heu-sol-therm-025-012.i	1.00020	0.00450	1.00581	0.00011	-0.00561	0.00450
heu-sol-therm-025-013.i	1.00090	0.00470	1.01360	0.00010	-0.01270	0.00470
heu-sol-therm-025-014.i	1.00080	0.00530	1.00491	0.00011	-0.00411	0.00530
heu-sol-therm-025-015.i	1.00020	0.00580	0.99913	0.00011	0.00107	0.00580
heu-sol-therm-025-016.i	1.00020	0.00490	1.00921	0.00011	-0.00901	0.00490
heu-sol-therm-025-017.i	1.00090	0.00550	1.00108	0.00012	-0.00018	0.00550
heu-sol-therm-025-018.i	1.00000	0.00610	0.99863	0.00011	0.00137	0.00610
heu-sol-therm-032-001.i	1.00150	0.00260	0.99945	0.00005	0.00205	0.00260
heu-sol-therm-038-001.i	1.00000	0.00250	0.99497	0.00015	0.00503	0.00250
heu-sol-therm-038-002.i	1.00000	0.00250	0.99721	0.00014	0.00279	0.00250
heu-sol-therm-038-003.i	1.00000	0.00250	0.99782	0.00014	0.00218	0.00250
heu-sol-therm-038-004.i	1.00000	0.00250	0.99514	0.00014	0.00486	0.00250
heu-sol-therm-038-005.i	1.00000	0.00250	0.99544	0.00014	0.00456	0.00250
heu-sol-therm-038-006.i	1.00000	0.00250	0.99635	0.00013	0.00365	0.00250
heu-sol-therm-038-007.i	1.00000	0.00320	0.99803	0.00014	0.00197	0.00320
heu-sol-therm-038-008.i	1.00000	0.00260	0.99823	0.00013	0.00177	0.00260
heu-sol-therm-038-009.i	1.00000	0.00330	0.99854	0.00015	0.00146	0.00330
heu-sol-therm-038-010.i	1.00000	0.00260	0.99742	0.00014	0.00258	0.00260
heu-sol-therm-038-011.i	1.00000	0.00250	0.99637	0.00014	0.00363	0.00250
heu-sol-therm-038-012.i	1.00000	0.00250	0.99573	0.00014	0.00427	0.00250
heu-sol-therm-038-013.i	1.00000	0.00500	1.00081	0.00014	-0.00081	0.00500
heu-sol-therm-038-014.i	1.00000	0.00500	1.00131	0.00014	-0.00131	0.00500
heu-sol-therm-038-015.i	1.00000	0.00500	1.00082	0.00015	-0.00082	0.00500
heu-sol-therm-038-016.i	1.00000	0.00500	1.00018	0.00014	-0.00018	0.00500
heu-sol-therm-038-017.i	1.00000	0.00260	0.99681	0.00014	0.00319	0.00260
heu-sol-therm-038-018.i	1.00000	0.00320	0.99541	0.00014	0.00459	0.00320
heu-sol-therm-038-019.i	1.00000	0.00320	0.99716	0.00015	0.00284	0.00320
heu-sol-therm-038-020.i	1.00000	0.00320	0.99721	0.00014	0.00279	0.00320
heu-sol-therm-038-021.i	1.00000	0.00250	0.99693	0.00014	0.00307	0.00250
heu-sol-therm-038-022.i	1.00000	0.00270	0.99749	0.00015	0.00251	0.00270
heu-sol-therm-038-023.i	1.00000	0.00270	0.99694	0.00014	0.00306	0.00270

heu-sol-therm-038-024.i	1.00000	0.00260	0.99711	0.00014	0.00289	0.00260
heu-sol-therm-038-025.i	1.00000	0.00320	0.99741	0.00014	0.00259	0.00320
heu-sol-therm-038-026.i	1.00000	0.00320	0.99748	0.00014	0.00252	0.00320
heu-sol-therm-038-027.i	1.00000	0.00320	0.99718	0.00014	0.00282	0.00320
heu-sol-therm-038-028.i	1.00000	0.00250	0.99749	0.00014	0.00251	0.00250
heu-sol-therm-042-001.i	0.99570	0.00390	0.99664	0.00007	-0.00094	0.00390
heu-sol-therm-042-002.i	0.99650	0.00360	0.99660	0.00007	-0.00010	0.00360
heu-sol-therm-042-003.i	0.99940	0.00280	1.00067	0.00005	-0.00127	0.00280
heu-sol-therm-042-004.i	1.00000	0.00340	1.00228	0.00004	-0.00228	0.00340
heu-sol-therm-042-005.i	1.00000	0.00340	0.99992	0.00004	0.00008	0.00340
heu-sol-therm-042-006.i	1.00000	0.00370	1.00050	0.00004	-0.00050	0.00370
heu-sol-therm-042-007.i	1.00000	0.00360	1.00145	0.00004	-0.00145	0.00360
heu-sol-therm-042-008.i	1.00000	0.00350	1.00204	0.00003	-0.00204	0.00350
heu-sol-therm-043-001.i	0.99860	0.00310	0.99479	0.00015	0.00381	0.00310
heu-sol-therm-043-002.i	0.99950	0.00260	1.00515	0.00009	-0.00565	0.00260
heu-sol-therm-043-003.i	0.99900	0.00250	1.00100	0.00008	-0.00200	0.00250
heu-sol-therm-050-001.i	0.99530	0.00860	1.00714	0.00015	-0.01184	0.00860
heu-sol-therm-050-002.i	0.99870	0.00830	1.00278	0.00015	-0.00408	0.00830
heu-sol-therm-050-003.i	0.99840	0.00790	1.00473	0.00015	-0.00633	0.00790
heu-sol-therm-050-004.i	0.99870	0.00840	1.00452	0.00015	-0.00582	0.00840
heu-sol-therm-050-005.i	0.99850	0.00850	1.00073	0.00015	-0.00223	0.00850
heu-sol-therm-050-006.i	0.99850	0.00810	1.00902	0.00015	-0.01052	0.00810
heu-sol-therm-050-007.i	0.99780	0.00780	0.99803	0.00015	-0.00023	0.00780
heu-sol-therm-050-008.i	0.99750	0.00840	0.99791	0.00015	-0.00041	0.00840
heu-sol-therm-050-009.i	0.99660	0.00820	0.99724	0.00014	-0.00064	0.00820
heu-sol-therm-050-010.i	0.99600	0.00900	0.97986	0.00014	0.01614	0.00900
heu-sol-therm-050-011.i	0.99640	0.00890	0.99113	0.00015	0.00527	0.00890