DUKE COGEMA
STONE & WEBSTER

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DCS-NRC-000156

Subject: Docket Number 070-03098
Duke Cogema Stone & Webster
Mixed Oxide (MOX) Fuel Fabrication Facility
Response to Request for Additional Information – Supporting MFFF Criticality Validation Report (DSER Open Item NCS-04)

References: 1) R. C. Pierson (NRC), *Draft Safety Evaluation Report on Construction of Proposed Mixed Oxide Fuel Fabrication Facility, Revision 1*, Dated 30 April 2003

As part of the review of Duke Cogema Stone & Webster's (DCS') Mixed Oxide Fuel Fabrication Facility (MFFF) Construction Authorization Request (CAR) documented in the Draft Safety Evaluation Report (Reference 1), NRC Staff identified an open item related to Nuclear Criticality Safety. In discussions with the staff at the 31 July 2003 public meeting, it was stated that the NRC staff was nearing the end of their review of the Criticality Validation Reports and it was possible that additional margin would be required. There was also a discussion on corrected information provided to DCS by Oak Ridge National Laboratory (ORNL).

It should be noted that the ORNL work performed for DCS was only to identify experiments. The actual calculation of k_{eff} for the purposes of determining uncertainty in the calculation of reactivity was done by DCS using controlled and verified computer programs in accordance with DCS QA procedures. The ORNL corrected data demonstrated no impact on the DCS validation report and further identified additional un-credited conservatism. Therefore, DCS believes that the USL values established in Validation Report Part II are adequate and AOA 3 and AOA 4 can be approved without the addition of more margin. Enclosure 1 to this letter provides additional details regarding this subject. In an effort to close the DSER Open Item (NCS-04), DCS requests a meeting with the NRC staff at its earliest convenience.

Please note that, in the interest of ensuring appropriate reflection of weapons grade plutonium criticality experience within the U.S. Department of Energy (DOE), the enclosed responses were the subject of a detailed review on the part of a DOE expert panel. The panel has concurred with DCS' approach, and their comments have been incorporated in Enclosure 1.

If I can provide any additional information, please feel free to contact me at (704) 373-7820.

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NMSS01

Sincerely,

for Peter S. Hastings, P.E.
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Enclosure 1: AOA (3) and AOA (4) Margin Discussion

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1. Introduction

In the NRC public meeting on 31 July, 2003, on open issues with criticality safety, NRC stated that, for MFFF Validation Report Part II dealing with AOA(3) – PuO_2 powders and AOA(4) MOX powders, NRC needed to perform further study. However, NRC stated that it expected that NRC would approve these AOAs only with the addition of margin.

It is DCS' understanding that NRC proposes that this additional margin be applied in addition to the approximate 2% bias and bias uncertainty and the 5% administrative margin already proposed by DCS in Validation Report Part II. The purpose of this letter is to show that there is no technical or regulatory basis for this additional margin.

2. Background

In December, 2001, DCS provided Revision 0 of Validation Report Part II (DCS-NRC-000071). In that report, 46 benchmarks for AOA(3) and 14 benchmarks for AOA(4) were selected according to the traditional technique (NUREG/CR-6361) of selecting experiments with similar H/Pu ratios, compositions, and EALF (energy at average lethargy causing fission). Comparison between the experimental values of criticality and DCS calculations of the critical configurations using standard statistical evaluation methods (USLSTATS, also NUREG/CR-6361) showed that conservative estimates of bias and bias uncertainty values were 1.75% and 1.96% for AOA(3) and AOA(4), respectively. When combined with an administrative margin of 5% (as was noted to be a historical bounding value, the USL for AOA(3) and AOA(4) was 0.9325 (1-0.0175-0.05) and 0.9304 (1-0.0196-0.05), respectively.

In 1999, ORNL completed initial development of NRC sponsored work on new analytical techniques to determine the acceptability of benchmarks (NUREG/CR-6655) called the Sensitivity and Uncertainty (S/U) methodology. This methodology consists of new computer models that compare design applications with a library of standard benchmark experiments and provide an evaluation parameter which can be used to determine the acceptability of the benchmarks for the design application. Accordingly, DCS contracted with ORNL beginning in 2001 and completing in 2002 to apply this new methodology to evaluate the available library of benchmarks against typical MFFF AOA(3) and AOA(4) design applications. That work (ORNL/TM-2001/262) determined that more benchmarks were applicable to the DCS design applications in addition to the ones DCS had selected by the traditional methods.

In 2002, based on comments by NRC that the statistical software used for the calculation of the bias and uncertainty in the bias determination indicated that the data was not normally distributed and that, in the case of AOA(4), only 14 experiments were used, DCS decided to use the information in the ORNL work as documented in ORNL/TM-2001/262. From the ORNL work identifying benchmarks for the various typical design applications, DCS determined that 90 unique benchmarks were applicable for AOA(3) and 66 unique benchmarks were applicable for AOA(4).

Additionally in response to NRC comments on the non-normality of the original data, and since the new data using the additional benchmarks was not shown to be normal, DCS used the treatment of the data recommended by NRC in NUREG/CR-6698 (called the Non-Parametric Method-NPM) to determine a conservative value of bias and the uncertainty in the bias.

Therefore, Part II of the validation report was revised in 2002 and provided to NRC in January of 2003 as DCS-NRC-000124. In that report, the conservative estimates of bias and bias uncertainty were shown to be 1.55% and 1.77% for AOA(3) and AOA(4), respectively. When combined with an administrative margin of 5% (as was noted to be a historical bounding value) the USL for AOA(3) and AOA(4) was 0.9345 (1-0.0155-0.05) and 0.9323 (1-0.0177-0.05), respectively. These are essentially unchanged from the original values (0.9325 and 0.9304) provided in December 2001 (DCS-NRC-000078).

In the NRC/DCS public meeting in March, 2003, NRC remarked that it was pleased that DCS had a) used the new S/U method to identify additional benchmarks, and b) used the recommended NPM approach to analyze the data when it was not shown to be normally distributed.

Note however, that use of these new approaches did not materially change the evaluated upper subcritical limits (USL) for AOA(3) and AOA(4), since the resulting USLs remain bounded by our design limit value of 0.93. However, the revised analysis did confirm that the bias and bias uncertainty of modern criticality calculational codes, such as SCALE together with a detailed (i.e., 238 energy group) library is approximately 2%. We have discussed this conclusion (i.e., bias and bias uncertainty of approximately 2%) with criticality plutonium experts from Los Alamos and Livermore and they agree that 2% should be a bounding value. We have discussed this with SCALE experts from ORNL and they concur with the premise that about 2% is bounding.

Therefore, the DCS calculations of the bias and uncertainty in the bias of about 2% are consistent with analyzed experiments and the expert views of national laboratory criticality experts.

3. Discussion

3.1 Impact of Recently Discovered Errors in ORNL Analysis

DCS contracted with ORNL in 2001 to use the new Sensitivity and Uncertainty (S/U) methodology (NUREG/CR 6655) for the purpose of "identifying the available plutonium and MOX critical experiments and evaluating their applicability for use."

The work was performed in 2001 and 2002 and resulted in an Oak Ridge report, ORNL/TM-2001/262 published in June, 2002. That report identified a number of critical benchmark experiments for each of the DCS supplied typical design configurations representative of AOA(3) PuO_2 powders and AOA(4) MOX powders.

DCS originally prepared a validation report in 2001 for Part II (PuO_2 and MOX powders) using traditional benchmark selection techniques (based on the direct similarity of fissile material form, composition, and neutron energy spectrum). However, NRC commented informally that the number of benchmarks was small in Part II.

Therefore, after reviewing the recommendations as to the applicability of the ORNL identified benchmarks, DCS revised Validation Report Part II and provided it to NRC in January 2003.

In late July, DCS learned that the work previously performed by ORNL contained some errors. ORNL stated that generally the results indicate that more experiments are applicable to the DCS systems than were indicated in the report. This means that the work reported by ORNL contained un-credited conservatism in the results which were eventually corrected. This section evaluates the impact of the ORNL errors.

It should also be noted that the ORNL work was only to identify experiments. The actual calculation of k_{eff} for the purposes of determining uncertainty in the calculation of reactivity was done by DCS using controlled and verified computer programs in accordance with DCS QA procedures.

The ORNL corrected data demonstrated no impact on the DCS validation report and further identified additional un-credited conservatism.

3.2 Impact of the Errors in ORNL Work

The ORNL report evaluated each of the typical design applications by applying the S/U methodology to the typical design configurations supplied by DCS. The result of this work was a listing of a correlation parameter (c_k) for each critical benchmark experiment contained in a selected ORNL library including those critical experiments previously selected by traditional (manual) means by DCS.

As a result of the ORNL published results, the numbers of experiments used in the MFFF validation report were identified according to the c_k acceptance criteria defined in the report as shown in Table 1.

Table 1 Numbers of identified benchmark experiments in ORNL/TM-2001/262

Design Application	Number of Experiments
AOA(3) (PuO_2 powder)	
Case AOA 3-1	30
Case AOA 3-2	60
Case AOA 3-3	61
AOA(4) (MOX powder)	
Case AOA4-1	59
Case AOA4-2	53
Case AOA4-3	44
Case AOA4-4-P40	19
Case AOA4-4-P8	45

The unique experiments used in each of the subgroups for AOA (3) and AOA (4) were combined to make a single group of 90 experiments for AOA (3) and 66 experiments for AOA (4) in the MFFF validation report.

As a result of a correction by ORNL of the errors, the c_k values were recalculated and provided to DCS. The revised c_k values were only slightly changed for most cases identified in the original analysis. In cases where there was a significant change, it was generally in the direction to increase the correlation of the experiment and thus the numbers of applicable experiments generally was unchanged or increased.

Based on that information, the revised numbers of applicable experiments identified according to the c_k acceptance criteria defined in the report are shown in Table 2 along with the previous numbers of experiments identified and shown in Table 1:

Table 2 Numbers of revised and originally identified benchmark experiments

Design Application	Number of Experiments	
	Original	Revised
AOA(3) (PuO2 powder)		
Case AOA 3-1	30	71
Case AOA 3-2	60	59
Case AOA 3-3	61	62
AOA(4) (MOX powder)		
Case AOA4-1	59	60
Case AOA4-2	53	53
Case AOA4-3	44	77
Case AOA4-4 P40	19	19
Case AOA4-4 P8	45	46

As can be seen in most cases the numbers of experiments in each of the subgroups increased. In particular, Cases AOA 3-1 and AOA 4-3 increased significantly. Case AOA 3-2 dropped by one experiment and the other cases increased slightly.

The net result of the updated results is that the total number of accepted experiments for AOA (3) has now increased to 91 (was 90) and for AOA (4) has increased to 79 (was 66).

Examination of the case of minimum (bounding) k_{eff} has not changed for each AOA. Since the total number of cases has not decreased and the case of minimum k_{eff} has not changed, there is no change to the bounding value of USL reported in the validation report. In fact, one NRC question which observed the apparent disparity in the numbers of experiments identified for each of the three AOA(3) design applications, is essentially resolved since all three cases now identify a consistent number of experiments (71, 59, and 62 experiments, respectively, for AOA 3-1, 3-2, and 3-3).

It is also significant that all three of these cases contain 59 or greater numbers of experiments. As shown in the NRC validation handbook (NUREG/CR-6698) when the number of experiments is 59 or greater, the bounding k_{eff} requires no additional nonparametric margin to ensure an adequate level of statistical certainty in the resulting USL.

It should also be reiterated that the ORNL work was performed only to identify experiments. The actual calculation of k_{eff} for the purposes of determining uncertainty in the calculation of reactivity was performed by DCS using controlled and verified computer programs in accordance with DCS QA procedures.

In summary, the ORNL corrected data shows no impact on the DCS validation report and shows that it contains un-credited conservatism as result of the corrected work.

3.3 Regulation

The need to perform criticality calculations for the MFFF is addressed in NUREG-1718, Section 6.4.3.3.4 (Requirements of 10 CFR 70.61 (Subcriticality of Operations and Margin of Subcriticality for Safety). This section states, in part,

> "To provide for NCS, the applicants description of measures to implement the subcriticality of operations and margin of safety for subcriticality requirements in 10 CFR 70.61 should be considered acceptable if the applicant has met the following acceptance criteria:"

Section A in the following text relates to a commitment to the ANS 8.x standards, which has been made by DCS.

Section B relates to the justification for minimum subcritical margin, which has been provided by DCS and which NRC has accepted.

Section C states the following:

> "C. The applicant commits to determining subcritical limits for k_{eff} calculations such that: k-subcritical = 1.0 – bias – margin where margin includes adequate allowance for uncertainty in the methodology, data, and bias to assure subcriticality."

Section D relates to a commitment to determining operating limits for controlled parameters. DCS has done this by committing to the requirement to show that all credible potential criticality events are highly unlikely, as required by 10 CFR 70.61.

Section E relates to a commitment to determining whether each calculation to establish subcritical limits for facility processes lie within the AOA of the calculation method employed. DCS has committed to this demonstration.

Section F relates to the applicant meeting the acceptance criteria in Section 5.4 [of NUREG-1718] as they relate to subcriticality of operations and margin of subcriticality for safety. This section basically relates to NCSEs. DCS has committed to perform such NCSEs.

Thus for purposes in determining the application of limits to be provided in criticality calculations, as noted in subsection C, it is sufficient to show that the combination of bias and margin, as defined in subsection C, will result in the calculations demonstrating that the facility is subcritical.

3.4 Accuracy of Code

3.4.1 Revision 0 of Part II

In December, 2001, DCS submitted revision 0 of Validation Report Part II (DCS-NRC-000071). In that report, using traditional methods of similarity of fissile material, DCS selected 46 benchmark experiments for AOA(3) and 14 experiments for AOA(4). Based on a statistical analysis of the data (USLSTATS) for AOA(3) and AOA(4), the bias and bias uncertainty was determined to be bounded by 0.0175 and 0.0197, respectively.

3.4.2 Revision 1, 2 of Part II

Comments from NRC observed that the treatment used in the statistical analysis of the data did not show that the data were normally distributed. Further, for AOA(4) only 14 experiments were used which is a small number of data points. Accordingly, as submitted in January, 2003, DCS submitted Revision 1 of Validation Report Part II (DCS-NRC-000124) and then again in response to NRC comments in July, 2003, a revised report (DCS-NRC-000147) which included additional experiments some of which had been suggested by ORNL in a report for DCS (ORNL/TM-2001/262) which was based on the new Sensitivity and Uncertainty (S/U) methodology.

In those submittals, using these new methods of experiment identification, DCS identified 90 benchmark experiments for AOA(3) and 66 experiments for AOA(4). Based on a statistical analysis of the data which did not depend on an assumption of normality and which was recommended in the NRC validation guide NUREG/CR-6698 (the Non-Parametric Method or NPM) for AOA(3) and AOA(4), the bias and bias uncertainty was found to be bounded by 0.0155 and 0.0177, respectively.

3.4.3 Revision 2 with the Impact of ORNL Errors

As noted previously, the work ORNL performed for DCS to recommend experiments which might be applicable contained some errors. According to ORNL, the errors were in sensitivity to the resonance self-shielding calculations. That work involved the determination of a correlation parameter which could be used to evaluate the applicability of a particular candidate experiment against a proposed design application. In some cases, the differences in the correlation parameter as a result of the ORNL errors were significant; in others they were not. However, generally the results indicate that more experiments were applicable to the DCS systems than previously reported. As noted previously, for AOA(3), instead of a total of 90 benchmarks, there are now a total of 91 candidate benchmarks. For AOA(4), instead of a total of 66 benchmarks, there are now a total of 79 candidate benchmarks.

However, incorporating the additional benchmarks does not necessarily result in a change in the bounding values of k_{eff} and hence, in the USL, since the USL is based on the overall minimum observed k_{eff} value. Thus, with the updated, slightly increased numbers of experiments, the bias and uncertainty in the bias remain bounded by 0.0155 for AOA(3). Results for AOA(4) have not been completed using KENO-VI with the newly identified experiments, but based on KENO-V results with the same data library, no change in the minimum k_{eff} is observed.

3.4.4 Revision 0 with Analysis on Non-Normality of Results

As noted above, Revision 0 of Part II of the validation report used traditional methods of benchmark selection based on the similarity of fissile material. For Revision 0, DCS selected 46 benchmark experiments for AOA(3) and 14 experiments for AOA(4). Based on a statistical analysis of the data (USLSTATS) for AOA(3) and AOA(4), the bias and uncertainty in the bias was found to be bounded by 0.0175 and 0.0197, respectively. As noted by NRC, the data was not shown to be normal. (However, as will be shown later, the data can be trended with a simple, low order bounding function whose residuals do appear to be normally distributed.)

Nevertheless, as discussed previously, the non-parametric method (as described in the NRC validation guide (NUREG/CR-6698) can be used to estimate bounding values of the bias and its uncertainty without any assumptions about the normality of the population. To do that the bias and its uncertainty is determined as follows:

Smallest k_{eff} value – Uncertainty for smallest k_{eff} – Nonparametric margin

where the nonparametric method (NPM) margin is an additional margin intended to account for small sample size. Recommended values for the nonparametric margin as a function of the degree of confidence are obtained from Table 2.2 of NUREG-6698.

In particular, as shown in Revision 0 of Part II, the lowest values of k_{eff} for AOA(3) and AOA(4) are 0.9912 and 0.9801, respectively. Additionally, the uncertainty in the smallest k_{eff} is 0.0031 and 0.0053 for AOA(3) and AOA(4), respectively. In the case of AOA(3), 46 benchmark experiments were used, and for AOA(4), 14 benchmark experiments were used. Using Table 2.2 of NUREG-6698 (also shown in the current version of Part II), the NPM margin for 46 experiments is 0.0 and for 14 experiments is 0.04.

Thus, using the benchmark experiments in Part II and the non-parametric method, bounding values of bias and uncertainty in the bias is 1.19% and 6.52% for AOA(3) and AOA(4), respectively (due to the severe imposition of NPM margin as a result of having only 14 experiments for AOA(4)).

Note that this analysis is only provided as an example of additional ways in which bounding values of bias and uncertainty in the bias can be determined. It shows, that the bias and uncertainty in the bias for AOA(3) is essentially unchanged from other methods. However, due to only having 14 experiments for AOA(4), there is a large impact of the NPM margin of 4% to the otherwise determined bias and uncertainty in the bias values of also about 2%. This analysis makes no assumptions about the distribution of the parent population. However, as will be shown later, while the AOA(4) data is due to the small number of experiments (14) and it is difficult to prove it is normally distributed, the data can be trended with a simple, low order bounding function whose differences do appear to have been drawn from a normally based parent population. (See Section 3.4.6).

3.4.5 Analysis of Additional Benchmark Experiments by the Traditional Method Assuming Non-Normality of Data

While 46 and 14 experiments were selected for AOA(3) and AOA(4), respectively, in Revision 0 of Part II and 90 and 66 experiments were identified with the help of the new S/U methodology in Revision 1 and 2 of Part II, there are other experiments that could have been selected using the traditional technique.

For example, the following experiments could be selected based upon their physical characteristics alone:

Table 3 AOA(3) Results with Additional Experiments Identified in Traditional Analysis

Experiment Identifier	Num Exp	H/X	Pu Content	EALF Range (eV)
PU-COMP-MIXED-002	29	0.04-49.6	100%	0.7-4920
PU-COMP-MIXED-001	5	0.04-49.6	100%	1.5-957000
PU-MET-FAST-001	1	0	100%	1.24 MeV
PU-MET-FAST-002	1	0	100%	1.26 MeV
PU-MET-FAST-003	5	0	100%	0.6-1.24 MeV
PU-MET-FAST-016	6	0	100%	7780-117000
PU-MET-FAST-017	5	0	100%	93900-782000
PU-MET-FAST-033	1	0	100%	402000
PU-MET-FAST-037	7	0	100%	18200-148000
PU-COMP-INTER-001	1	0	100%	308
AOA		0-49.6	100%	0.7eV-1.26MeV
Anticipated		1.16-5.97		3.1-65000
Total Experiments	61			
Min k_{eff}	0.9876+/-0.0006			

While this experiment set has not been analyzed for normality (as will be shown in Section 3.4.6 , it most likely does have a normal parent population), it has been analyzed using the non-parametric method (NPM). Based upon this experiment set, the bounding (minimum) k_{eff} value is for experiment PU-MET-FAST-003 Case 3 which has a k_{eff} of 0.9876, a σ of 0.0006, and an experimental uncertainty of 0.0030. Using the NPM, a conservative bounding value of bias and uncertainty in the bias is 0.0155. Since there are 61 experiments, no NPM margin is necessary.

Further, the AOA definition as determined in the traditional approach by the range of parameters of H/Pu, Pu content, and EALF in the experiment set, bounds the anticipated design application values (H/Pu=1.16-5.97, 100% Pu content, EALF=3.1-65000 eV) as well as other key parameters shown in Table 5-1 of the current Part II validation report, completely covering the anticipated ranges of those parameters.

Table 4 AOA(4) Results with Additional Experiments Identified in Traditional Analysis

Experiment Identifier	Num Exp	H/X	Pu Content	EALF Range (eV)
PU-8-1 to PU-29-9	14	2.77-7.33	8-29%	0.6-41.4
MIX-COMP-THERM-001	3	3.3-17.5	22%	0.0002-0.002
MIX-COMP-THERM-005	7	2.2-11.9	4%	0
NSE-55, Table 5	10	2.8	30%	38.5-43.9
BNWL-2129, Table 3	31	30.6	15%	0.14-.26
BNWL-2129, Table 4	19	7.1-9.4	27-28%	1.5-6.1
AOA		2.7-30.6	4-30%	0-43.9
Anticipated		1.15-1.58 (+0.1%)	6.3, 22%	0.8-175 (-0.3%)
Total Experiments	84			
Min k_{eff}	0.9778+/- 0.0006			

For the experiments identified using the traditional technique for AOA(4) and shown Table 4, while this experiment set has not been analyzed for normality (as will be shown in Section 6, it most likely does have a normal parent population), it has been analyzed using the non-parametric method (NPM). Based upon this experiment set, the bounding (minimum) k_{eff} value is for experiment BNWL-2129 Table 3 Case 26 which has a k_{eff} of 0.9778, a σ of 0.0006, and an experimental uncertainty of about 0.005. Using the NPM, a conservative bounding value of bias and uncertainty in the bias is 0.0272. Since there are 84 experiments, no NPM margin is necessary.

Further, the AOA definition as determined in the traditional approach by the ranges of parameters H/Pu, Pu content, and EALF shown above nearly bounds the anticipated design application values (H/X=1.15-1.58, 6.3 or 22% Pu content, EALF=0.8-175 eV) as well as other key parameters shown in Table 5-2 of the current Part II validation report. The anticipated ranges of parameters which slightly exceed the AOA ranges (e.g., H/X_{min}=1.15 vs. 2.7, $EALF_{max}$=175 vs. 43.9 eV) can be treated as out of AOA conditions with additional AOA margin considered consistent with ANSI/ANS-8.1. Based on the trends of these parameters already shown in the current Part II, the impact is expected to be less than 0.3% for these cases.

3.4.6 Analysis of benchmark experiments with results trended and showing normality of the data

Finally, while most of the above analyses have used the non-parametric method (NPM) to analyze the above data since it does not rely on any assumptions of normality, this is not the only way to analyze the data. In fact, as will be shown, the data currently provided in

Part II (90 experiments for AOA(3) and 66 experiments for AOA(4)) can be shown to be from a normally distributed parent population with a trend.

Shown in Figure 1 below is the data for AOA(3) trended with a fit of slightly higher order than the simple linear fit often used with the uncertainty included. The differences of the data from the fit (the residuals) have been analyzed by the standard, yet rigorous Anderson-Darling test for normality. The goodness of normality parameter (p-value) for that test is 0.2666 which indicates, since it is greater than 0.05, that the differences are normal. Thus, a conservative bound on the trend of the bias can be determined statistically and is also shown on the figure.

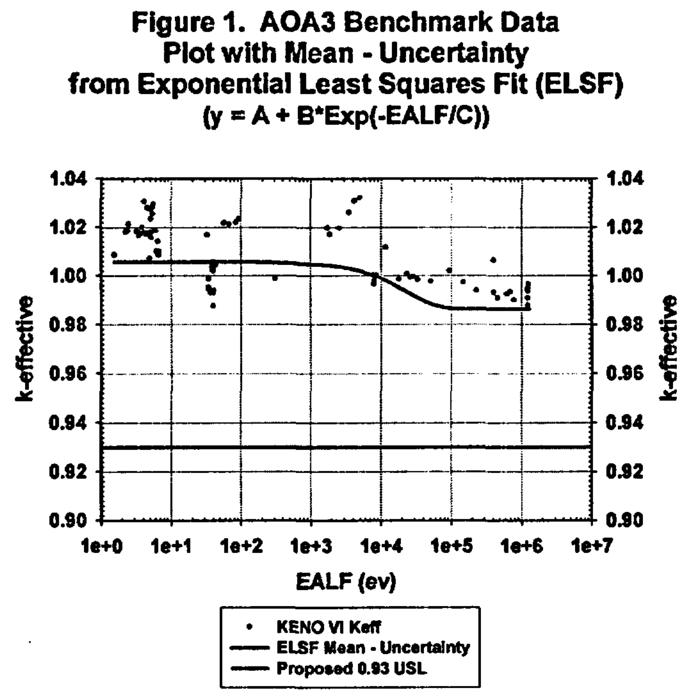

Figure 1 AOA(3) Benchmark Data Plot with Mean Uncertainty from Exponential Least Squares Fit

Taking the minimum value of the fit along with the maximum conservative statistically determined bound on the trend shows that a bounding value of 0.0108 in the bias and uncertainty in the bias would be expected to bound the performance of the KENO-VI code in calculating reactivity over the range of the benchmarks.

This value of 0.0108 in the bias and uncertainty in the bias is bounded by the currently calculated values of bias and uncertainty in the bias shown in the current validation report of 0.0155 for AOA(3).

Similarly, shown in Figure 2 below is the data for AOA(4) trended with a fit of slightly higher order than the simple linear fit often used with the uncertainty included. The differences of the data from the fit have been analyzed by the standard, yet rigorous Anderson-Darling test for normality. The goodness of normality parameter (p-value) for that that test is 0.095 which indicates, since it is greater than 0.05, that the differences are normal. Thus, a conservative bound on the trend of the bias can be determined statistically and is also shown on the figure.

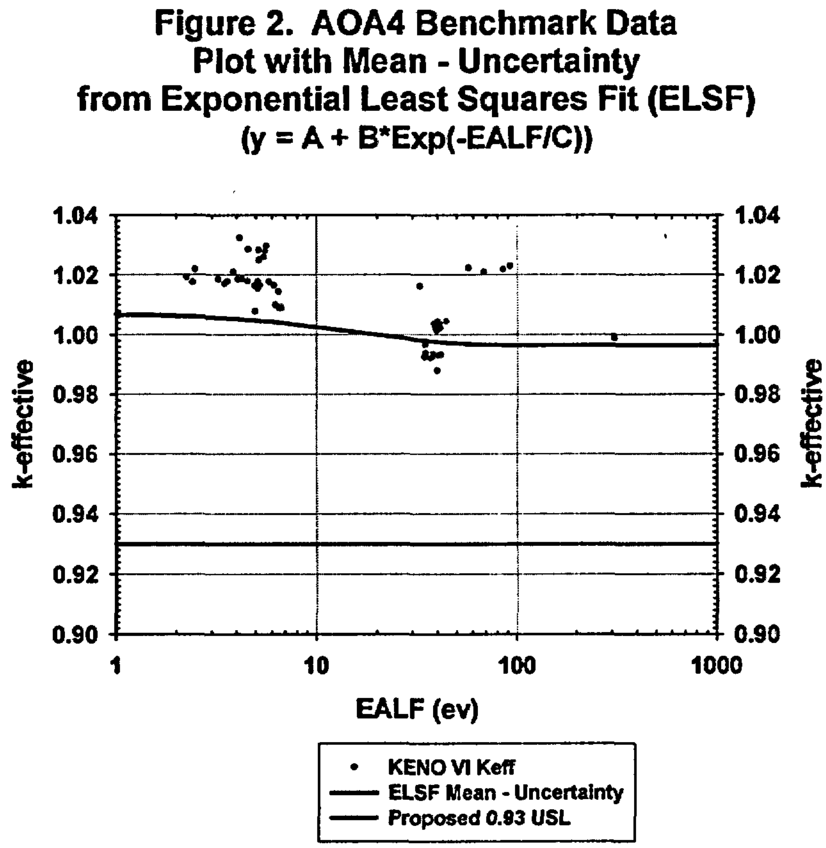

Figure 2 AOA(4) Benchmark Data Plot with Mean Uncertainty from Exponential Least Squares Fit

Taking the minimum value of the fit along with the maximum conservative statistically determined bound on the trend shows that a bounding value of 0.0035% in the bias and uncertainty in the bias would be expected to bound the performance of the KENO-VI code in calculating reactivity over the range of the benchmarks.

This value of 0.0035 in the bias and uncertainty in the bias is bounded by the currently calculated values of bias and uncertainty in the bias shown in the current validation report of 0.0177 for AOA(4).

3.5 Summary

As noted previously, the ability of KENO to determine conservatively the reactivity can be analyzed in several ways. The number of benchmarks selected to determine the code accuracy can be selected in several ways. Shown in the following Figures 3 and 4 are plots of the six ways discussed previously for AOA(3) and AOA(4) as a function of the traditional average energy parameter EALF (energy of average lethargy causing fission).

Note that in most cases, the determined bias and uncertainty in the bias is bounded by 2%. However, for the AOA(4) Case 4 in which the Revision 0 version of Part II contained only 14 experiments is shown, there is a large non-typical bias and uncertainty in the bias of about 6.5% due to the imposition of 4% NPM margin. However, this is an artifact of using only 14 experiments and not supported by other methods of determination. Clearly, as shown previously, with a more reasonable number of experiments, a bounding value of bias and uncertainty in the bias would be more consistent with the 2% value observed as a bounding result for the other methods presented here.

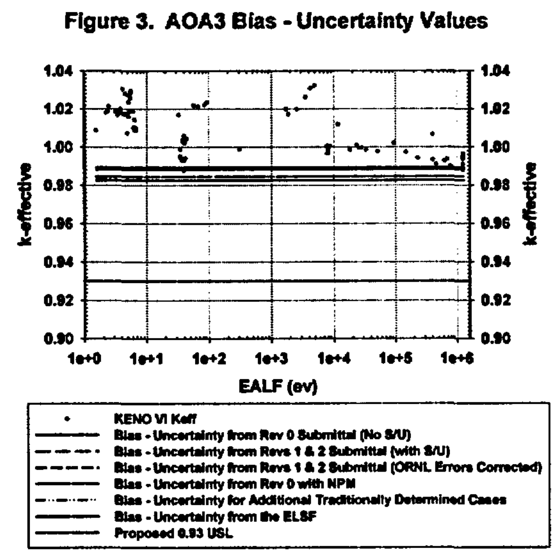

Figure 3 AOA(3) Bias Uncertainty Values

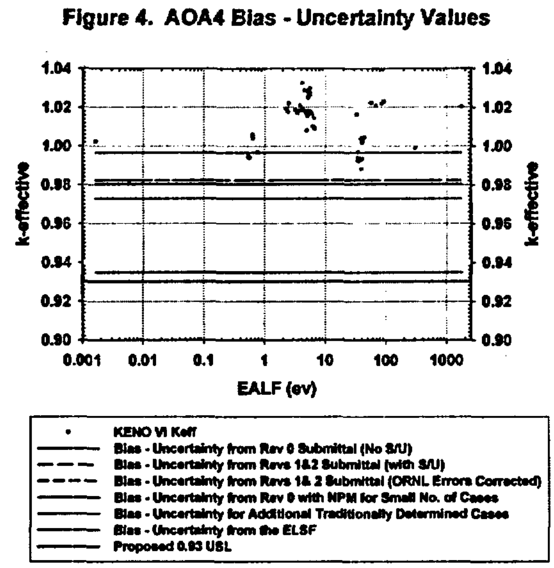

Figure 4 AOA(3) Bias Uncertainty Values

As can be seen, the bias and margin DCS has committed to using, as required by NUREG-1718, is 7%. This results in a maximum calculated k_{eff} of 1-0.07 of 0.93.

However, as can be seen in the figures, a conservative estimate of bias and uncertainty in the bias, as would be expected, is only about 2%, except in the artificial case of analysis of only 14 experiments for AOA(4) and the application of corresponding large NPM margin. Use of the conservative value of 7% bias, uncertainty in the bias, uncertainty in the data, and the method, results in a very large safety margin (7% vs. about 2%).

The regulation (effectively interpreted by NUREG-1718, Section 6.4.3.3.4) only requires that the calculations demonstrate that units be clearly subcritical. Based upon this criterion, as well as the various ways which DCS has analyzed the data, this requirement has been met. Even with potential question about some details of the analysis, it is not credible that the margin DCS has applied in the design of the facility (7%) would be insufficient.

4. Conclusion

Part II of the MFFF criticality validation report covering the material types of PuO_2 powder (AOA(3)) and MOX powder (AOA(4)) has proposed a maximum upper subcritical k_{eff} limit of about 0.93. Based on the expectation of experts, the analysis of data proposed in the original Part II validation report, the revised analysis of the data based upon the latest methods being developed by ORNL for NRC, and based upon additional analyses as described in this document, it has been shown that the proposed bias and margin as required by NUREG-1718 of 7% is ample to demonstrate that the units will be subcritical when compared with the expected bias and uncertainty in the bias of about 2%.

Since this result is consistent with the requirements of NUREG-1718 and with analysis of the data, DCS believes that the USL values established in Validation Report Part II are adequate and AOA(3) and AOA(4) can be approved without the addition of more margin. Thus DCS requests that, in view of the information provided in this document, NRC reconsider the position that margin, above the 7% margin DCS is currently using, needs to be increased.