October 2, 2003

MEMORANDUM TO: Brian Smith, Acting Chief
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards
Office of Nuclear Material Safety
and Safeguards

FROM: Andrew Persinko, Sr. Nuclear Engineer **/RA/**
Special Projects Section
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards, NMSS

SUBJECT: SEPTEMBER 11, 2003, MEETING SUMMARY: MEETING WITH DUKE COGEMA STONE & WEBSTER TO DISCUSS NUCLEAR CRITICALITY SAFETY RELATED TO MIXED OXIDE FUEL FABRICATION FACILITY REVISED CONSTRUCTION AUTHORIZATION REPORT

On September 11, 2003, U.S. Nuclear Regulatory Commission (NRC) staff met with Duke Cogema Stone & Webster (DCS), the mixed oxide fuel fabrication facility (MFFF) applicant, to discuss the validation of nuclear criticality safety computer codes related to the revised construction authorization request (CAR or revised CAR) submitted to NRC on October 31, 2002. The meeting agenda, summary, DCS handouts, attendance list, and NRC handouts are attached (Attachments 1, 2, 3, 4, and 5 respectively).

Docket: 70-3098

Attachments: 1. Meeting Agenda
2. Meeting Summary
3. DCS Handouts
4. Attendance List
5. NRC Handouts

cc:

P. Hastings, DCS	L. Zeller, BREDL
J. Johnson, DOE	G. Carroll, GANE
H. Porter, SCDHEC	D. Silverman, DCS
J. Conway, DNFSB	D. Curran, GANE

MEETING AGENDA
MIXED OXIDE FUEL FABRICATION FACILITY
September 11, 2003

<u>September 11, 2003</u>

9:00 AM	Introduction
9:10 AM	Discussions of nuclear criticality safety validation report
12:00 NOON	Lunch
1:00 PM	Discussions of nuclear criticality safety validation report
3:15	Summary / Actions
3:30	Adjourn

Attachment 1

MEETING SUMMARY
MIXED OXIDE FUEL FABRICATION FACILITY
September 11, 2003

Purpose:

The purpose of the meeting was to discuss the unresolved nuclear criticality safety issue related to the Mixed Oxide (MOX) Fuel Fabrication Facility Construction Authorization Request (CAR) submitted by DCS on October 31, 2002, identified as NCS-4 in the NRC staff's Draft Safety Evaluation Report (DSER) dated April 30, 2003.

Summary:

The meeting was a technical, working level meeting that covered the remaining nuclear criticality safety unresolved issue, NCS-4, in detail. Handouts were provided by DCS as the basis for discussion. The handouts are provided in Attachment 3.

A summary of the issues discussed is provided below:

Nuclear Criticality Safety

NRC opened the meeting by asking DCS what methodology or methodologies it wants to use in its criticality validation report, and cited staff's memorandum dated September 10, 2003, that documented a phone call with DCS. The memorandum can be accessed in NRC'S ADAMS document system under ML032530534.

DCS stated that it proposes to place less reliance on the sensitivity/uncertainty (S/U) method and rely on a more traditional validation approach. Doing so would make many of the NRC questions regarding the S/U method moot. DCS, however, stated that it may rely on the S/U method at some future time as the method matures. The traditional methodology will be based on NUREG/CR- 6698, "Guide for Validation of Nuclear Criticality Safety Calculational Methodology." DCS's proposed approach, consisting of six steps, is described further in Attachment 3. During the meeting, DCS discussed these six steps.

With regard to steps 2 and 3, step 2 is to develop screening criteria and step 3 is to identify experiments within the screening criteria. NRC requested that DCS provide the bases for its screening criteria and justification for benchmark experiments that DCS intends to include even though they fall outside the screening criteria. NRC staff questioned the difference between "primary" and "secondary" parameters on slide 8. DCS responded that primary parameters can be quantified whereas secondary parameters are not, and are of lesser importance. DCS stated that it considers secondary criteria in addition to primary criteria in identifying key parameters. NRC questioned whether both the primary and secondary criteria had to be met to conclude that a benchmark should be included. DCS responded that mainly the primary screening criteria were used to select applicable benchmarks.

On slide 11, NRC staff stated that it appears that the screening criteria (including H/Pu ratio of 0-50) appear to be overly broad and not in agreement with NUREG/CR-6698. DCS responded that it did not literally apply the NUREG - - it followed the steps in the NUREG, but not

Attachment 2

DUKE COGEMA STONE&WEBSTER SLIDES
MOX FUEL FABRICATION FACILITY

Attachment 3

DUKE COGEMA
STONE & WEBSTER

DCS-NRC MEETING ON CRITICALITY SAFETY VALIDATION REPORT, PART II

11 Sep 2003
NRC Offices

Attachment 3

Agenda

DUKE COGEMA STONE & WEBSTER

MFFF Validation Report, Part II

1. Background
2. Approach
3. AOA(3)
4. AOA(4)
5. Results/Conclusions

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Background (1 of 2)

- MFFF Validation Report, Part II, (Rev. 0) initially submitted, Dec, 2001.
- Relatively small number of benchmarks were selected manually and analyzed by standard statistical methods (USLSTATS).
- NRC informal comments were that the benchmark data was not normally distributed and, in the case of AOA(4), only 14 benchmarks were selected.
- During late 2001-early 2002, DCS contracted with ORNL to use new Sensitivity and Uncertainty (S/U) methodology to identify applicable experiments.
- ORNL study identified a number of additional benchmarks.
- Of these, DCS used 90 benchmarks for AOA(3) and 66 benchmarks for AOA(4), submitting revised Validation Report Part II, January, 2003 (Rev. 1).

Background (2 of 2)

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- To address NRC concern about non-normality, the non-parametric method (NPM) was used.
- Meeting held at NRC offices, March 2003, in which NRC requested clear definition of validated AOA and justification for details of the report.
- DCS revised Validation Report, Part II (Rev. 2) and provided it on 2 July, 2003.
- NRC questions received in late June, were responded to on 28 July 2003.
- Responses discussed in public meeting on 31 July 2003.
- NRC said Parts I and III would be approved essentially as submitted.
- However, NRC stated that it would need additional margin to be included on AOAs for Part II (AOA(3) and AOA (4)).
- DCS responded with a letter on 26 August 2003.

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NRC Questions

1. Provide more justification of validity/correctness of S/U work performed by ORNL for DCS.
2. Provide information about the QA of the ORNL work.
3. Provide justification of the selection criteria used in the ORNL work (S/U) to select the experiments.
4. Provide information as to how example experiments in Tables 3 and 4 of the letter were identified and determined as being appropriate.
5. Explain how the bounding values shown below Figures 1 and 2 were obtained.

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Status of Validation Report, Part II

- As discussed in the DCS letter of 26 Aug 2003, the selection of benchmark experiments can be performed in several ways with essentially the same result.
- As a result of NRC questions as to the validity and justifications of the ORNL work on S/U for the selection of experiments, DCS is using a traditional technique for benchmark selection.
- The experiments have already been described in previous reports.

DCS Process Outline

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- DCS will describe the approach, expected benchmark selection including justification, and results.
- Methodology based on NUREG 6698 Section 2.5
  - Step 1: Identify key parameters of system.
  - Step 2: Develop screening criteria.
  - Step 3: Identify experiments within screening criteria.
  - Step 4: Determine AOA based on experiments.
  - Step 5: Show that the system falls within the AOA.
  - Step 6: Document the results for the AOA.

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AOA(3) Identification of Key Parameters

- AOA identification approach (NUREG 6698, Section 2.5, Step 1)

  Primary

  a. Fissile Material: Pu
  b. Isotopic composition of fissile material: ^{239}Pu: 96%, ^{240}Pu: 4%
  c. Pu content: 100%
  d. Moderator: hydrogen
  e. H/Pu: 0-6
  f. EALF: 0.5-65,000 eV

  Secondary

  a. Physical form: PuO_2 powder and water mixtures
  b. Reflector: Bare, Water, cadmium and boron absorbers
  c. Density: 11.46 g/cc max
  d. Geometry: arrays of cylinders, spheres, isolated cylinders, complex units of non uniform slabs and cylinders

AOA(3) Justification of Primary and Secondary Classifications

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- Primary parameters, such as fissile material, moderator, and EALF, have a major and direct influence on the reactivity of a benchmark
- Secondary parameters such as physical form and geometry are well modeled in the code and thus have a less important influence

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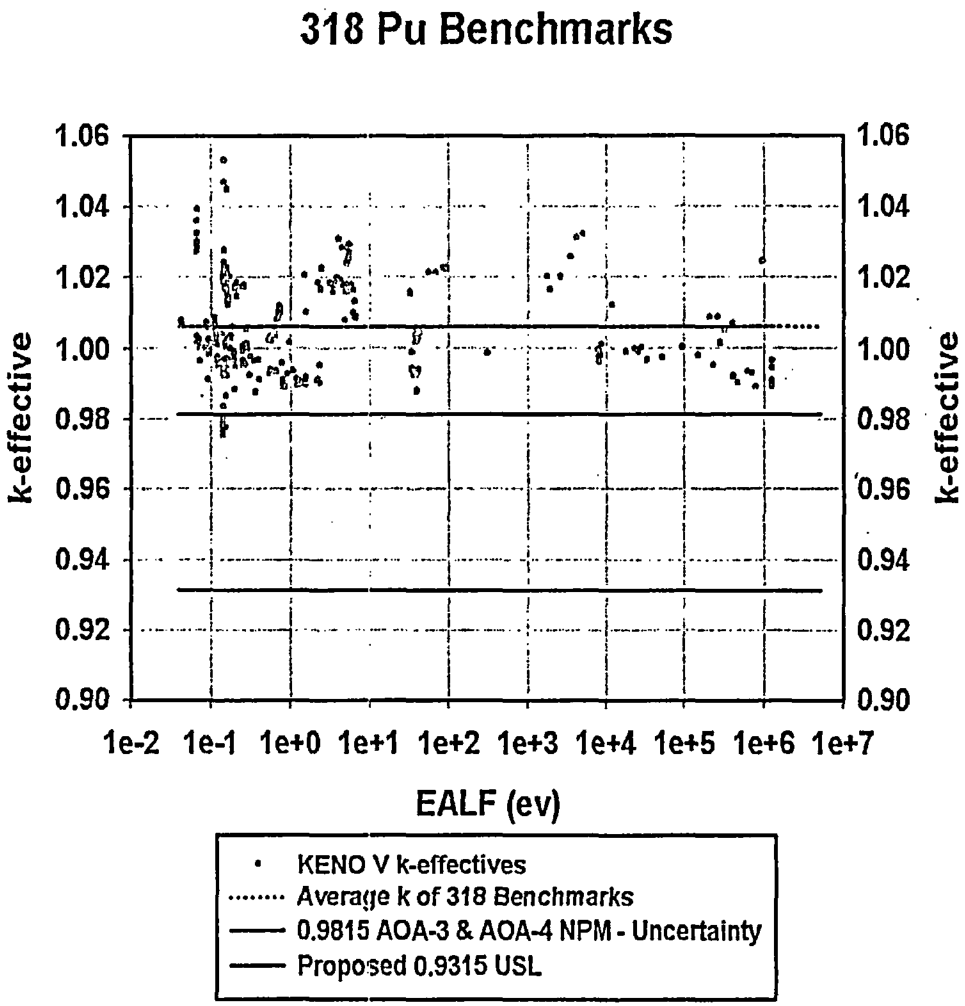
Comparison of k_{eff} Data for 318 Experiments



Summary

- All candidate benchmarks before selection
- Even though all would not be expected to meet screening criteria, they nevertheless show that all KENO results are clearly bounded by 0.93 (and essentially by 0.98).
- Average of the data actually slightly above 1
- No apparent trend
- Large margin between all data and proposed USL

AOA (3) Screening Area of Applicability for Benchmark Experiments

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- Screening AOA selected (based on NUREG 6698, Section 2.5, Step 2)

Primary

a. Fissile Material: Pu
b. Isotopic composition of fissile material: ^{239}Pu:86%-100%, ^{240}Pu:0-8%
c. Pu content: 90-100%
d. Moderator: hydrogen
e. H/Pu: 0-50
f. EALF: 0-10^6 eV

Secondary

a. Physical form: PuO_2 powder, Pu Metal and hydrogenous material mixtures
b. Reflector: Bare or hydrogenous, neutron absorbers
c. Density: 11.46 g/cc max
d. Geometry: arrays and contiguous units

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AOA(3) Critical Benchmarks Selected

Table of selected benchmarks that meet the criteria (NUREG 6698, Section 2.5, Step 3)

Experiment	Num Exp	Fissile Mat'l	Pu Content	^{240}Pu [wt. %]	Moderator	H/Pu	EALF [eV]	Description	Comment
Selection Criteria		Pu	90-100%	0-8%	Hydrogen	0-50	0-10^6		
PU-COMP-MIXED-001	5	Pu	100%	2.2-18.35	Hydrogen	5.0-49.6	1.548-957,000	PuO_2- polystyrene compacts	High ^{240}Pu content justified since little to no trend observed
PU-COMP-MIXED-002	29	Pu	100%	2.2-18.35	Hydrogen	0.04-49.6	0.685-4,900	PuO_2- polystyrene compacts	High ^{240}Pu content justified since little to no trend observed
PU-MET-FAST-016	6	Pu	100%	5.97	Hydrogen	0	7760-11,700	Cylinders of plutonium metal sealed in an aluminum can with a steel lid	Hydrogen is interspersed within the cylinders (similar to MFFF storage)
PU-MET-FAST-017	5	Pu	100%	5.97	Hydrogen	0	93,500-782,000	Cylinders of plutonium metal sealed in an aluminum can with a steel lid	Hydrogen is interspersed within the cylinders (similar to MFFF storage)
PU-MET-FAST-037	7	Pu	100%	5.97	Hydrogen	0	18,200-148000	Cylinders of plutonium contained in a seamless aluminum cans	Hydrogen is interspersed within the cylinders (similar to MFFF storage)
PU-MET-FAST-003	2	Pu	100%	6	N/A	0	628,000-694,000	Unmoderated metal button arrays	No moderation (similar to MFFF storage evaluated w/o moderation)
PU-COMP-INTER-001	1	Pu	100%	5.4	Hydrogen and carbon	0.37	308	Plutonium oxide, graphite, and boron	Carbon has very small reactivity effect relative to hydrogen
Total	55								

Comparison of k_{eff} Data for AOA-3

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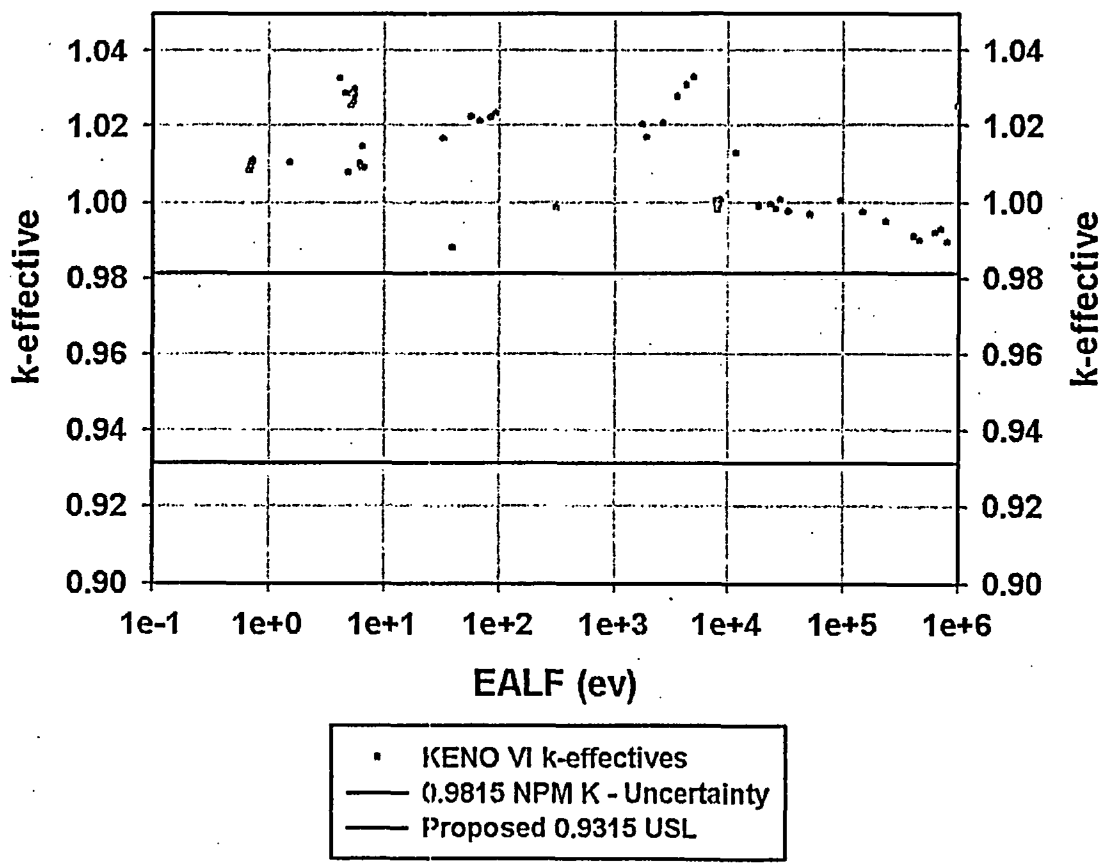
55 AOA-3 Benchmarks



Summary

- 55 applicable benchmarks
- Very similar to AOA (4)
- All data (including experimental uncertainty) bounded by 0.9815
- No significant trend
- Large margin between data and proposed USL

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AOA(3) Validated AOA

Table 5-3 AOA(3) Comparison of Key Parameters and Definition of Validated AOA

Parameter	Design Application	Benchmarks	Validated AOA
Fissile Material	Pu	Pu	Pu
Isotopic composition	4 wt. % ^{240}Pu	2.2 wt. % to 18.35 wt. % ^{240}Pu	4 wt. % ^{240}Pu
Pu Content	100%	100%	100%
Moderator	Hydrogen	Hydrogen[1]	Hydrogen
H/Pu	1.16 to 5.97	0 to 50	1.16 to 5.97
EALF [eV]	3.1 to 65000	957,000 1.5 to ~~782,000~~	3.1 to 65000
Physical form	PuO_2 Powder and hydrogenous mixtures	PuO_2 Powder, Pu metal and hydrogenous mixtures	PuO_2 Powder and hydrogenous mixtures
Reflector	Water, Cd, Concrete	Plexiglas, air, water	Water or air
Density	11.46 g/cc max	19.5 g/cc max	11.46 g/cc max
Geometric shape	Parallelepipeds Arrays of cylinders Spheres	Arrays and contiguous units	Arrays and contiguous units

[1] One experiment also contained carbon

AOA(4) Identification of Key Parameters

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- AOA identification approach (NUREG 6698, Section 2.5, Step 1)

  Primary

  a. Fissile Material: Pu
  b. Isotopic composition of fissile material: ^{239}Pu:96%, ^{240}Pu:4%
  c. Pu content: 6.5% and 22%
  d. Moderator: hydrogen
  e. H/(U+Pu): 0-1.6
  f. EALF: 0.8-175 eV

  Secondary

  a. Physical form: MOX powder and water mixtures
  b. Reflector: Bare, Water
  c. Density: 5.5 g/cc max
  d. Geometry: spheres, isolated cylinders, complex units of non uniform slabs and cylinders

AOA (4) Screening Area of Applicability for Benchmark Experiments

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- Screening AOA selected (based on NUREG 6698, Section 2.5, Step 2)

Primary

a. Fissile Material: Pu
b. Isotopic composition of fissile material: ^{239}Pu:86%-100%, ^{240}Pu:0-8%
c. Pu content: 0-30%
d. Moderator: hydrogen
e. H/(U+Pu): 0-10
f. EALF: 0-1,000 eV

Secondary

a. Physical form: MOX powder and hydrogenous material mixtures
b. Reflector: Bare or hydrogenous
c. Density: 7 g/cc max
d. Geometry: contiguous units

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AOA(4) Critical Benchmarks Selected

Experiment	Num Exp	Fissile Mat'l	Pu Content	^{240}Pu [wt. %]	Moderator	H/X	EALF [eV]	Description	Comment
Selection Criteria		Pu	0-30	0-8%	Hydrogen	0-10	0-1,000		
MIX-COMP-INTER-001	13	Pu	8.1-29.3	11.5	Hydrogen	2.8-7.3	0.63-41.71	Rectangular parallelepipeds, Compacts of UO_2+PuO_2 and Polystyrene	High ^{240}Pu content justified since little to no trend observed
MIX-COMP-THERM-001	3	Pu	22%	11.5	Hydrogen	3.3-17.5	0.1-0.9	MOX fuel pin arrays	H/X >10 justified since no trend observed and H/X not well defined for pin arrays. High 240Pu content justified since little to no trend observed
MIX-COMP-THERM-005	7	Pu	4%	18.2	Hydrogen	2.2-11.9	0.09-0.4	MOX fuel pin arrays	H/X >10 justified since no trend observed and H/X not well defined for pin arrays. High 240Pu content justified since little to no trend observed.
NSE-55, Table 5 w/o strong absorbers	7	Pu	30%	11.5	Hydrogen	2.8	38.5-43.9	MOX polystyrene compacts with poison plates	Only experiments with weak absorbers. High 240Pu content justified since little to no trend observed.
BNWL-2129, Table 3, w/o strong absorbers	16	Pu	15%	14.6	Hydrogen	30.6	0.14-0.26	MOX polystyrene compacts with poison plates	Only experiments with weak absorbers. Similar experimental design to BNWL 2129 Table 4. High 240Pu content justified since little to no trend observed.
BNWL-2129, Table 4 w/o strong absorbers	10	Pu	27-28%	8	Hydrogen	7.1-9.4	1.5-6.1	MOX polystyrene compacts with poison plates	Only experiments with weak absorbers
MIX-COMP-THERM-002	2	Pu	2%	7.9	Hydrogen	0	0.58	MOX fuel pin arrays	
MIX-COMP-THERM-003	3	Pu	7%	8.6	Hydrogen	0	0.55-0.91	MOX fuel pin arrays	
MIX-COMP-THERM-009	1	Pu	2%	8	Hydrogen	0	0.55	MOX fuel pin array	
PU-COMP-INTER-001	1	Pu	100%	5.4	Hydrogen	0.37	308	Plutonium oxide, graphite, and boron	Carbon has very small reactivity effect relative to hydrogen; High Pu content used to cover intermediate energy range
PU-COMP-MIXED-001	3	Pu	100%	2.2-11.5	Hydrogen	5-14.95	32-1740	PuO_2- polystyrene compacts	High ^{240}Pu content justified since no trend observed; High Pu content used to cover intermediate energy range
PU-COMP-MIXED-002	4	Pu	100%	11.5	Hydrogen	5	57-93	PuO_2- polystyrene compacts	High ^{240}Pu content justified since no trend observed; High Pu content used to cover intermediate energy range
Total	70								

Comparison of k_{eff} Data for AOA-4

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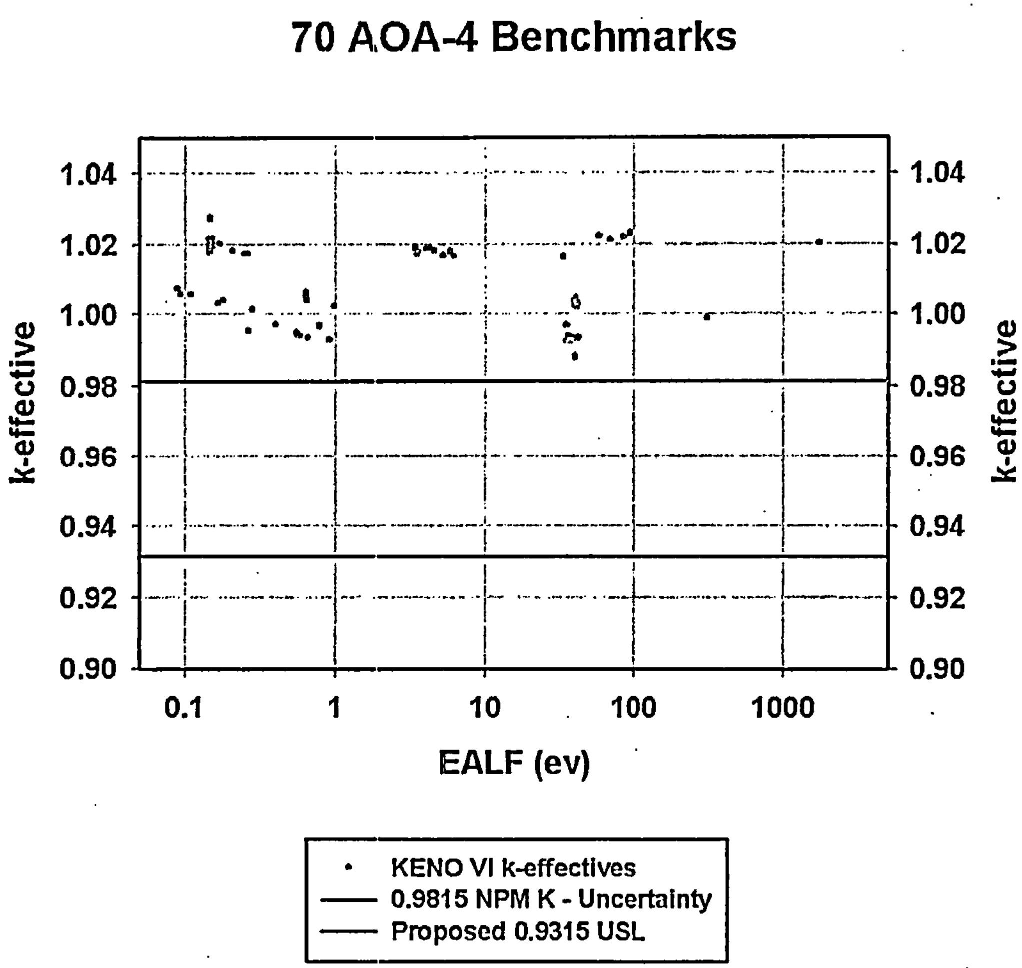

Summary

- 70 applicable benchmarks
- Very similar to AOA (3)
- All data (including experimental uncertainty) bounded by 0.9815
- No significant trend
- Large margin between data and proposed USL

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AOA(4) Validated AOA

Table 5-4 AOA(4) Comparison of Key Parameters and Definition of Validated AOA

Parameter	Design Application	Benchmarks	Validated AOA
Fissile Material	Pu	Pu	Pu
Isotopic composition	4 wt. % ^{240}Pu	2.2 wt. % to 11.6 wt. % ^{240}Pu	4 wt. % ^{240}Pu
Pu Content	6.5% and 22%	1.5 to 100%	6.5% and 22%
Moderator	Hydrogen	Hydrogen[1]	Hydrogen
H/(U+Pu)	0 to 1.6	0 to 30.6	0 to 1.6
EALF [eV]	0.8 to 175	0 to 1740	0 to1740
Physical form	MOX Powder and hydrogenous mixtures	MOX Powder, Pu metal and hydrogenous mixtures	MOX Powder and hydrogenous mixtures
Reflector	Bare and Water	Plexiglas, air, water	Water or air
Density	5.5 g/cc max	11 g/cc max	5.5 g/cc max
Geometric shape	Spheres isolated cylinders, complex units	Arrays and contiguous units	Contiguous units

[1] One experiment also contained carbon

Preliminary Results/Conclusions

- Based on traditional methods of criticality benchmark selection, 55 applicable experiments for AOA(3) and 70 applicable experiments for AOA(4) have been selected.
- The data has been analyzed and found to be non-normal and thus the NPM has been applied. However, since there are 55 applicable experiments for AOA(3) and 70 experiments for AOA(4), in accordance with the method of NUREG-6698 (Table 2.2), there is no NPM margin applied.
- Preliminary results:
  - The bounding k_{eff} for both AOA (3) and AOA (4) is 0.9881.
  - The resulting USL with a 5% administrative margin including experimental uncertainty is 0.9315.

NRC HANDOUTS

NRC Concerns with Benchmark S'election Methodology for MOX
September 11, 2003 Public Meeting

This represents NRC's initial concerns with the screening criteria and the basis for selected benchmarks presented in the public meeting. This list is not necessarily an exhaustive list of questions or concerns.

Selection Criteria for AOA(3): Slide 11

Identification of important parameters reasonable. Ranges questioned as below:

H/Pu = 0-50	Both low (because no hydrogen, one of most important nuclides) and high range are of concern. NUREG/CR-6698: ± 20 at% H.
EALF = 0-10^6 eV	Both low (thermal) and high (fast) range are of concern. NUREG/CR-6698: intermediate spectrum (1 eV-100 keV).

Benchmarks for AOA(3): Slide 12

PCM001:	Generally OK (except PCM001-05: H/Pu appears too high)
PCM002:	Generally OK (H/Pu appears too low or high in some cases)
PMF016:	Of concern. No hydrogen present.
PMF017:	Of concern. No hydrogen present, fast spectrum.
PMF037:	Of concern. No hydrogen present, fast spectrum.
PMF003:	Of concern. No hydrogen present, fast spectrum.
PCI001:	Generally OK, but presence of carbon and boron needs to be justified.

Selection Criteria for AOA(4): Slide 16

Identification of important parameters reasonable. Ranges questioned as below:

Pu content = 0-30%	Low (no Pu, one of most important nuclides) range is of concern. NUREG/CR-6698 has no guidance for Pu-U systems.
H/(U+Pu) = 0-10	Both low (because not hydrogen, one of most important nuclides) and high range are of concern. NUREG/CR-6698: ± 20 at% H.
EALF = 0-1000 eV	Low (thermal) range is of concern.

NUREG/CR-6698: intermediate spectrum (1 eV-100 keV).

Benchmarks for AOA(4): Slide 17

MCI001:	Pu-15 and Pu-29 cases OK. Pu-8 cases of concern. H/X somewhat high and thermal spectrum.
MCT001:	Of concern. Heterogeneous lattice and thermal spectrum.
MCT005:	Has not been previously reviewed by NRC staff.
NSE55:	OK.
BNWL2129T3:	Has not been previously reviewed by NRC staff.
BNWL2129T4:	Generally OK (H/X somewhat high, otherwise good).
MCT002:	Of concern. Heterogeneous lattice and thermal spectrum, no hydrogen.
MCT003:	Has not been previously reviewed by NRC staff.
MCT009:	Of concern. Heterogeneous lattice and thermal spectrum, no hydrogen.
PCI001:	Of concern. Pu-content high, H/X somewhat low.
PCM001:	Of concern. Pu-content high, H/X somewhat high for some cases.
PCM002:	Of concern. Pu-content high.

necessarily the criteria given in Table 2.3. NRC staff asked what is the basis for including plutonium metal experiments and what is the basis for having an H/Pu ratio less than or equal to 50. NRC staff stated that it would need a technical basis for why screening criteria are applicable.

NRC staff questioned the Energy of Average Lethargy Causing Fission (EALF) values of 0.0 - 1E6 electron volts, since such a range would cover thermal, intermediate, and fast neutrons. DCS stated that most cases fell into the intermediate range.

Regarding slide 11, NRC staff questioned including lattice arrays in the MOX powder areas defined as AOA (4), and stated that DCS needs to justify the inclusion of lattice arrays. The SCALE code treats heterogeneous lattices differently from homogeneous systems.

DCS stated that the experiments should be broader than the range covered by design calculations in order to determine trends in the bias. NRC stated that it was not appropriate to define the area of applicability very broadly to include a large number of benchmarks; only experiments that are truly applicable should be included.

Individual benchmarks were then discussed. The NRC staff's preliminary comments on individual benchmarks are provided in Attachment 5.

In summary, NRC staff stated that DCS should:

1. Justify its screening criteria and justify use of experiments that fall outside of the screening criteria, and how bias and uncertainty is extrapolated beyond the data.

2. Describe how it is applying NUREG/CR-6698 (including use of primary and secondary criteria, and ranges in Table 2.3).

NRC staff stated that the questions in its September 10 memorandum are moot based on DCS' decision to follow a traditional validation methodology, except for questions 4 and 5 which still apply and need to be answered by DCS. The information contained in DCS' August 29, 2003, submittal is also moot, since this is no longer consistent with DCS' proposed methodology.

NRC staff stated that in its view, revision of Part II of the Validation Report was necessary to address the new approach. DCS agreed to evaluate this issue and provide a response.

DUKE COGEMA STONE&WEBSTER SLIDES
MOX FUEL FABRICATION FACILITY

Attachment 3

MEETING ATTENDEES

NAME	AFFILIATION
Andrew Persinko	Nuclear Regulatory Commission (NRC)
Muffet Chatterton	NRC
Christopher Tripp	NRC
John Lubinski	NRC
Kathy Gibson	NRC
Linda Gross	NRC
David Brown	NRC
Brian Smith	NRC
Ken Ashe	Duke Cogema Stone & Webster (DCS)
Peter Hastings	DCS
Bob Foster	DCS
Charles Henkel	DCS
Thomas Doering	DCS
William Peters	DCS
Dan Moss	Numark Associates
Paloma Sarria	Numark Associates
Daniel Horner	McGraw-Hill

NRC HANDOUTS