January 8, 2004

MEMORANDUM TO: Joseph G. Giitter, Chief
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards
Office of Nuclear Material Safety
and Safeguards

THRU: Margaret Chatterton, Team Leader **/RA/**
Criticality Team
Special Projects Section
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards, NMSS

FROM: Christopher S. Tripp, Sr. Nuclear Process Engineer **/RA/**
Criticality Team
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards, NMSS

SUBJECT: DECEMBER 17-19, 2003, IN-OFFICE REVIEW SUMMARY: DUKE COGEMA STONE & WEBSTER CONSTRUCTION AUTHORIZATION REQUEST SUPPORTING DOCUMENTATION FOR CRITICALITY CODE VALIDATION

BACKGROUND

On December 17-19, 2003, U.S. Nuclear Regulatory Commission (NRC) staff (Christopher S. Tripp) conducted an in-office review at Duke Cogema Stone & Webster (DCS) Headquarters in Charlotte, NC. The purpose of the visit was to review documentation related to Open Item NCS-4 on nuclear criticality code validation. The most recent version of the criticality code Validation Report, Part II, Rev. 3, was submitted by letter on October 10, 2003. A letter containing NRC staff's questions on this version of the validation report was issued on November 7, 2003. A public meeting was held on November 13, 2003, at NRC Headquarters, to discuss the issues in this letter, as documented in the December 3, 2003, meeting summary. During that meeting, it was suggested that information relevant to resolving the open issue be reviewed at DCS Headquarters. The purpose of the in-office review was to review design information applicable to Questions 10-18 in the November 7, 2003, letter.

Docket No. 70-3098

Attachment: Validation Information Provided During In-Office Review Dec. 17-19, 2003

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

MEMORANDUM TO: Joseph G. Giitter, Chief
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards
Office of Nuclear Material Safety
and Safeguards

THRU: Margaret Chatterton, Team Leader /**RA/**
Criticality Team
Special Projects Section
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards, NMSS

FROM: Christopher S. Tripp, Sr. Nuclear Process Engineer **/RA/**
Criticality Team
Special Projects and Inspection Branch
Division of Fuel Cycle Safety
and Safeguards, NMSS

SUBJECT: DECEMBER 17-19, 2003, IN-OFFICE REVIEW SUMMARY: DUKE COGEMA STONE & WEBSTER CONSTRUCTION AUTHORIZATION REQUEST SUPPORTING DOCUMENTATION FOR CRITICALITY CODE VALIDATION

BACKGROUND

On December 17-19, 2003, U.S. Nuclear Regulatory Commission (NRC) staff (Christopher S. Tripp) conducted an in-office review at Duke Cogema Stone & Webster (DCS) Headquarters in Charlotte, NC. The purpose of the visit was to review documentation related to Open Item NCS-4 on nuclear criticality code validation. The most recent version of the criticality code Validation Report, Part II, Rev. 3, was submitted by letter on October 10, 2003. A letter containing NRC staff's questions on this version of the validation report was issued on November 7, 2003. A public meeting was held on November 13, 2003, at NRC Headquarters, to discuss the issues in this letter, as documented in the December 3, 2003, meeting summary. During that meeting, it was suggested that information relevant to resolving the open issue be reviewed at DCS Headquarters. The purpose of the in-office review was to review design information applicable to Questions 10-18 in the November 7, 2003, letter.

Docket No. 70-3098

Attachment: Validation Information Provided During In-Office Review Dec. 17-19, 2003

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

DISTRIBUTION: SPIB r/f FCSS r/f RPierson JHolonich JHull, OGC Hearing File
SRosenberg, EDO DMcIntyre, OPA DAyers, RII CNoelke, RII Wgloerson Rvirgilio,OSP
ML040090019
G:\FCSS\SPB\CST\ In-House Review Summary12-03.wpd

OFC	SPIB		SPIB	
NAME	CTripp:dw		MChatterton	
DATE	1/ 08 /04		1/ 08 /04	

OFFICIAL RECORD COPY

The staff's concerns with the chosen benchmarks for area(s) of applicability AOA(3) (PuO_2 powders) and AOA(4) (mixed oxide (MOX) powders) fell into two broad categories: (1) the Pu-metal benchmark issue (the use of plutonium metal benchmarks to validate PuO_2 design applications), and (2) the plutonium assay issue (the use of PuO_2-polystyrene benchmarks with a plutonium content of ~30wt% Pu to validate 100wt% Pu design applications and benchmarks with 100wt% Pu content to validate 6.3 and 22wt% Pu design applications). For both of these issues, DCS' justification rested largely on similarities between the ^{239}Pu fission spectra of proposed design applications and those of selected benchmarks.

DISCUSSION

Pu-Metal Benchmark Issue

At the November 13, 2003 meeting, DCS informed the staff that the Pu-metal benchmarks were included to validate calculations for PuO_2 powder storage units at the front end of the Aqueous Polishing (AP) process. To better understand this issue, the staff reviewed preliminary floor plans, equipment drawings, and criticality control flow diagrams for the MOX Fuel Fabrication Facility (MFFF). The staff reviewed the following nuclear criticality safety evaluations (NCSEs) and their associated calculation documents:

- "Nuclear Criticality Safety Evaluation of PuO_2 Storage Unit", DCS01-DCM-DS-ANS-H-35039-A.
- "Criticality Safety of the PuO_2 3013 Can Store", DCS01-DCM-CG-CAL-H-06351-A.
- "Criticality Safety of the Polished PuO_2 Buffer Storage Unit DCE with Extended Capacity", DCS01-DCE-CG-CAL-H-06770-B.

The staff reviewed drawings of the 3013 Storage Unit and Pu Buffer Storage Unit and the criticality calculations for these areas. Whether the dry powder (H/Pu = 0) cases are the most reactive in these areas is relevant to which benchmarks are chosen, because the most reactive cases determine the subcritical limits. The dry powder cases are also those most similar to the Pu-metal benchmarks. The staff therefore reviewed the results of DCS' sensitivity studies for the 3013 Storage Unit showing that the most reactive case was for powder at full theoretical density, with an H/Pu = 0.

In these calculations, the maximum allowable mass of PuO_2 in each 3013 can was modeled and the powder density allowed to vary, assuming a constant 1wt% H_2O (H/Pu ~ 0.3). Thus, the level of powder in each can changed as the density was varied. The calculations showed that k_{eff} increased uniformly with increasing density, and that all cases with 1wt% H_2O were less reactive than the dry (H/Pu = 0) case at full theoretical density. (This is thought to be due to the large amount of neutron interaction between pits in the 3013 Storage Unit.) DCS also presented information comparing the geometric arrangement, materials of construction, and dimensions of the PuO_2 powder storage cans and pits to those in certain Pu-metal benchmarks (especially PMF003, PMF016, PMF017, and PMF037). The staff stated that it would need to perform some independent calculations to confirm the bounding nature of the dry powder cases and the degree of similarity between these design calculations and Pu-metal benchmarks. As stated during the November 13, 2003, meeting, there was still a question of whether it is appropriate to lump the Pu-metal benchmarks together with the PuO_2-polystyrene benchmarks (i.e., analyze them in a single AOA); this part of the issue was not resolved during the in-office review.

A generic issue concerned what code options were used during calculation of the benchmark experiments and were therefore considered validated. This issue was brought to light because DCS modeled some Pu-metal benchmarks using the LATTICECELL cross section treatment option, but stated that it considered the code validated when using the INFHOMMEDIUM cross section treatment option. DCS therefore presented sensitivity studies showing there was essentially no difference between the calculated k_{eff} for Pu metal benchmarks using the INFHOMMEDIUM and LATTICECELL cross section treatment options. These studies showed that the INFHOMMEDIUM treatment option was used, k_{eff} decreased slightly in most (20 out of 23) cases. The recalculated Upper Safety Limit (USL) was also essentially unchanged from the original USL for AOA(3). The staff stated that while this helped answer some questions from the November 7, 2003 letter, there was still a need to describe which code options are considered validated (Question 16 in November 7, 2003, letter).

Plutonium Assay Issue

One of the two main issues concerned the inclusion of certain benchmarks with very different Pu-content from expected design applications in both AOA(3) and AOA(4). DCS stated (during the November 13, 2003 meeting and the in-office review) that the justification for including these was basically that: (1) ^{239}Pu fission dominated all other nuclear reactions in the systems modeled; and (2) that it was therefore reasonable to neglect the presence of ^{238}U in these cases. DCS, therefore, provided the results of sensitivity studies in which all of the ^{238}U was removed from each of the 29.3wt% PuO_2 benchmarks used to validate AOA(3) and AOA(4). This analysis showed that in all cases removal of the ^{238}U resulted in at most an ~8% difference in k_{eff}. In addition, the analysis only observed only small changes in the fission, absorption, and leakage spectra. DCS concluded that these findings showed that the presence of ^{238}U has only a small effect on the overall neutronic behavior of the system, and therefore there is a high degree of applicability between pure Pu design applications and the lower assay MOX benchmarks. However, the staff noted that for AOA(4), 100wt% Pu benchmarks were used to validate systems with much more uranium than in DCS' studies (i.e., a Pu content between 6.3 and 22wt%). DCS stated that the pure Pu benchmarks would not be applicable to 6.3wt% Pu systems, but performed similar sensitivity calculations to those above for 22wt% Pu systems. These calculations were not ready for staff review during the in-office review. During these discussions, the staff stated that the importance of the ^{238}U in the system neutronics could be expected to grow as the Pu-assay decreased, and that at some point the Pu-content of the MOX would likely be too low to be useful for validating pure Pu applications. The staff stated that it would need to perform independent calculations to confirm the DCS conclusions. The staff further stated that this type of analysis could be useful in justifying inclusion of other benchmarks.

Comparison of ^{239}Pu Fission Spectra

As part of addressing the Pu assay issue, DCS also presented information related to justifying the inclusion of benchmarks on the basis of a comparison of the ^{239}Pu fission spectra. The staff reviewed this information, which led to the conclusions that: (1) the ^{239}Pu fission reaction is dominant over all other important nuclide-reaction pairs in the system; and (2) the ^{239}Pu fission spectrum is more sensitive to changes in system parameters than the absorption of leakage spectrum.

As part of the justification that ^{239}Pu fission dominates other reactions in the region of interest, DCS provided the following information (contained in the attachment):

1. A comparison of the ^{239}Pu total and fission cross sections across the entire energy range

2. A calculation of k_{inf} as a function of energy of average lethargy causing fission (EALF) for MOX-water systems with various Pu assays, to show that 22wt% Pu systems are more similar to pure Pu systems than they are to 6.3wt% Pu systems.

3. The aforementioned sensitivity studies on removal of ^{238}U from 29.3wt% Pu systems.

As part of the justification that the fission spectrum is more sensitive to changes in the system parameters than absorption or leakage, DCS provided the following information (contained in the attachment):

1. A calculation of k_{inf} as a function of EALF for a fully-reflected 3013 container filled with a PuO_2-water mixture at different moderation levels.

2. A comparison of the fission, absorption, and leakage spectra for the filled 3013 container, for 58 MOX-water benchmarks at 8.1 and 29.3wt% Pu-content, and for infinite UO_2 and MOX-water systems at 6.3, 22, and 100wt% Pu-content.

3. A three-dimensional graph of the variation in the fission, absorption, and leakage spectra as a function of EALF for the 3013 container.

4. A three-dimensional graph of the variation in the fission, absorption, and leakage spectra as a function of experiment number for the 58 MOX-water benchmarks.

5. Physics-based arguments as to why the absorption and leakage spectra are less sensitive to changes in neutron energy than the fission spectra.

In addition, in the Validation Report, the homogenizer/pelletizer design application was used for some of the spectral comparisons. The staff therefore reviewed the following document as part of this issue:

- “Criticality Safety of the Final Mix Homogenization and Pelletizing Station Units NPE and NPF”, DCS01-NPE-CG-CAL-H-03165-C.

The staff reviewed all the information described above and stated that it would need to perform some additional analysis to confirm DCS’s results.

Questions in November 7, 2003, Letter

The staff also reviewed material that DCS had assembled to address the 18 questions in the November 7, 2003, letter. Questions 1-9 were not intended to be addressed during this in-house review.   However, the staff stated that most of these questions would be addressed by better describing DCS' process for benchmark selection; the basic issue with this process was the basis for DCS' screening criteria and its justification for benchmarks falling outside them. The staff stated that a detailed description of DCS' process and how it fits with the process described in NUREG/CR-6698 (or other established procedures) is needed. The materials reviewed did not contain a detailed "flowchart" or stepwise procedure as discussed in the November 13, 2003, meeting. The staff pointed this out to DCS. It was also apparent from discussions that parts of DCS' process described in its validation report were not actually used in the final analysis. The staff stated that if parts of its process did not affect the final results, it would be sufficient for DCS to show that this was the case rather than answering the staff's questions in detail. The staff further stated that there were two alternative means of addressing the open item: (1) fully justifying DCS's process for benchmark selection (discussing any deviations from the criteria); or (2) justifying individual benchmarks technically on a case-by-case-basis.

Questions 1-7 and 12 were not addressed during the in-office review except to review the responses. The remaining questions appeared to be addressed in whole or in part by the information presented, as summarized below:

Questions 8 and 9: Largely addressed by the sensitivity studies on removal of ^{238}U from MOX (for 29.3wt% Pu-content MOX only). However, the lack of a screening criterion on Pu-content needs to be addressed and the results extended to 22wt% Pu-content MOX for AOA(4).

Questions 10, 11, and 13: Addressed fully by the information provided.

Questions 14 and 15: DCS stated that the ^{239}Pu fission spectrum was not the only factor considered in accepting benchmarks falling outside the screening criteria. The staff stated that it was not apparent from Validation Report, Part II, Rev. 3 (Sections 5.1 and 5.2) what other factors were used to justify particular benchmarks. Staff further stated that the degree to which these questions needed to be answered depended on how much weight was given to the ^{239}Pu fission spectrum versus other factors. DCS questioned how the justification for the individual benchmarks should be documented, and the staff stated that it should address how they meet the screening criteria, where they deviate from the screening criteria, and why they should be included despite those deviations. Qualitative arguments are acceptable if the justification is self-evident; otherwise, quantitative arguments and analysis may be needed.

Question 16: The major concern was addressed by resolving the INFHOMMEDIUM vs. LATTICECELL issue, but it is still necessary to state what other code options (including such data-based options as albedos and biasing) were used in benchmark calculations and are therefore considered validated.

Questions 17 and 18: The portion pertaining to the INFHOMMEDIUM vs. LATTICECELL issue was addressed, but the acceptability of the specific benchmarks in the question still needs to be demonstrated.

The status of these questions was discussed during the exit briefing on December 19, 2003. The material in the attachment was provided to the staff and may be referenced in DCS' responses.

Exit Briefing

The findings in this report were presented during the exit briefing on December 19, 2003. DCS stated that it understood the NRC position and that it understood the questions in the November 7, 2003, letter.

Partial List of Attendees

DCS
Tom Doering, Licensing
Ken Ashe, Licensing
Peter Hastings, Licensing and Safety Assessment
Charles Henkel, Criticality Safety
Jim Thornton, Nuclear Safety
Tommy Touchstone
Phil Hammond, Licensing
Bill Peters, Criticality Safety
Bob Foster, Criticality Safety

DOE
Mosi Dayani, DOE/NA-261

NRC
Christopher Tripp, NMSS/FCSS/SPIB

VALIDATION INFORMATION
PROVIDED DURING IN-OFFICE REVIEW
DECEMBER 17-19, 2003