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STONE & WEBSTER

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Subject: Docket Number 070-03098
Duke Cogema Stone & Webster
Mixed Oxide (MOX) Fuel Fabrication Facility
Response to 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. Enclosure 1 of this letter provides a response to close open item NCS-04.

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

Sincerely,

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NMSS01

Enclosure: Response to DSER Open Item on Nuclear Criticality Safety

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Enclosure 1
Response to DSER Open Item On Nuclear Criticality Safety

Open Item NCS-4

Determination of design basis USLs for each process type, and determination of normal condition subcritical margin. Clarification of DCS' commitment to the preferred use of dual parameter control. (DSER Section 6.1.3.4.2 and 6.1.3.5.1) (NCS-4)

As a result of the 20 March 2003 meeting between DCS and NRC the above question was clarified with the identification of four sub-questions [4(a), 4(b), 4(c), and 4(d)]. The questions and responses follow.

Question-4(a):

The three validation reports show a comparison of the key parameters in the design applications and selected benchmarks (e.g., Table 5-2 in Part 1). NRC notes that there are gaps in some of the graphs in some of the reports. Correspondingly, there are clusters of experiments which have different minimum keff (e.g., Figure 6-6 in Part 2) which could infer that the minimum keff was not applicable over the entire range in some reports. There are also differences in some of the parameters (e.g., reflectors, etc). It appears that, in some cases, the design applications represent an extrapolation from the parameters in the benchmarks. Please justify that the validation results cover the ranges of parameters referred to in the validation reports.

Response:

Two methods are used to identify applicable experiments for validating areas of applicability. The first approach involves selecting experiments based on a comparison of key physical parameters characterizing the system, such as H/Pu ratio, energy of average lethargy causing fission (EALF), physical form, etc. For AOA(3) PuO_2 powders and AOA(4) MOX powders, this traditional method failed to identify a sufficient number of experiments, and the sensitivity and uncertainty (S/U) methodology (i.e., the second approach) has been employed to identify experiments.

In the case in which traditional comparison of key parameters is made, the resulting validated area of applicability is defined by the ranges of key parameters in the resulting experimental benchmark set. Since the experiments identified by the S/U technique can have widely varying values of key physical parameters, a more restrictive definition of the AOA is employed. The AOA for a validation study which employs the S/U technique is defined by the ranges of key physical parameters of the typical design applications used as input to the S/U technique.

Generally, the resulting areas of applicability contain the corresponding key parameters of the anticipated design applications for which the code system will be used to determine reactivity. In some cases, parameter values for design applications may fall outside the validated area of applicability. In these cases, DCS commits to identifying additional margin, referred to as AOA margin, in the associated calculations or NCSEs, consistent with the approach described in NUREG-6698. The required margin is typically quantified by extrapolating observed trends in the bias as a function of the parameter.

Action:

1. Revise the validation reports to clarify that the area of applicability is defined by the characteristics of the benchmark experiments (for traditional analyses) or the input design applications (for S/U analyses).
2. Revise the validation reports to specify the actions to be taken if the characteristics of the design application are outside the area of applicability.

QNCS-4(b):

Regarding the Pu Oxalate calculations in Part III,

- **i. Confirm that the characteristics shown in abnormal calculations (Table 4-2) which show that minimum H/Pu is 30, are correct.**
- **ii. If so, confirm that the characteristics shown in normal calculations (Table 4-1) which show that minimum H/Pu is less than 30, are not relevant.**
- **iii. Revise argument to show that the therefore narrowed AOA is appropriate.**

Response:

The relevant calculations involving Pu oxalate as shown in Tables 4-1 and 4-2 have been reviewed. These calculations show that, for the limiting cases, the minimum H/Pu is 30.

Further, as shown in Table 4-1, for Pu Oxalate, the expected H/Pu is actually at a generally much higher value (e.g., evaporators KCD EV 3000 and 5000 and tanks KCD TK1000/1500/2000). (Note that, the normal fissile material in many of the components listed in Table 4-1 is NOT Pu oxalate, but rather some other material such as Pu nitrate and PuO_2. These materials are not the subject of Part III but are the subject of other parts of the validation report.)

Only in the case of the filter KCA FLT 7000 and precipitators KCA PREC5000 & 6000 is the H/Pu listed as less than 30 for the normal conditions evaluation. In those cases, the lower H/Pu is much less reactive than the abnormal conditions values which are evaluated for H/Pu higher than 30 and thus the behavior of the uncertainty is not relevant. Therefore, limiting the characteristics of AOA(5) to areas greater than 30 is appropriate.

Under these conditions, Pu Oxalate as shown in Figures 4-12 and 4-13 is of similar reactivity as the validated Pu nitrate and validated PuO_2 powder (falls between them), and is clearly bounded (by over 2% at H/Pu=30) by PuO_2F_2 which is used for the calculations. Thus, the use of PuO_2F_2 (rather than Pu oxalate) represents additional calculational margin and is also validated in this region. Therefore, for PuO_2F_2, a lower limit for the bounding, abnormal cases of H/Pu=30 is appropriate.

Action:

Revise part III of the validation report to include the above justification, as appropriate, in Section 4.4.

QNCS-4(c):

In the validation report part I for AOA(1), it is noted that some cases involve reflectors containing boron (discussed in Attachment 5) and cadmium (discussed in Attachment 6).

- **i. While the approach may be sufficient for boron, provide an improved justification to show that it is appropriate to AOA(1).**
- **ii. Further, it is noted that the justification for the applicability of the validation for cadmium (discussed in Attachment 6) depends on only four cadmium benchmark experiments. Provide an improved justification that the validation report results are appropriate for situations involving cadmium reflectors.**

Response:

Boron in reflectors. As noted in the validation report Part I for AOA(1) involving plutonium nitrate solutions, borated concrete is used in reflector regions of several MFFF plutonium nitrate aqueous solution design applications. However, the validation presented in the body of the report included no benchmark experiment data or results for plutonium nitrate solution systems that include borated concrete neutron absorber materials. Attachment 5 of validation report Part I presented benchmark experiment data and validation results for high enrichment uranium nitrate aqueous solution systems that include borated concrete supplemental absorber materials. The validation results presented for high enrichment uranium nitrate solution systems indicated that the CSAS26 criticality analysis sequence and the 238GROUPNDF5 cross-section library produce comparable results for systems with and without borated concrete neutron absorber materials present. This conclusion supported the use of the USL-1 for AOA-1 presented in Section 6.1 of the validation report as an acceptance criterion for plutonium nitrate aqueous solution systems that include borated concrete supplemental neutron absorber materials.

This justification was based upon the following:

The impact of comparable quantities of boron in the reflectors of experiments with uranyl nitrate produced no significant difference in bias results for systems that include borated concrete neutron absorbers as compared to systems that do not (Table 6 in attachment 5 of validation report Part I). The absorption neutron spectra in the borated concrete for both the uranyl nitrate benchmark experiments and similar calculations using plutonium nitrate were almost identical indicating the effect of the borated concrete was very similar for both uranyl and plutonium nitrates (Figure 1 in attachment 5 of validation report Part I).

As the content of the boron in the reflector of the benchmark experiments was varied from its experimental value to zero, a trending analysis of the results did not indicate any strong trends.

These three observations described more fully in Attachment 5, Part I of the validation report, support the conclusion that there is no significant impact on the validation report biases and uncertainties with the presence of boron in the concrete reflector of MFFF plutonium nitrate solutions and the results are therefore valid for these conditions.

Cadmium in reflectors. While it is true that the justification of the negligible impact of cadmium reflectors on the applicability of the AOA(1) results was based upon only four experiments containing cadmium, DCS has performed additional work involving larger numbers of experiments to support this conclusion.

For the further analysis, benchmark experiments were selected from the benchmark handbook which used cadmium absorbers in the reflector of plutonium nitrate experiments. The set of benchmark experiments used cadmium sheets in thicknesses comparable to that used in MFFF applications. Approximately half of the experiments involved cadmium and half of the experiments did not. A comparison between the results of the benchmark calculations which involved cadmium showed no increase in bias over those with no cadmium. Therefore, this supports the case that the influence of cadmium, as used in the MFFF, has no significant impact on the validation report conclusions.

Action:

Add the explanation as above (Boron reflector discussion), as appropriate, to the main body of the validation report, Part I at the end of Section 6.1.3.

Add the explanation as above (Cadmium reflector discussion), as appropriate, to the main body of the validation report, Part I at the end of the first paragraph in Section 6.1.3.

Revise Appendix 6 of validation report Part I to include the information on additional experiments with cadmium.

Enclosure 1
Response to DSER Open Item On Nuclear Criticality Safety

QNCS-4(d):

Revised CAR Section 6.3.4.2 provides information on specific safety principles to be used in the MFFF. Included in this section is a summary which includes the following "(d) the preferred use of two-parameter control over single parameter control." Please provide additional information regarding DCS commitment to the preferred use of dual parameter control.

Response:

The commitment to the preference to dual parameter control was in response to RAI-80. That response was as follows:

The preference for two-parameter control over one-parameter control is consistent with the safety principles stated in CAR Section 6.3.4.2. Two-parameter control inherently incorporates diverse forms of control, which generally result in higher levels of control reliability than single-parameter control. However, such a criticality control scheme incorporating the preferred MFFF hierarchy of criticality controls is not feasible for a MFFF. Therefore, the MFFF design preference is to rely on passive geometry control as the preferred criticality safety control, followed by reliance on dual independent controls on control parameters.

The purpose of Tables 6-1 and 6-2 is to show the criticality control methods for the main criticality control units in the MFFF. In all cases of parameters indicated as used for criticality control in the MFFF ("YES" in the tables), the design of the MFFF is such that no single credible failure will result in a criticality. As shown in Tables 6-1 and 6-2, criticality control in many locations in the MFFF is by the preferred passive geometry control that is implemented by design. In other cases, such as shown in Table 6-2 in the powder area, geometry control is not practical due to the changing geometry that results from the process. That is, there exists a variety of hoppers, scales, conveyors, mixers, and locations of material containers each with a varying geometry. In those cases, both mass and moderation is each controlled such that no single failure will result in a criticality. However, it is obviously important to control both of these parameters.

Further clarification defining favored criticality safety design approach commitments will be added to the end of CAR Section 6.3.4.2. The clarification will indicate that specific safety principles incorporated during the development of the MFFF design in order to enhance the inherent reliability of criticality controls are summarized as follows: (a) the preferred use of passive engineered features over active engineered features, (b) the preferred use of engineered features over administrative controls, (c) the preferred use of enhanced administrative controls over simple administrative controls, and (d) the preferred use of two-parameter control over single parameter control.

When the CAR section was revised, discussion from the third paragraph of the response was included.

As stated in the first paragraph of the RAI 80 response above, dual-parameter control is not feasible for the MFFF (i.e., owing to assumed Pu-239 content). Therefore, the MFFF design preference is to rely on passive geometry control as the preferred criticality safety control, followed by reliance on dual independent controls on control parameters. That is (as noted above), for many areas in which passive geometry control is not feasible, the MFFF will employ active engineered controls; it is necessary in these cases to control both mass and moderation independently. In all such cases, events that challenge either of these parameters will be shown to be highly unlikely to result in a potential criticality.

The use of dual parameter control has no impact compared to single parameter control when determining that an event is highly unlikely. In both cases it must be demonstrated that criticality safety controls (IROFS) are sufficiently reliable and independent to prevent criticality.

While DCS to date has not identified a situation where dual-parameter control is feasible, DCS acknowledges the NRC Staff's preference to maintain the option in the preferred hierarchy of criticality controls (e.g., for consideration in possible future changes).

Action:

Revise the last paragraph of CAR Section 6.3.4.2 (10/31/02) as follows:

Specific safety principles incorporated during the development of the MFFF design in order to enhance the inherent reliability of criticality controls are summarized as follows: (a) the preferred use of passive engineered features over active engineered features, (b) the preferred use of engineered features over administrative controls, (c) the preferred use of enhanced administrative controls over simple administrative controls, and (d) where practical, the use of two parameter control over single parameter control[1]. ~~, and (d) the preferred use of two-parameter control over single parameter control~~

[1] Two-parameter control inherently incorporates diverse forms of control, which generally result in higher levels of control reliability than single-parameter control. However, such a criticality control scheme incorporating the preferred MFFF hierarchy of criticality controls typically is not feasible for the MFFF owing to assumed Pu-239 content. Therefore, the MFFF design preference is to rely on passive geometry control as the preferred criticality safety control, followed by reliance on dual independent controls on control parameters. The preference for use of two-parameter control is maintained in the hierarchy of preferred controls for consideration in the event of changes in design where two-parameter control could be feasible.