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U.S. Nuclear Regulatory Commission
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Subject: Submittal of Intermediate Milestone—CNWRA Comments on DOE's Methodology for Determining Spent Nuclear Fuel Criticality Consequences and Risk, IM 01402.571.260

Dear Ms. Bloomer:

Enclosed is the subject report which documents CNWRA comments on criticality consequences and risk. This report provides input to criticality consequences and risk section of the DOE report based on the guidance provided by M. Rahimi. Accordingly, the title of the report has been changed to accurately reflect the contents of this milestone. This report provides a review of the DOE criticality consequences and risk methodology, and identifies several deficiencies and limitations in the DOE methodology such as a potential use of the one-dimensional RELAP computer code (developed for reactor cores) for transient criticality analysis, a validation of the thermal-hydraulic-neutronic code proposed for analyzing possible external criticality events, and source term changes due to the external criticality event. These comments may require update depending upon the review of the additional information that DOE plans to provide to NRC based on the discussions at the Appendix 7 meeting on July 9–10, 2002. New information is expected from DOE by October 31, 2002.

If you have any questions regarding this report, please feel free to contact Oleg Povetko at (210) 522-5258.

Sincerely yours,

Vijay Jain
Element Manager
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VJ:jg
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CNWRA COMMENTS ON DOE'S METHODOLOGY FOR DETERMINING SPENT NUCLEAR FUEL CRITICALITY CONSEQUENCES AND RISK

Prepared for

U.S. Nuclear Regulatory Commission
Contract NRC–02–97–009

Prepared by

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San Antonio, Texas

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CONTENTS

1 CNWRA COMMENTS ON REVISION 1 OF THE DISPOSAL CRITICALITY ANALYSIS METHODOLOGY TOPICAL REPORT

In November 2000, the U.S. Department of Energy (DOE) submitted Revision 1 of a topical report on a methodology that will be used in a License Application to demonstrate a potential for, and consequences of, the materials within or outside the potential repository at Yucca Mountain achieving critical configurations (DOE, 2000). The submission was intended to address the open items in the U.S. Nuclear Regulatory Commission (NRC) safety evaluation report for disposal criticality analysis and request the NRC acceptance of additional portions of the methodology. At the Appendix 7 Meeting held July 9–10, 2002, the DOE informed NRC that it had revised its overall methodology presented in the report and will submit the revisions in September 2002. The major change in the DOE approach is that if the total probability of all critical configurations for all the wasteforms and all waste packages is below the regulatory probability criterion [i.e., 10 CFR 63.114(d)], no consequence analyses for any criticality events will be performed. The DOE previous approach depicted in Revision 1 of the topical report included performing consequence analyses for critical configurations irrespective of probability. This report documents the results of the Center for Nuclear Waste Regulatory Analyses review of those sections of Revision 1 of the topical report that present the proposed methodology for estimating consequences and risk of criticality event
(Sections 3.7, 3.8).

1.1 Section 3.7

Describe how a nonconservative bias identified during the criticality consequence validation process will be included into the consequence calculations.

The consequence calculations in Section 3.7 of the topical report are proposed to be validated with experimental data. Comparisons with experimental data may lead to a conclusion that the model yields a nonconservative prediction of the actual consequences of a criticality event. It is not clear how the nonconservative bias identified during the validation process will be included in the consequence calculations.

1.2 Section 3.7.2.1

Clarify that incremental increase in the radionuclide inventory accessible for transport to the external environment as a principal consequence of the criticality event will include potential change in the source term (additional radionuclides available for transport including those with short half-lives) for use by the total system performance assessment model and in the receptor dose calculations.

In the example of steady-state criticality consequences, referenced in the topical report (CRWMS M&O, 1996), only 36 isotopes are considered in calculations, and in another example (CRWMS M&O, 1999a), 61 isotopes are considered. It is not clear if the change in source term because of criticality will be considered by the total system performance assessment model and in the receptor dose calculations.

1.3 Section 3.7.1

Explain how results for fuel aged for 15,000 years and results for criticality event consequences presented for a time of 25,000 years after disposal correspond to the consequences of the criticality event during the repository compliance period of 10,000 years.

In the referenced example of steady-state criticality consequences (CRWMS M&O, 1996), the assumption is made that the fuel has aged/decayed for 15,000 years prior to a criticality event, and results are presented for a 25,000-year time point. For Am-241, for instance, an activity increment of 20,000 percent of the precriticality amount was estimated at the end of a 16,000-year period because of a 1,000-year duration criticality event. It is not clear how these results correspond to the consequences of the criticality event during the repository compliance period of 10,000 years.

1.4 Section 3.7.1

Clarify how the source term for the total system performance assessment model (CRWMS M&O, 2000) will be changed because of the additional inventory (additional radionuclides not included in the total system performance assessment model) if a criticality event occurs in a saturated zone in proximity to the receptor.

Only a set of 18 radionuclides is considered now in the total system performance assessment model in the evaluation of postclosure performance (CRWMS M&O, 2000). For a criticality event in the saturated zone in proximity of water wells, short-lived fission products that transport rapidly to the location of the receptor could be formed before they decay to stable nuclides, which could lead to larger doses than the doses from the long-lived radionuclides considered significant for nominal conditions. In the referenced analysis of criticality consequences for plutonium deposition in Yucca Mountain tuff fractures (CRWMS M&O, 1998) with the plutonium replacement not modeled, it was estimated that 603 Ci [2.23×10^{13} Bq] of total activity was generated caused by a 590 Watts criticality event. No breakdown by radionuclides of this inventory was provided. Provide breakup of this inventory by all generated radionuclides.

1.5 Section 3.7.1.1

Clarify why carbon is considered as a much less effective moderator than water.

The efficiency of a substance in slowing down neutrons without excessive absorption is given by the moderating ratio, the ratio of the slowing-down power to the absorption cross section. This value is higher for carbon than it is for water, 216 versus 62, according to Glasstone (1981). For large systems, moderators with a high moderating ratio are preferred.

1.6 Section 3.7.1.2

Provide clarification that the radiolytic creation of nitric acid assessed in Bechtel SAIC Company, LLC (2001) is considered a potential consequence of an internal criticality event.

Chemical species produced by radiolysis accelerate corrosion of the repository engineered barrier subsystem. Scoping calculation results documented in Bechtel SAIC Company, LLC (2001) estimated that approximately 4.7 kg [10.36 lb] per waste package of nitric acid could possibly be produced during 10,000 years of a one-kilowatt average static criticality event. This calculation means that radiolytic contributions to enhanced corrosion rates from criticality events should be given due consideration.

1.7 Section 3.7.2

Provide reactivity insertion rates quantitatively that distinguish two regimes of the energy release discussed in this section and clarify what mechanisms would prevent high power pulse from recurring.

Two regimes of the energy release are discussed: high power pulse with short duration and cumulative buildup of radionuclide increments for a periodic pulsing. It is not clear what the principal difference is between these two regimes and why high power pulse with short duration cannot recur over and over again, which would lead to the "cumulative buildup of radionuclide increments."

1.8 Section 3.7.3.2

Justify the potential application of RELAP5/MOD3 or a similar code with similar or equivalent characteristics to two-dimensional flows perpendicular to fuel bundles, to systems with potential spatial variations in feedback parameters, to systems with highly enriched fuel, to systems where water is not the principal moderator, and to the wider range of neutron kinetics than in light-water reactor systems.

It is understood that no acceptance is sought for the particular code used for criticality consequence evaluations for transient criticality internal to waste package. It is stated that the code of choice "will have similar or equivalent characteristics" to the RELAP5/MOD3 code. Examples presented in CRWMS M&O (1999a,b, 1997) for illustration of the transient criticality consequence analyses use the RELAP5/MOD3 code in their analyses. This code was developed for NRC for simulations of transient phenomena in pressurized water reactor systems, such as loss of coolant, and is intended for light-water reactor applications. The RELAP5/MOD3 code was designed for analyses of one-dimensional flows parallel to fuel bundles. The code contains a limited ability to model multidimensional effects. Certain nonlinear or multidimensional effects caused by spatial variations of the feedback parameters cannot be accounted for with such a (point reactor kinetics) model (Idaho National Engineering and Environmental Laboratory, 1995). The validation of the chosen transient criticality code will be complicated because there are no direct natural analogs or experiments with exactly the geometry and parameter ranges expected for repository configurations for either the internal or external hypothetical transient events.

1.9 Section 3.7.3.2

Provide clarification for how the thermal-hydraulic-neutronic code will be validated to ensure effects of a criticality event on the rock-mechanical properties are calculated properly.

The thermal-hydraulic-neutronic computer code, based on a referenced computational framework (Gratton, et al., 1997) and proposed for analyzing possible external criticality events, accounts for time varying rock mechanical properties, mechanical-strain rates, dilation, melting, and mixing of the deposit region constituents caused by the criticality event and couples them to reactivity feedback mechanisms.

1.10 Section 3.8.2

Clarify if radionuclides in colloidal form will be considered in the total system performance assessment model for criticality consequence calculations.

It is indicated in the report that the EQ3/6 code is used to evaluate geochemical models of the criticality produced inventories. According to assumption 5.9 in DOE (2001), precipitated solids are deposited in the waste package, remain in place, and are not mechanically eroded or entrained as colloids in the advected water. The EQ3/6 code calculations yield the values for dissolved concentrations of radionuclides and do not consider suspension of colloids in the solution. As stated in Section 3.7.3.2 of the topical report, analyses of the direct consequences of transient criticalities external to the waste package are conducted using a code based on a computational framework developed in Gatton, et al. (1997). A material inventory in that study was adopted from work performed by Kastenberg (1996) and other studies. Kastenberg (1996) indicates that because of the propensity of plutonium to form colloidal particles or to be sorbed onto other formed colloids, the apparent solubility can approach one parts per million versus one parts per billion for the true solute. The study concludes that plutonium is most likely to be transported as colloids.

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