	Scientific Analysis/Calculation Error Resolution Document *Complete only applicable items.*	QA: QA Page 1 of 5

1. Document Number:	2. Revision/Addendum:	3. ERD:
ANL-DS0-NU-000001	00	06

4. Title:	5. No. of Pages Attached:
Screening Analysis of Criticality Features, Events, and Processes for License Application	4

6. Description of and Justification for Change (Identify affected pages, applicable CRs and TBVs):

Introduction:

This document is being written as an action to resolve the following CRs:

CR-14019: Incorrect plutonium accumulation

CR-14169: Wrong submittal date for output DTN in ANL-DS0-NU-000001 ERD 05

Background Information Summary:

Actions to resolve CR-14019 resulted in a change to the direct inputs to ANL-DS0-NU-000001 REV 00 – Tables 4.1-9 and 4.1-10. Subsequent to ANL-DS0-NU-000001 REV 00 ERD 05 being issued it was noticed that the output DTN (i.e., DTN: MO0705CRITPROB.000) did not have the submittal date updated to reflect the latest revision of the output DTN on the replacement page promulgating the issuance of CR-14169. While incorporating this change in this ERD it was also noticed that the page number shows page 8-9 but should be 8-11. This is being updated in this ERD. This ERD will incorporate the changes to Tables 4.1-9 and 4.1-10 as a result of source document changes, update the applicable source information, and correct the DTN submittal date information. This ERD is written using page changes with changed lines identified with change bars. All prior ERD (ERD01 through ERD05) and ACN (ACN 01) changes have been incorporated into the pages changed due to this ERD and are also identified by change bars.

AMR Changes:

Please see attached for changed pages. Changed pages of ANL-DS0-NU-000001 REV 00 are as follows: 4-15; 4-16; 8-9; and 8-11. DIRS reference 179645 was changed to 186580.

Impact Evaluations/Results:

The following documents were evaluated for impact: : LA-SAR, ANL-EBS-PA-000014 Rev. 00, ANL-EBS-MD-000076 Rev. 00 ACN 01, ANL-WIS-MD-000024 Rev. 01 ACN 01, ANL-WIS-MD-000026 Rev. 00, and ANL-WIS-MD-000027 Rev. 00 ACN 01.

No documents are impacted by these changes.

The changes in this ERD do not impact the conclusion of ANL-DS0-NU-000001 REV 00 nor any other affected document as the input parameter changes are not used in any calculation, and only used for comparitive reference purposes.

	Printed Name	Signature	Date
7. Checker	Susan LeStrange	Susan LeStrange	3/10/2010
8. QCS/QA Reviewer	Brian Mitcheltree	Brian Mitcheltree	3/10/10
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10. Responsible Manager	Jerry McNeish	Jerry A McNeish	3.10.10

engineering barrier failure event scenario. The fissile mass accumulations in the invert or host rock for the igneous and seismic scenarios inTable 4.1-9 were obtained from DTNs: MO0609SPAINOUT.002 [DIRS 186580], file: *Dissolved U and Pu acc total with sensitivities.xls*, and MO0705PHREEMOD.000 [DIRS 183622], file: *Mass Accumulated.xls*.

Table 4.1-9. Fissile Mass Accumulation in Invert or Host Rock

Waste Form	Plutonium Accumulation (kg)	Total Uranium Accumulation (kg)	^{235}U Accumulation (kg)
Nominal (Early Failure) Scenario [a]			
Commercial SNF	1.49×10^{-7}	2.68×10^{0}	3.98×10^{-2}
DOE3 (N Reactor)	NA	3.32×10^{2}	5.32×10^{0}
DOE1 (FFTF)	3.57×10^{-4}	1.03×10^{1}	8.31×10^{-2}
DOE9 (TMI II)	NA	1.76×10^{1}	4.92×10^{-1}
Seismic Scenario			
DOE1 (FFTF) [b]	8.63×10^{-4}	6.50×10^{1}	2.74×10^{-1}
Igneous Scenario			
Commercial SNF [b]	7.31×10^{-7}	7.48×10^{1}	9.72×10^{-1}
DOE3 (N Reactor) [c]	NA	1.09×10^{-1}	1.37×10^{-3}
DOE1 (FFTF) [c]	6.34×10^{-3}	1.09×10^{1}	5.85×10^{-1}
DOE9 (TMI II) [c]	NA	9.24×10^{0}	2.50×10^{-1}

Sources: [a] DTN: MO0604SPANOMIN.000 [DIRS 182944], file: *CSNF Results.xls*, spreadsheet: "Table for Report," file: *DOE SNF Results.xls*, spreadsheet: "Table for Report."
[b] DTN: MO0705PHREEMOD.000 [DIRS 183622], file: *Mass Accumulated.xls*.
[c] DTN: MO0609SPAINOUT.002 [DIRS 186580], file: *Dissolved U and Pu acc total with sensitivities.xls*.

FFTF = Fast Flux Test Facility; NA = not available.

The minimum mass necessary for external criticality (based on a critical limit of 0.96) for all the cases evaluated is summarized in Table 4.1-10, which shows that the masses in the external environment necessary for criticality are higher, often much higher, than the predicted fissile mass accumulation that is also shown in Table 4.1-10. The largest percentage (71%) of a minimum critical mass accumulated in the invert or host rock was from commercial SNF for a seismic scenario. The minimum critical masses were calculated using optimal conditions for criticality that are improbable in the invert or host rock.

The DOE-owned SNF waste forms addressed in *Geochemistry Model Validation Report: External Accumulation Model* (SNL 2007 [DIRS 181395]) (i.e., N Reactor (DOE3), TMI-II (DOE9), and Fast Flux Test Facility (FFTF) (DOE1)) make up approximately 90% of the metric tons of heavy metal in the DOE-owned SNF inventory expected to be stored in the repository. Some of the other DOE-owned SNF with high enrichments, such as Shippingport light water breeder reactor (DOE5) and Ft. St. Vrain (DOE6), are also not expected to be a concern due to the corrosion resistance of the waste form (SNL 2007 [DIRS 181395], Section 6.9.3[a]).

Table 4.1-10. Summary of External Criticality Results - Minimum Mass for a Critical Limit of 0.96

Scenario	Waste Package Type	Calculated Accumulation or Mass Released from Waste Package	Mass of Uranium or Plutonium (for FFTF) Required to Achieve k_{eff} = 0.96			
		Uranium or Plutonium mass (kg)	Invert (kg)	Fractured Tuff (kg)	Lithophysae Array (kg)	Large Lithophysae (kg)
Seismic	N-Reactor	Not calc [a]	266,000	∞ [b]	Not calc	Not calc
	TMI-II Fuel	Not calc	350	∞	Not calc	Not calc
	Commercial SNF	90.3 [c]	126	∞	Not calc	Not calc
	FFTF (Plutonium mass)	0	1.66	4.3	Not calc	Not calc
Igneous	N Reactor	0.109	∞	∞	∞	∞
	TMI-II	9.24	538	∞	∞	∞
	Commercial SNF	74.8	159	∞	1390	∞
	FFTF (Plutonium mass)	2.49×10^{-2}	1.66	4.3	4.0	2.2

[a] "Not calc" means that this scenario was of little interest given that it was bounded by another scenario. In most cases, this simply meant that, if commercial SNF waste was very subcritical, then TMI-II and N Reactor had to be subcritical also.

[b] "∞" means that an infinite amount of fissile waste released in this model will not produce an arrangement that can reach a k_{eff} of 0.96.

[c] Maximum mass released from the waste package.

Source: The mass required to achieve k_{eff} = 0.96 is from DTN: MO0705SCALEGEO.000 [DIRS 183634], files: *DOEF.xls*, "SJN_All" and "UBN_All;" file: *FFTF.xls*; "PBL," "PBN," "PJF," "PBV;" file: *CSNF.xls*, "BBN5," "UBL5." Table values were abstracted from (SNL 2007 [DIRS 181395], Table 6.9-1 [a]).

Fort St. Vrain SNF (DOE6) SNF fuel particles have an integral silicon carbide (SiC) protective layer that not only retains the fission products but also protects the uranium and thorium dicarbide (ThC_2) from oxidation and hydrolysis (DOE 2003 [DIRS 166027], p. 48). Comparative analyses have indicated that the Fort St. Vrain fuel has the lowest degradation rate of all DOE-owned SNF and should behave significantly better in terms of fissile material dissolution, transport, and accumulation. Graphite moderated reactors such as Fort St. Vrain are considered as "converter" reactors where fissile isotopes are produced (^{233}U for this system) as the ^{235}U is consumed (Radulescu et al. 2004 [DIRS 165482], Section 3.2.8.2). A canister loaded with five Fort St. Vrain blocks contains sufficient quantities of ^{233}U to have criticality potential in solution; however, a mechanism to separate the uranium from within the SiC coated fertile particles, and then a mechanism to accumulate it in a concentrated fissile mass in a favorable geometry is not credible.

A number of studies have indicated both air and water oxidation of uranium and thorium oxide fuel pellets [(Th, U)O_2] such as used in the Shippingport light water breeder reactor fuel (DOE5 proceeds more slowly than for pure uranium oxide (UO_2), and decreases with decreasing UO_2 content in the (Th, U)O_2 (DOE 2003 [DIRS 166027], p. 33). Tests have shown that the thorium oxide pellets in the Shippingport light water breeder reactor fuel have an excellent resistance to

176331 Regulatory Guide 3.71, Rev. 1. 2005. *Nuclear Criticality Safety Standards for Fuels and Material Facilities.* Washington, D.C.: U.S. Nuclear Regulatory Commission. ACC: MOL.20060206.0325.

178058 ASTM A 887-89 (Reapproved 2004). 2004. *Standard Specification for Borated Stainless Steel Plate, Sheet, and Strip for Nuclear Application.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 258746.

178394 70 FR 53313. Implementation of a Dose Standard After 10,000 Years. Internet Accessible.

180319 10 CFR 63. 2007. Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada. Internet Accessible.

184076 40 CFR 197. 2006. Protection of Environment: Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada. Internet Accessible.

LS-PRO-0203. *Q-List and Classification of Structures, Systems, Components and Barriers.*

SCI-PRO-001. *Qualification of Unqualified Data*.

SCI-PRO-005. *Scientific Analyses and Calculations*.

SCI-PRO-004. *Managing Technical Product Inputs*.

IM-PRO-002. *Control of the Electronic Management of Information*.

IM-PRO-003. *Software Management*.

8.3 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

164713 LA0307BY831811.001. Characterize Igneous Framework Additional Output. Submittal date: 07/29/2003.

172059 MO0409SPAACRWP.000. Aqueous Corrosion Rates for Non-Waste Form Waste Package Materials. Submittal date: 09/16/2004.

172682 MO0501BPVELEMP.001. Bounded Horizontal Peak Ground Velocity Hazard at the Repository Waste Emplacement Level. Submittal date: 01/11/2005.

173280 LB0407AMRU0120.001. Supporting Calculations and Analysis for Seepage Abstraction and Summary of Abstraction Results. Submittal date: 07/29/2004.

186580 MO0609SPAINOUT.002. PHREEQC Modeling Inputs and Outputs for Geochemistry Model Validation Report: External Accumulation Model. Submittal date: 01/21/2010.

183006 MO0708FREQCALC.000. Seismic Frequency Calculation of Waste Package Containers. Submittal date: 08/10/2007.

183007 MO0708CDSPSEIS.000. CDSP Seismic Damage Calculation. Submittal date: 08/13/2007.

8.4 PRODUCT OUTPUT, LISTED BY DATA TRACKING NUMBER

MO0705CRITPROB.000. Probability of Criticality. Submittal date: 08/20/2009.

8.5 SOFTWARE CODES

160873 SAPHIRE V. 7.18. 2002. WINDOWS 2000/NT 4.0. STN: 10325-7.18-00.