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Criticality Evaluation of DOE SNF Codisposal Canister with Melt and Dilute MTR Fuel(u)

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1.0 Introduction

The objective of this analysis is to characterize a codisposal canister containing uranium-aluminum ingots. The composition of an ingot is expected to be consistent with the eutectic composition of the binary alloy (13.2 wt % uranium, 86.8 wt. % aluminum) with uranium-235 enrichment at 10 to 20%. This analysis evaluates the reactivity of critical safety scenarios for disposing aluminum based Department of Energy owned research reactor spent nuclear fuel (DOE-SNF). For this analysis the aluminum based highly enriched uranium has been melted and diluted with U-238 to reduce the U-235 enrichment to 10 to 20%. Criticality calculations were performed to determine the k_{eff} of various configurations.

2.0 Description

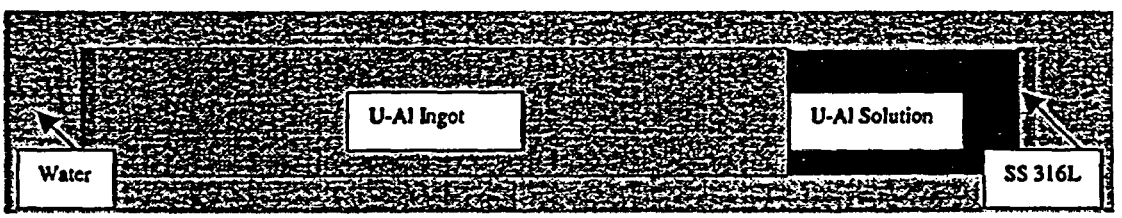
All design parameters and assumptions that are identified in this document are for the preliminary stage of the design process and are considered unqualified; all of these design parameters and assumptions will require subsequent confirmation (or superseding inputs) as the design proceeds. This document will not directly support any construction, fabrication, or procurement activity.

Table 2.0.1. Dimensions Used In Model

	Material	Inner Radius (cm)	Outer Radius (cm)	Inner Length (cm)	Outer Length (cm)
Codisposal Canister	SS 316L	21.75	22.5	254	262.8

The preliminary design for the codisposal canister is a stainless steel 316L, right circular cylinder. The dimensions of the canister are shown in Table 2.0.1. From Reference 4, the diluted uranium-aluminum ingot was assumed to nominally occupy 75% of the volume of the canister. In the criticality scenarios examined here, the remainder of the canister is assumed to be filled with water, and, as the ingot erodes, the material goes into solution. The density of the U-Al ingot is 3 g/cc.

Figure 2.0.1. Codisposal Container – X-Z View



3.0 Requirements Documentation

The requirements documentation applicable to this report is that standard documentation applicable to all site criticality safety evaluations, as outlined in Reference 7.

4.0 Methodology

4.1 Computer Codes

The SCALE system (Reference 8) operating on a DEC Alpha computer with the Unix operating system was used exclusively to calculate k_{eff} values in this study. The SCALE code was developed at ORNL for the NRC. The SCALE code was installed on the DEC Alpha computer using the supplied installation routines. Correct installation was verified by completion of the supplied sample problems. Differences between the observed sample problem outputs and the supplied outputs were restricted to differences in time and date stamps and other text header differences. The computer was password locked and no changes were made to the SCALE configuration during the period of this analysis.

Two SCALE drivers were employed in this analysis – CSAS25 and CSAS4. CSAS25 calls on the BONAMI-S and NITAWL-S modules for the calculation of flux-weighted macroscopic cross sections (accounting for resonance self shielding) and then calls the KENO Va. module to perform the Monte Carlo k_{eff} calculation. CSAS4 is identical to CSAS25, but automatically adjusts specified parameters to search for the maximum k_{eff}. The 27-group ENDF/B-IV cross section library was used for all calculations. The combination of the input parameters (number of generations, number of neutrons per generation, and number of generations skipped) for each of the SCALE calculations resulted in one sigma values of about 0.002.

4.2 Bias and Bias Uncertainty

Nuclear criticality codes use neutron cross section data libraries that are based on experimental data. Benchmark validation calculations must be performed to determine the computational bias associated with these codes and the cross section libraries. An allowance for calculational bias and experimental uncertainties in benchmark calculations must be included in the k_{eff} calculations for this study.

The validation methodology utilized to determine the bias and bias uncertainty in this study is reported in "Westinghouse Savannah River Company Nuclear Criticality Safety Methods Manual" (Reference 5). This methodology determines the value of bias and bias uncertainty for a particular area of applicability by statistically analyzing the benchmark calculated k_{eff} values for benchmark experiments (Reference 6).

The bias and bias uncertainty determined from an applicable set of experiments is 0.008. This value represents a value that bounds 95% of the applicable population with 95% confidence. Additionally, an area of applicability (AOA) margin of 0.01 will be included because the available population of experiments (Reference 6) did not completely bound the range of U-235 enrichments. The addition of this margin is conservative, as evaluation of critical experiments does not show any appreciable bias with regard to U-235 enrichment in solutions. The k_{eff} results in Table 5.2.2 have been adjusted by +0.018 (Code Bias) to account for code and cross section uncertainties. The k_{eff}s shown in Table 5.2.1 and Figures 5.2.1 – 5.2.3 are raw, unadjusted values.

4.3 General Approach

The goal of this study is to determine the k_{eff} of various degraded conditions of a DOE-SNF canister for the melt dilute option. The study considers a variety of initial quantities of the U-Al ingot in the canister. With the free volume of the canister filled with water, the reactivity effects of the U-Al material eroding and becoming suspended in the water are examined. The volume of the ingot material eroded is increased until a maximum k_{eff} value is found. This process is repeated for uranium enriched to 10, 15 and 20% U-235.

4.4 Assumptions

4.4.1 It is assumed that all fuel is fresh and unburned for criticality analyses; i.e., there is no credit for burnup or fission product poisoning. This assumption is conservative because fresh fuel is more neutronicaly reactive than spent fuel.

4.4.2 Some of the MTR fuels contain U-234. This was ignored per Reference 4. MTR fuel may contain 1% U-234. After diluting with U-238 this is reduced to a trace quantity. Additionally, U-234 is not a fissionable isotope; its presence or absence would have no significant effect on these calculations.

4.4.3 The waste package is assumed to be fully flooded with water for criticality calculations. The assumption is conservative and has been used as a scenario in previous analyses (References 2 & 3).

4.4.4 The density of the U-Al ingot is assumed to be 3 g/cc, from Reference 4.

5.0 Evaluation & Results

5.1 Modeling

The system modeled is extremely conservative with respect to actual possible configurations. The absence of fission products in the burned fuel with all void space filled with water is conservative. Additionally, the canister is assumed to be in a bath of water with at least 30 cm of water on all sides. This provides ideal neutron reflection.

Three U-235 enrichments were considered; 10, 15 and 20%. For each enrichment, the initial quantity of U-Al mixture was varied about the nominal value of 75% full. The quantity of material eroded from the U-Al ingot was increased to determine the maximum k_{eff}. Table 5.1.1 details the material composition of the U-Al solution. Dimensions and material weight percents are given for several amounts of ingot material erosion, for several initial amounts of ingot material. These weight percents are independent of U-235 enrichment.

For example, the first 6 cases in Table 5.1.1 are for the condition where the ingot initial fills 45% of the canister. The first case with the solution filling 55% of the canister is then the base case with no erosion of ingot material. For the second case the ingot material has been eroded from an initial length of 114.3 cm to 101.6 cm. The ingot material is placed in solution in the solution space, which now occupies 60% of the canister. The density of the solution has increased from the initial density of water to 1.165. The weight percentages of the materials follow.

Table 5.1.1. U-Al Solution Material and Configurations

% Vol. of Solution	Length of Solution Space	Length of Ingot Space	Solution Density (g/cc)	wt% H	wt% O	wt% Al	wt% U
Ingot Initially Fills 45%							
55	139.70	114.30	0.998	11.160	88.820	0.000	0.000
60	152.40	101.60	1.165	8.781	69.760	18.626	2.833
70	177.80	76.20	1.427	6.144	48.811	39.099	5.946
80	203.20	50.80	1.624	4.725	37.539	50.115	7.621
90	228.60	25.40	1.777	3.839	30.496	56.998	8.668
99	251.46	2.54	1.888	3.284	26.090	61.303	9.323
Ingot Initially Fills 50%							
55	139.70	114.30	1.180	8.596	68.295	20.059	3.050
60	152.40	101.60	1.332	6.983	55.475	32.587	4.956
70	177.80	76.20	1.570	5.077	40.333	47.384	7.206
80	203.20	50.80	1.749	3.988	31.685	55.836	8.491
90	228.60	25.40	1.888	3.284	26.090	61.303	9.323
99	251.46	2.54	1.989	2.834	22.513	64.799	9.854
Ingot Initially Fills 55%							
50	127.00	127.00	1.198	8.381	66.585	21.729	3.304
60	152.40	101.60	1.499	5.585	44.370	43.439	6.606
70	177.80	76.20	1.713	4.188	33.270	54.287	8.256
80	203.20	50.80	1.874	3.350	26.612	60.793	9.245
90	228.60	25.40	1.999	2.791	22.175	65.129	9.904
99	251.46	2.54	2.090	2.427	19.281	67.957	10.334
Ingot Initially Fills 60%							
45	114.30	139.70	1.221	8.127	64.565	23.704	3.605
50	127.00	127.00	1.399	6.384	50.715	37.238	5.663
60	152.40	101.60	1.665	4.467	35.490	52.118	7.926
70	177.80	76.20	1.856	3.436	27.295	60.126	9.144
80	203.20	50.80	1.999	2.791	22.175	65.129	9.904
90	228.60	25.40	2.110	2.350	18.672	68.552	10.425
Ingot Initially Fills 65%							
40	101.60	152.40	1.248	7.822	62.140	26.073	3.965
50	127.00	127.00	1.599	4.886	38.819	48.863	7.431
60	152.40	101.60	1.832	3.553	28.226	59.216	9.005
70	177.80	76.20	1.999	2.791	22.175	65.129	9.904
80	203.20	50.80	2.124	2.298	18.260	68.955	10.486
90	228.60	25.40	2.222	1.954	15.520	71.633	10.893
Ingot Initially Fills 70%							
35	88.90	165.10	1.284	7.449	59.178	28.968	4.405
40	101.60	152.40	1.499	5.585	44.370	43.439	6.606

% Vol. of Solution	Length of Solution Space	Length of Ingot Space	Solution Density (g/cc)	wt% H	wt% O	wt% Al	wt% U
50	127.00	127.00	1.799	3.722	29.571	57.901	8.805
60	152.40	101.60	1.999	2.791	22.175	65.129	9.904
70	177.80	76.20	2.142	2.233	17.738	69.465	10.564
80	203.20	50.80	2.249	1.861	14.781	72.355	11.003
Ingot Initially Fills 75%							
30	76.20	177.80	1.332	6.983	55.475	32.587	4.956
35	88.90	165.10	1.570	5.077	40.333	47.384	7.206
40	101.60	152.40	1.749	3.988	31.685	55.836	8.491
50	127.00	127.00	1.999	2.791	22.175	65.129	9.904
60	152.40	101.60	2.166	2.147	17.056	70.132	10.665
70	177.80	76.20	2.285	1.744	13.857	73.258	11.141
80	203.20	50.80	2.374	1.469	11.669	75.397	11.466
Ingot Initially Fills 80%							
25	63.50	190.50	1.399	6.384	50.715	37.238	5.663
30	76.20	177.80	1.665	4.467	35.490	52.118	7.926
40	101.60	152.40	1.999	2.791	22.175	65.129	9.904
50	127.00	127.00	2.199	2.030	16.125	71.041	10.804
60	152.40	101.60	2.333	1.595	12.669	74.419	11.317
70	177.80	76.20	2.428	1.313	10.433	76.604	11.650
80	203.20	50.80	2.500	1.116	8.868	78.134	11.882
Ingot Initially Fills 85%							
20	50.80	203.20	1.499	5.585	44.370	43.439	6.606
30	76.20	177.80	1.999	2.791	22.175	65.129	9.904
40	101.60	152.40	2.249	1.861	14.781	72.355	11.003
50	127.00	127.00	2.399	1.395	11.085	75.967	11.553
60	152.40	101.60	2.500	1.116	8.868	78.134	11.882
70	177.80	76.20	2.571	0.930	7.389	79.579	12.102
80	203.20	50.80	2.625	0.797	6.334	80.610	12.259
Ingot Initially Fills 90%							
15	38.10	215.90	1.665	4.467	35.490	52.118	7.926
20	50.80	203.20	1.999	2.791	22.175	65.129	9.904
30	76.20	177.80	2.333	1.595	12.669	74.419	11.317
35	88.90	165.10	2.428	1.313	10.433	76.604	11.650
40	101.60	152.40	2.500	1.116	8.868	78.134	11.882
50	127.00	127.00	2.600	0.859	6.821	80.134	12.186
80	203.20	50.80	2.750	0.507	4.030	82.861	12.601

5.2 Evaluation

The calculated k_{eff}s are listed in Table 5.2.1 and plotted in Figures 5.2.1 through 5.2.3. For each curve representing an initial volume of the U-Al ingot, the maximum k_{eff} occurs where the density of the solution is very nearly equal to 2. While the magnitude of the k_{eff} varies with the initial volume of material and the U-235 enrichment, the point of maximum k_{eff} is constantly at the point where the solution density is approximately 2. The configurations with 15% U-235 appeared to be the most useful in the melt dilute option design. Additional, configurations with this enrichment were examined.

Table 5.2.1. Codisposal Canister Calculations

U-235 Enrichment	Initial Quantity U-Al (% vol. Filled by Ingot)	Quantity of U-Al Solution (% vol. Filled by water-U-Al mixture)	Input File	Keff w/o bias	Sigma	Ave. Energy Group
20%	75	25	md_gr0_025	0.365	0.002	19.97
		26	md_gr0_026	0.396	0.003	21.13
		30	md_gr0_030	0.761	0.002	24.73
		35	md_gr0_035	0.932	0.003	24.65
		40	md_gr0_040	0.990	0.003	24.45
		43	md_gr0_043	0.996	0.003	24.34
		45	md_gr0_045	0.988	0.003	24.26
		47	md_gr0_047	0.996	0.003	24.19
		50	md_gr0_050	0.990	0.003	24.07
		55	md_gr0_055	0.978	0.004	23.90
		60	md_gr0_060	0.953	0.004	23.72
		70	md_gr0_070	0.916	0.004	23.38
		80	md_gr0_080	0.880	0.003	23.09
20%	85	16	md_gr1_016	0.446	0.002	22.61
		20	md_gr1_020	0.856	0.003	24.51
		25	md_gr1_025	0.949	0.003	24.28
		28	md_gr1_028	0.962	0.004	24.11
		30	md_gr1_030	0.963	0.003	23.99
		32	md_gr1_032	0.949	0.004	23.87
		40	md_gr1_040	0.909	0.004	23.42
		50	md_gr1_050	0.853	0.003	22.95
		60	md_gr1_060	0.795	0.004	22.49
		80	md_gr1_080	0.708	0.004	21.83
20%	87	14	md_gr3_014	0.474	0.002	23.08
		15	md_gr3_015	0.648	0.002	24.26
		20	md_gr3_020	0.918	0.002	24.33
		23	md_gr3_023	0.945	0.003	24.14
		25	md_gr3_025	0.944	0.003	24.00
		27	md_gr3_027	0.939	0.003	23.89

U-235 Enrichment	Initial Quantity U-Al (% vol. Filled by Ingot)	Quantity of U-Al Solution (% vol. Filled by water-U-Al mixture)	Input File	Keff w/o bias	Sigma	Ave. Energy Group
		30	md_gr3_030	0.928	0.003	23.69
		35	md_gr3_035	0.895	0.003	23.38
		50	md_gr3_050	0.800	0.004	22.59
		60	md_gr3_060	0.745	0.003	22.16
		80	md_gr3_080	0.668	0.003	21.48
20%	88	13	md_gr4_013	0.488	0.002	23.17
		15	md_gr4_015	0.770	0.002	24.41
		17	md_gr4_017	0.876	0.003	24.37
		20	md_gr4_020	0.929	0.003	24.19
		23	md_gr4_023	0.943	0.003	24.00
		25	md_gr4_025	0.929	0.002	23.86
		27	md_gr4_027	0.924	0.003	23.72
		30	md_gr4_030	0.906	0.003	23.52
		35	md_gr4_035	0.868	0.003	23.19
20%	90	11	md_gr2_011	0.518	0.002	23.25
		15	md_gr2_015	0.868	0.003	24.21
		18	md_gr2_018	0.910	0.004	24.02
		20	md_gr2_020	0.909	0.004	23.85
		21	md_gr2_021	0.905	0.004	23.78
		25	md_gr2_025	0.888	0.004	23.45
		30	md_gr2_030	0.851	0.004	23.07
		35	md_gr2_035	0.808	0.003	22.76
15%	50%	51	md_grg_051	0.340	20.82	0.001
		60	md_grg_060	0.667	24.93	0.001
		70	md_grg_070	0.845	24.81	0.002
		80	md_grg_080	0.909	24.64	0.002
		85	md_grg_085	0.925	24.56	0.002
		90	md_grg_090	0.926	24.48	0.002
		99	md_grg_099	0.929	24.35	0.002
15%	55%	46	md_grf_046	0.343	20.80	0.001
		50	md_grf_050	0.493	24.66	0.001
		60	md_grf_060	0.804	24.83	0.002
		70	md_grf_070	0.897	24.68	0.002
		75	md_grf_075	0.915	24.58	0.002
		80	md_grf_080	0.922	24.48	0.002
		85	md_grf_085	0.930	24.40	0.002
		90	md_grf_090	0.926	24.31	0.002
15%	60%	41	md_gre_041	0.341	20.79	0.001
		45	md_gre_045	0.525	24.77	0.001

U-235 Enrichment	Initial Quantity U-Al (% vol. Filled by ingot)	Quantity of U-Al Solution (% vol. Filled by water-U-Al mixture)	Input File	Keff w/o bias	Sigma	Ave. Energy Group
		50	md_gre_050	0.729	24.90	0.001
		55	md_gre_055	0.829	24.81	0.002
		60	md_gre_060	0.885	24.71	0.002
		65	md_gre_065	0.908	24.60	0.002
		70	md_gre_070	0.920	24.50	0.002
		75	md_gre_075	0.926	24.40	0.002
		80	md_gre_080	0.923	24.30	0.002
		90	md_gre_090	0.912	24.12	0.002
15%	65%	36	md_grd_036	0.346	20.82	0.001
		40	md_grd_040	0.559	24.74	0.001
		45	md_grd_045	0.762	24.84	0.001
		50	md_grd_050	0.853	24.75	0.002
		55	md_grd_055	0.895	24.64	0.002
		60	md_grd_060	0.916	24.53	0.002
		65	md_grd_065	0.919	24.40	0.002
		70	md_grd_070	0.922	24.30	0.002
		80	md_grd_080	0.903	24.09	0.002
		90	md_grd_090	0.886	23.88	0.002
15%	70	31	md_gra_031	0.348	20.96	0.001
		35	md_gra_035	0.604	24.80	0.001
		40	md_gra_040	0.797	24.79	0.002
		45	md_gra_045	0.875	24.69	0.002
		50	md_gra_050	0.902	24.56	0.002
		55	md_gra_055	0.918	24.42	0.002
		60	md_gra_060	0.919	24.28	0.002
		70	md_gra_070	0.900	24.04	0.002
		80	md_gra_080	0.873	23.80	0.002
15%	75	26	md_gr7_026	0.352	21.15	0.001
		30	md_gr7_030	0.655	24.78	0.001
		35	md_gr7_035	0.828	24.72	0.002
		40	md_gr7_040	0.891	24.58	0.002
		45	md_gr7_045	0.911	24.42	0.002
		48	md_gr7_048	0.915	24.34	0.002
		50	md_gr7_050	0.913	24.28	0.002
		52	md_gr7_052	0.908	24.22	0.002
		55	md_gr7_055	0.905	24.12	0.002
		60	md_gr7_060	0.890	23.98	0.002
		70	md_gr7_070	0.859	23.69	0.002
		80	md_gr7_080	0.823	23.44	0.002
15%	80	21	md_gr9_021	0.360	21.60	0.002

U-235 Enrichment	Initial Quantity U-Al (% vol. Filled by Ingot)	Quantity of U-Al Solution (% vol. Filled by water-U-Al mixture)	Input File	Keff w/o bias	Sigma	Ave. Energy Group
		25	md_gr9_025	0.705	24.71	0.002
		30	md_gr9_030	0.859	24.61	0.003
		35	md_gr9_035	0.890	24.42	0.003
		40	md_gr9_040	0.901	24.23	0.003
		45	md_gr9_045	0.908	24.24	0.003
		50	md_gr9_050	0.876	23.88	0.003
		55	md_gr9_055	0.854	23.69	0.004
		60	md_gr9_060	0.834	23.54	0.004
		70	md_gr9_070	0.791	23.23	0.003
15%	87	14	md_gr8_014	0.402	22.63	0.002
		15	md_gr8_015	0.545	24.18	0.002
		20	md_gr8_020	0.821	24.44	0.003
		23	md_gr8_023	0.865	24.30	0.003
		25	md_gr8_025	0.867	24.21	0.003
		27	md_gr8_027	0.867	24.09	0.004
		30	md_gr8_030	0.855	23.94	0.004
		35	md_gr8_035	0.835	23.67	0.004
		40	md_gr8_040	0.806	23.44	0.003
		50	md_gr8_050	0.753	22.99	0.004
		70	md_gr8_070	0.662	22.28	0.003
10%	45%	56	md_grj_056	0.290	21.20	0.001
		60	md_grj_060	0.340	23.16	0.001
		70	md_grj_070	0.600	24.94	0.001
		80	md_grj_080	0.719	24.86	0.001
		90	md_grj_090	0.772	24.74	0.002
		95	md_grj_095	0.788	24.69	0.002
		99	md_grj_099	0.794	24.65	0.002
10%	55%	46	md_gri_046	0.293	21.11	0.001
		50	md_gri_050	0.369	24.07	0.001
		60	md_gri_060	0.650	24.89	0.001
		70	md_gri_070	0.750	24.78	0.001
		80	md_gri_080	0.789	24.64	0.002
		85	md_gri_085	0.800	24.58	0.002
		90	md_gri_090	0.801	24.51	0.002
		99	md_gri_099	0.797	24.39	0.002
10%	65%	36	md_grh_036	0.297	21.18	0.001
		40	md_grh_040	0.425	24.59	0.001
		45	md_grh_045	0.606	24.89	0.001
		50	md_grh_050	0.699	24.82	0.001
		55	md_grh_055	0.751	24.75	0.001

U-235 Enrichment	Initial Quantity U-Al (% vol. Filled by Ingot)	Quantity of U-Al Solution (% vol. Filled by water-U-Al mixture)	Input File	Keff w/o bias	Sigma	Ave. Energy Group
		60	md_grh_060	0.777	24.66	0.002
		70	md_grh_070	0.798	24.48	0.002
		80	md_grh_080	0.794	24.32	0.002
		90	md_grh_090	0.777	24.16	0.002
10%	75	35	md_gr5_035	0.679	24.79	0.002
		40	md_gr5_040	0.746	24.67	0.003
		45	md_gr5_045	0.779	24.58	0.003
		50	md_gr5_050	0.784	24.45	0.004
		55	md_gr5_055	0.782	24.32	0.003
		60	md_gr5_060	0.779	24.23	0.003
		65	md_gr5_065	0.773	24.11	0.004
		75	md_gr5_075	0.750	23.90	0.004
10%	85	16	md_gr6_016	0.319	21.91	0.002
		25	md_gr6_025	0.733	24.54	0.003
		30	md_gr6_030	0.764	24.39	0.004
		35	md_gr6_035	0.764	24.21	0.004
		40	md_gr6_040	0.745	24.02	0.004
		45	md_gr6_045	0.722	23.83	0.003
		50	md_gr6_050	0.708	23.67	0.004
		55	md_gr6_055	0.684	23.50	0.003

Figure 5.2.1. Codisposal Canister Calculations – 20 % U-235

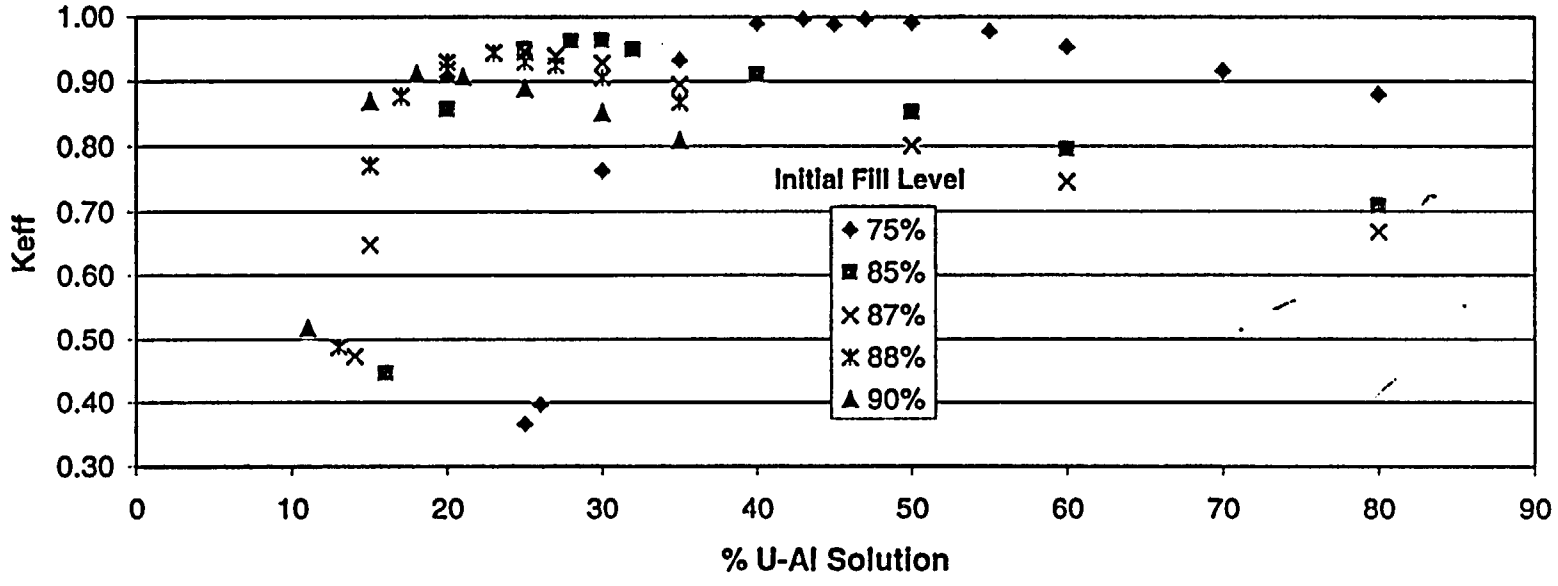


Figure 5.2.2a. Codisposal Canister Calculations – 15 % U-235

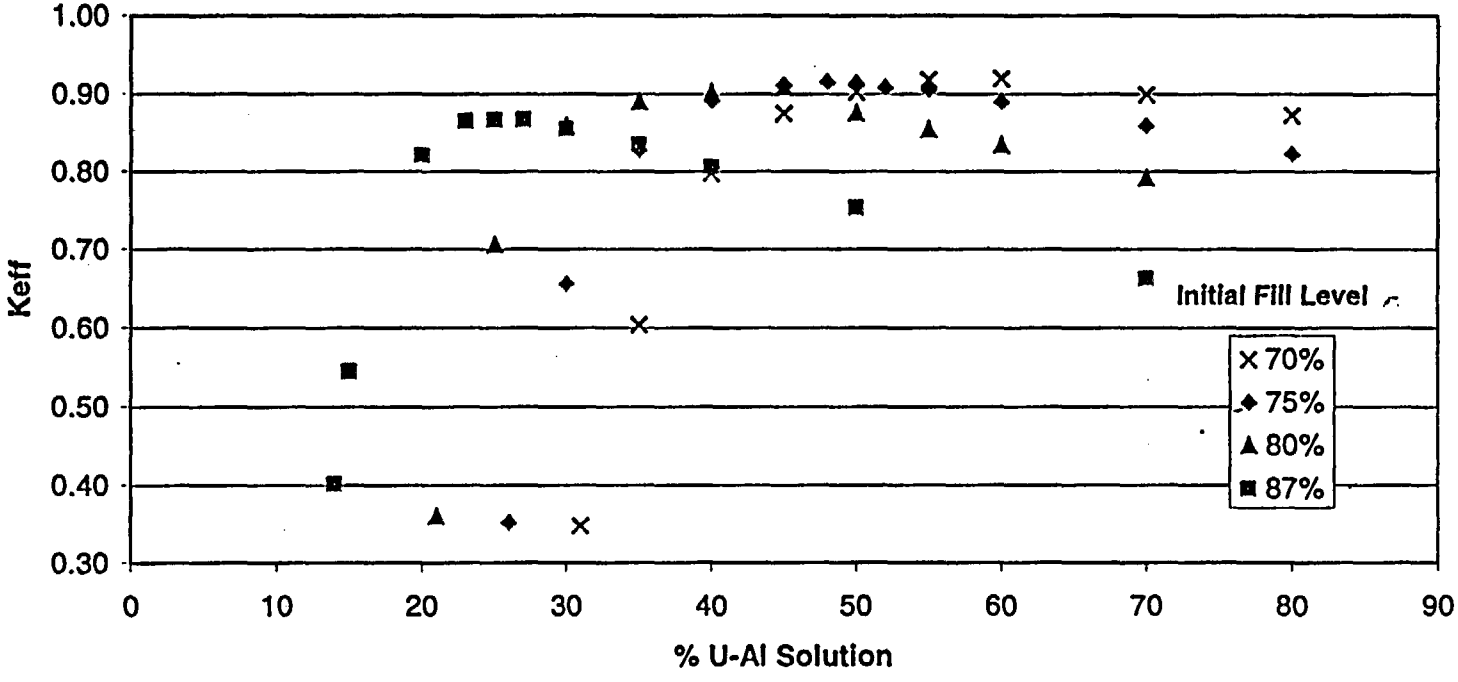


Figure 5.2.2b. Codisposal Canister Calculations – 15 % U-235

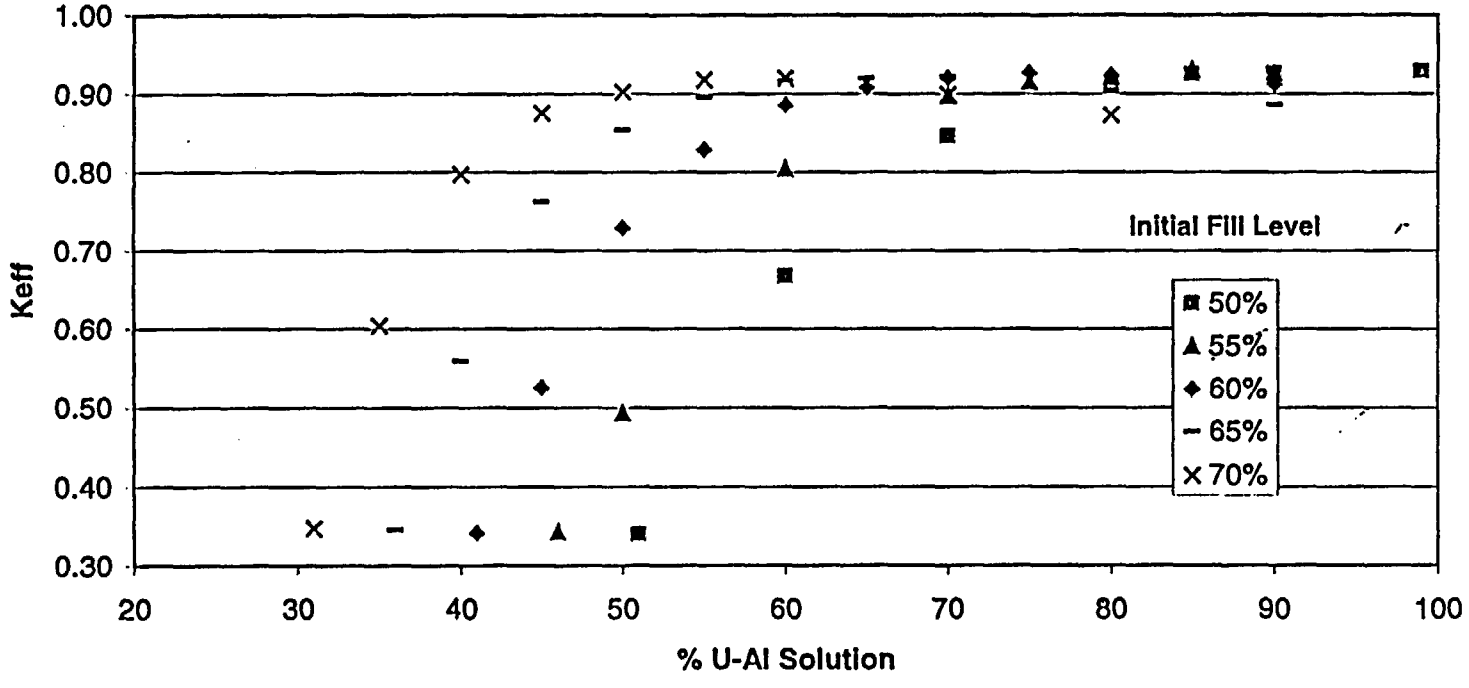


Figure 5.2.3. Codisposal Canister Calculations – 10 % U-235

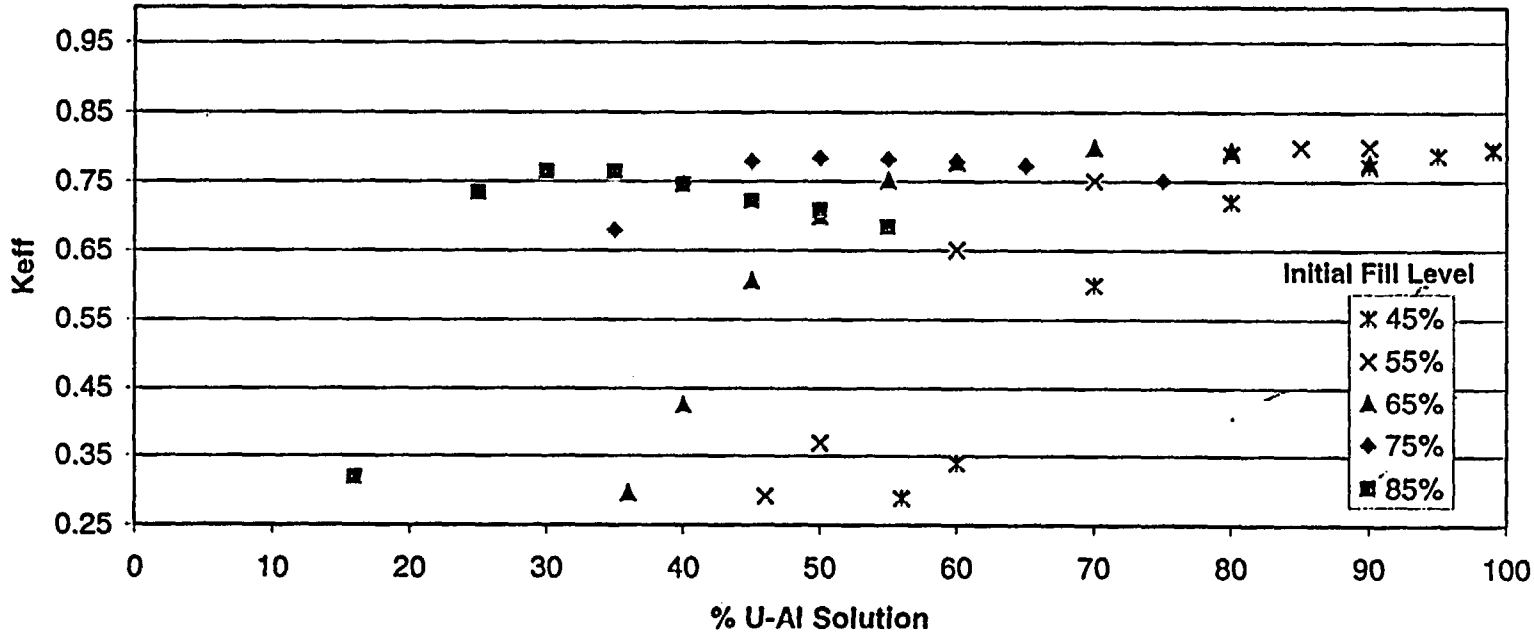


Table 5.2.2 summarizes the criticality calculations for the various configurations. The k_{eff} results in Table 5.2.2 have been adjusted by +0.018 (Code Bias) to account for code and cross section uncertainties (Section 4.2). The k_{effs} + 2*sigma + bias values represents the bounding reactivity value for each configuration. These values should be used in the preliminary design process for the melt dilute option.

Table 5.2.2. Codisposal Canister Summary

% U-235	Initial Fill Level	Max. Keff	Calculation Uncertainty (Sigma)	Code Bias	Keff+2*Sigma +Bias
20%	75%	0.996	0.003	0.018	1.020
	85%	0.963	0.003	0.018	0.987
	87%	0.945	0.003	0.018	0.969
	88%	0.943	0.003	0.018	0.967
	90%	0.910	0.004	0.018	0.936
15%	50%	0.929	0.002	0.018	0.951
	55%	0.930	0.002	0.018	0.952
	60%	0.926	0.002	0.018	0.948
	65%	0.922	0.002	0.018	0.944
	70%	0.919	0.002	0.018	0.941
	75%	0.915	0.002	0.018	0.937
	80%	0.908	0.003	0.018	0.932
	87%	0.867	0.004	0.018	0.893
10%	45%	0.794	0.002	0.018	0.816
	55%	0.801	0.002	0.018	0.823
	65%	0.798	0.002	0.018	0.820
	75%	0.784	0.004	0.018	0.810
	85%	0.764	0.004	0.018	0.790

Two additional configurations were examined. Case md_sr1_048 varied the quantity of water initially present in the canister free space. This case began with the most reactive case for 15% U-235 (the md_gr7_048 case) and used the SCALE CSAS4 sequence to vary the density of water from the density in case md_gr7_048 to zero. The results of this sequence demonstrated that the k_{eff} decreased as the density of water decreased. Hence, the most reactive condition is the condition where the canister free space is filled with full density water.

The final case, md_grc_048 examined the possible placement of the solution region away from the canister end. This case also began with case md_gr7_048, but moved the solution region to the center of the canister. The resulting k_{eff} was 0.915 + or - 0.002 which is exactly equal to the md_gr7_048 case. Therefore, placement of the solution region has no effect on the configuration's k_{eff}. This is consistent with the results of the base, no erosion, cases which all had k_{effs} less that 0.40. This indicates that the ingot material does not contribute significantly to the reactivity of the system.

6.0 Summary and Conclusions

The criticality analyses performed for the melt dilute option for the disposal of highly enriched uranium-aluminum fuel has determined the maximum k_{effs} for different initial configurations with varying amounts of material degradation. These k_{effs} has been corrected for the bias, bias uncertainty and AOA margin used. The AOA margin could be reduced by additional validation.

All design parameters and assumptions that are identified in this document are for the preliminary stage of the design process and are considered unqualified; all of these design parameters and assumptions will require subsequent confirmation (or superseding inputs) as the design proceeds. This document will not directly support any construction, fabrication, or procurement activity.

7.0 References

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