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Range of Neutronic Parameters For Repository Criticality Analyses

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1.0 Introduction

The "Range of Neutronic Parameters For Repository Criticality Analyses" technical report contains a comparison of the benchmark criticality analyses (including the laboratory critical experiment (LCEs) and the commercial reactor criticals (CRCs)) used to support the validation of the criticality model, and the expected repository analyses used to support the criticality control of the repository. This report also documents the development of the Upper Subcritical Limit (USL) for the repository criticality analyses.

1.1 Background

The United States Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) is developing a methodology for criticality analysis to support disposal of commercial spent nuclear fuel in a geologic repository. A topical report on the disposal criticality analysis methodology is scheduled to be submitted to the United States Nuclear Regulatory Commission (NRC) for formal review in July 1998. The following discussion provides a comparison of the benchmark criticality analyses and the expected repository criticality analyses to establish a "range of applicability" (ROA) for parameters important to the criticality analyses. This discussion also documents the development of the USL for the repository criticality analyses. This report is in support of the development of the disposal criticality analysis methodology.

1.2 Objective

The objective of this report is to establish the ROA for select parameters and compare the ranges to the ranges expected in the repository criticality models. This report also documents the development of the USL for the repository criticality analyses. The results of this will support the development and validation of the criticality models used in the disposal criticality analysis methodology. These models and their validation will be discussed in the Disposal Criticality Analysis Methodology Topical Report.

1.3 Scope

The scope of this report includes the following benchmark analyses:

- LCE Homogeneous Mixture Criticals
- LCE Lattice Criticals
- CRCs

Additional types of critical experiments may be added in revisions to this report.

1.4 Quality Assurance

The Quality Assurance (QA) program applies to the development of this report. The data provided in this report will indirectly be used to develop the methodology for evaluating the Monitored Geologic Repository (MGR) waste package and engineered barrier segment. The QAP-2-3 (*Classification of Permanent Items*) evaluation entitled *Classification of the Preliminary MGDS Repository Design* (Reference 1, TBV-228) has identified the waste package as an MGR (formerly MGDS) item important to safety, waste isolation, and physical protection of materials. The Waste Package responsible manager has evaluated the technical document development activity in accordance with QAP-2-0, *Conduct of Activities*. The QAP-2-0 activity evaluation, *Develop Technical Documents* (Reference 2), has determined that the preparation and review of this technical document is subject to *Quality Assurance Requirements and Description* (Reference 3) requirements. As specified in NLP-3-18, *Documentation of QA Controls on Drawings, Specifications, Design Analyses, and Technical Documents*, this activity is subject to QA controls. The data used in this report is Qualified Data. All of the referenced calculation files were developed under the *Quality Assurance Requirements and Description*, Reference 3.

1.5 Use of Computer Software

No scientific and engineering software or computational software was used in the development of this report.

2.0 Description of Calculations

This section provides a description of the analyzed systems used to generate the supporting analytic results reported in this document. The following subsections include characterizations of the analyses for comparison to expected repository parametric ranges. Reference 4 documents the characterization data reported in Section 2.0.

2.1 Description of Homogeneous LCEs

The LCEs presented in this section represent solutions containing uranium, plutonium, or both uranium and plutonium. All of the LCEs in this section are fresh fuel experiments. Reference 5 describes these LCE configurations.

Calling these experiments "homogeneous" is a misnomer. Most of the experiments are homogeneous, but the set also includes 51 thermal arrays. The name "Homogeneous LCEs" is a carry over from the original issuance (REV 00) of Reference 5 and is maintained for consistency between the reports. The following list is a breakdown of the "Homogeneous LCEs". Included in the list, in parentheses, is the number of experiments that fit into the given category.

1) Homogeneous Thermal Systems (209)
   a) Mixed plutonium and natural uranium (34)
   b) Plutonium (73)
   c) High-enriched uranium, U-235 (81)
   d) Low-enriched uranium, U-235 (15)
   e) High-enriched uranium, U-233 (6)
2) Homogeneous Fast Systems (10)
   a) High-enriched uranium, U-233 (10)
3) Thermal Arrays (51)
   a) High-enriched uranium, U-235 (22)
   b) Intermediate-enriched uranium, U-235 (29)

The term "Homogeneous LCEs" is used in the rest of this document to represent the entire set listed above.

Table 2.1-1. Mixed Plutonium and Natural Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	AWRE1	AWRE2	AWRE3	AWRE4	AWRE5
Concentration	U C (g/L)	228.5	228.5	228.5	228.5	71.3
	Pu C (g/L)	101.3	101.3	101.3	101.3	31.58
Enrichment	U-235 (wt%)	0.72%	0.72%	0.72%	0.72%	0.66%
	Pu-239 (wt%)	93.90%	93.90%	93.90%	93.90%	93.90%
	U-233 (wt%)	0.00%	0.00%	0.00%	0.00%	0.00%
Density (g/cc)	U (fissile)	1.64E-03	1.64E-03	1.64E-03	1.64E-03	4.68E-04
	U (fissionable)	2.29E-01	2.29E-01	2.29E-01	2.29E-01	7.13E-02
	Pu (fissile)	9.56E-02	9.56E-02	9.56E-02	9.56E-02	2.98E-02
	Pu (fissionable)	1.01E-01	1.01E-01	1.01E-01	1.01E-01	3.16E-02
	Total (fissile)	9.72E-02	9.72E-02	9.72E-02	9.72E-02	3.03E-02
	Total (fissionable)	3.30E-01	3.30E-01	3.30E-01	3.30E-01	1.03E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	1.64E-03	1.64E-03	1.64E-03	1.64E-03	4.68E-04
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.27E-01	2.27E-01	2.27E-01	2.27E-01	7.08E-02
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	9.51E-02	9.51E-02	9.51E-02	9.51E-02	2.97E-02
	Pu-240	5.74E-03	5.74E-03	5.74E-03	5.74E-03	1.79E-03
	Pu-241	4.40E-04	4.40E-04	4.40E-04	4.40E-04	1.32E-04
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0313	0.0321	0.0318	0.0323	0.0106
	H/X	234	234	234	234	830

Table 2.1-1. Mixed Plutonium and Natural Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	AWRE6	AWRE7	AWRE8	AWRE9	AWRE10
Concentration	U C (g/L)	71.3	71.3	42.2	42.2	39.6
	Pu C (g/L)	31.58	31.58	18.61	18.61	17.5
Enrichment	U-235 (wt%)	0.66%	0.66%	0.70%	0.70%	0.75%
	Pu-239 (wt%)	93.90%	93.90%	93.99%	93.99%	93.90%
	U-233 (wt%)	0.00%	0.00%	0.00%	0.00%	0.00%
Density (g/cc)	U (fissile)	4.68E-04	4.68E-04	2.97E-04	2.97E-04	2.97E-04
	U (fissionable)	7.13E-02	7.13E-02	4.22E-02	4.22E-02	3.96E-02
	Pu (fissile)	2.98E-02	2.98E-02	1.75E-02	1.75E-02	1.65E-02
	Pu (fissionable)	3.16E-02	3.16E-02	1.86E-02	1.86E-02	1.75E-02
	Total (fissile)	3.03E-02	3.03E-02	1.78E-02	1.78E-02	1.68E-02
	Total (fissionable)	1.03E-01	1.03E-01	6.08E-02	6.08E-02	5.71E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	4.68E-04	4.68E-04	2.97E-04	2.97E-04	2.97E-04
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.08E-02	7.08E-02	4.19E-02	4.19E-02	3.93E-02
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	2.97E-02	2.97E-02	1.75E-02	1.75E-02	1.64E-02
	Pu-240	1.79E-03	1.79E-03	1.04E-03	1.04E-03	9.97E-04
	Pu-241	1.32E-04	1.32E-04	8.00E-05	8.00E-05	7.20E-05
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0105	0.0109	0.0068	0.0068	0.0065
	H/X	830	830	1430	1430	1521

Table 2.1-1. Mixed Plutonium and Natural Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	PNL1158	PNL1159	PNL1161	PNL1577	PNL1678
Concentration	U C (g/L)	11.05	10.78	41.04	262.79	262.55
	Pu C (g/L)	11.83	11.73	12.19	172.56	172.82
Enrichment	U-235 (wt%)	0.71%	0.71%	0.44%	0.56%	0.56%
	Pu-239 (wt%)	91.10%	91.10%	91.10%	91.12%	91.12%
	U-233 (wt%)	0.00%	0.00%	0.00%	0.00%	0.00%
Density (g/cc)	U (fissile)	7.80E-05	7.60E-05	1.80E-04	3.06E-03	1.48E-03
	U (fissionable)	1.10E-02	1.08E-02	4.10E-02	5.43E-01	2.62E-01
	Pu (fissile)	1.09E-02	1.07E-02	1.12E-02	3.27E-01	1.58E-01
	Pu (fissionable)	1.19E-02	1.17E-02	1.22E-02	3.57E-01	1.73E-01
	Total (fissile)	1.10E-02	1.08E-02	1.13E-02	3.30E-01	1.60E-01
	Total (fissionable)	2.30E-02	2.26E-02	5.33E-02	9.01E-01	4.36E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.00E-06	1.00E-06	2.00E-06	3.80E-05	1.80E-05
	U-235	7.80E-05	7.60E-05	1.80E-04	3.06E-03	1.48E-03
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.10E-02	1.07E-02	4.08E-02	5.40E-01	2.61E-01
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	3.00E-06	3.00E-06	3.00E-06	1.03E-04	5.00E-05
	Pu-239	1.08E-02	1.07E-02	1.11E-02	3.25E-01	1.57E-01
	Pu-240	9.87E-04	9.75E-04	1.01E-03	2.96E-02	1.44E-02
	Pu-241	5.50E-05	5.50E-05	5.70E-05	1.61E-03	7.78E-04
	Pu-242	1.10E-05	1.10E-05	1.10E-05	3.32E-04	1.61E-04
	Am-241	6.10E-05	6.00E-05	6.30E-05	1.87E-03	9.05E-04
Flux Spectrum	AENCF (MeV)	0.003929	0.0038	0.005965	0.059559	0.050685
	H/X	2374	2405	2268	135	134

Table 2.1-1. Mixed Plutonium and Natural Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

Experiment >		PNL1783	PNL1868	PNL1969	PNL2070	PNL2565
Concentration	U C (g/L)	262.88	173.98	174.67	174.53	63.38
	Pu C (g/L)	173.22	118.71	119.04	118.9	41.69
Enrichment	U-235 (wt%)	0.56%	0.56%	0.56%	0.56%	0.56%
	Pu-239 (wt%)	91.12%	91.12%	91.12%	91.12%	91.12%
	U-233 (wt%)	0.00%	0.00%	0.00%	0.00%	0.00%
Density (g/cc)	U (fissile)	3.86E-03	2.97E-03	9.85E-04	2.55E-03	1.06E-03
	U (fissionable)	6.85E-01	5.26E-01	1.75E-01	4.51E-01	1.88E-01
	Pu (fissile)	4.13E-01	3.29E-01	1.09E-01	2.81E-01	1.13E-01
	Pu (fissionable)	4.51E-01	3.59E-01	1.19E-01	3.07E-01	1.24E-01
	Total (fissile)	4.17E-01	3.32E-01	1.10E-01	2.84E-01	1.14E-01
	Total (fissionable)	1.14E+00	8.87E-01	2.94E-01	7.60E-01	3.12E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	4.80E-05	3.70E-05	1.20E-05	3.20E-05	1.30E-05
	U-235	3.86E-03	2.97E-03	9.85E-04	2.55E-03	1.06E-03
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	6.81E-01	5.23E-01	1.74E-01	4.49E-01	1.87E-01
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	1.31E-04	1.04E-04	3.50E-05	8.90E-05	3.60E-05
	Pu-239	4.11E-01	3.27E-01	1.08E-01	2.80E-01	1.13E-01
	Pu-240	3.75E-02	2.99E-02	9.89E-03	2.55E-02	1.03E-02
	Pu-241	2.03E-03	1.62E-03	5.36E-04	1.38E-03	5.56E-04
	Pu-242	4.20E-04	3.34E-04	1.11E-04	2.86E-04	1.15E-04
	Am-241	2.37E-03	1.87E-03	6.20E-04	1.60E-03	6.42E-04
Flux Spectrum	AENCF (MeV)	0.053863	0.034163	0.033596	0.037432	0.012952
	H/X	134	211	210	211	654

Table 2.1-1. Mixed Plutonium and Natural Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	PNL2666	PNL2767	PNL3187	PNL3391	PNL3492
Concentration	U C (g/L)	63.65	63.55	365.2	363.66	363.66
	Pu C (g/L)	41.89	41.83	102.19	103.37	103.37
Enrichment	U-235 (wt%)	0.56%	0.56%	0.70%	0.70%	0.70%
	Pu-239 (wt%)	91.12%	91.12%	91.12%	91.13%	91.12%
	U-233 (wt%)	0.00%	0.00%	0.00%	0.00%	0.00%
Density (g/cc)	U (fissile)	3.59E-04	1.26E-03	2.71E-03	2.76E-03	2.78E-03
	U (fissionable)	6.36E-02	2.24E-01	3.85E-01	3.92E-01	3.95E-01
	Pu (fissile)	3.84E-02	1.35E-01	9.87E-02	1.02E-01	1.03E-01
	Pu (fissionable)	4.19E-02	1.47E-01	1.08E-01	1.12E-01	1.12E-01
	Total (fissile)	3.87E-02	1.36E-01	1.01E-01	1.05E-01	1.06E-01
	Total (fissionable)	1.06E-01	3.72E-01	4.93E-01	5.04E-01	5.08E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	4.00E-06	1.60E-05	2.70E-05	2.70E-05	2.80E-05
	U-235	3.59E-04	1.26E-03	2.71E-03	2.76E-03	2.78E-03
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	6.33E-02	2.23E-01	3.82E-01	3.89E-01	3.92E-01
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	1.20E-05	4.30E-05	3.10E-05	3.20E-05	3.30E-05
	Pu-239	3.82E-02	1.34E-01	9.82E-02	1.02E-01	1.02E-01
	Pu-240	3.48E-03	1.22E-02	8.96E-03	9.26E-03	9.37E-03
	Pu-241	1.89E-04	6.63E-04	4.85E-04	5.02E-04	4.74E-04
	Pu-242	3.90E-05	1.37E-04	1.00E-04	1.04E-04	1.06E-04
	Am-241	2.18E-04	7.67E-04	5.68E-04	5.90E-04	6.16E-04
Flux Spectrum	AENCF (MeV)	0.011603	0.011971	0.041582	0.040747	0.04386
	H/X	651	652	227	223	218

Table 2.1-1. Mixed Plutonium and Natural Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	PNL3593	PNL3694	PNL3795	PNL3808	PNL3896
Concentration	U C (g/L)	379.55	380.41	6.5	161.72	3.8
	Pu C (g/L)	107.91	108.27	195.61	47.08	110.13
Enrichment	U-235 (wt%)	0.68%	0.70%	2.31%	0.70%	2.30%
	Pu-239 (wt%)	91.12%	91.12%	91.57%	91.12%	91.57%
	U-233 (wt%)	0.00%	0.00%	0.00%	0.00%	0.00%
Density (g/cc)	U (fissile)	2.78E-03	2.66E-03	1.61E-04	1.38E-03	1.64E-04
	U (fissionable)	4.06E-01	3.77E-01	6.98E-03	1.96E-01	7.13E-03
	Pu (fissile)	1.03E-01	9.84E-02	1.98E-01	5.19E-02	1.24E-01
	Pu (fissionable)	1.12E-01	1.08E-01	2.16E-01	5.67E-02	1.34E-01
	Total (fissile)	1.06E-01	1.01E-01	1.99E-01	5.33E-02	1.24E-01
	Total (fissionable)	5.19E-01	4.86E-01	2.24E-01	2.53E-01	1.42E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	2.80E-05	2.60E-05	1.00E-05	1.40E-05	1.00E-05
	U-235	2.78E-03	2.66E-03	1.61E-04	1.38E-03	1.64E-04
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	4.03E-01	3.75E-01	6.81E-03	1.94E-01	6.96E-03
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	3.30E-05	3.10E-05	5.80E-05	1.60E-05	3.60E-05
	Pu-239	1.02E-01	9.80E-02	1.98E-01	5.17E-02	1.23E-01
	Pu-240	9.37E-03	8.97E-03	1.71E-02	4.73E-03	1.07E-02
	Pu-241	4.74E-04	4.54E-04	8.48E-04	2.39E-04	5.28E-04
	Pu-242	1.06E-04	1.01E-04	1.47E-04	5.30E-05	9.10E-05
	Am-241	6.16E-04	5.91E-04	1.06E-03	3.16E-04	6.58E-04
Flux Spectrum	AENCF (MeV)	0.046137	0.044829	0.039649	0.020591	0.023571
	H/X	213	212	125	551	241

Table 2.1-1. Mixed Plutonium and Natural Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	PNL3897	PNL3898	PNL3999	PNL5300
Concentration	U C (g/L)	2.3	247.33	250.3	251.64
	Pu C (g/L)	58.3	72.74	73.64	74.25
Enrichment	U-235 (wt%)	2.29%	0.70%	0.70%	0.70%
	Pu-239 (wt%)	91.57%	91.12%	91.12%	91.11%
	U-233 (wt%)	0.00%	0.00%	0.00%	0.00%
Density (g/cc)	U (fissile)	6.60E-05	1.96E-03	1.82E-03	1.77E-03
	U (fissionable)	2.89E-03	2.79E-01	2.58E-01	2.52E-01
	Pu (fissile)	7.41E-02	7.47E-02	6.93E-02	6.80E-02
	Pu (fissionable)	8.06E-02	8.16E-02	7.57E-02	7.43E-02
	Total (fissile)	7.42E-02	7.67E-02	7.11E-02	6.97E-02
	Total (fissionable)	8.38E-02	3.61E-01	3.34E-01	3.26E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	4.00E-06	2.00E-05	1.80E-05	1.80E-05
	U-235	6.60E-05	1.96E-03	1.82E-03	1.77E-03
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.82E-03	2.77E-01	2.56E-01	2.50E-01
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	2.20E-05	2.40E-05	2.20E-05	2.20E-05
	Pu-239	7.38E-02	7.44E-02	6.89E-02	6.77E-02
	Pu-240	6.40E-03	6.81E-03	6.31E-03	6.20E-03
	Pu-241	3.17E-04	3.44E-04	3.19E-04	3.13E-04
	Pu-242	5.50E-05	7.70E-05	7.10E-05	7.00E-05
	Am-241	3.95E-04	4.49E-04	4.17E-04	4.09E-04
Flux Spectrum	AENCF (MeV)	0.014467	0.02973	0.029328	0.029174
	H/X	475	343	339	336

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	PU003-1	PU003-2	PU003-3	PU003-4	PU003-5
Concentration	Pu C (g/L)	33.32	34.32	37.43	38.12	40.65
Enrichment	Pu-239 (wt%)	98.24%	98.24%	96.88%	96.88%	96.88%
Density (g/cc)	Pu (fissile)	3.27E-02	3.37E-02	3.63E-02	3.69E-02	3.94E-02
	Pu (fissionable)	3.33E-02	3.43E-02	3.74E-02	3.81E-02	4.07E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	3.27E-02	3.37E-02	3.63E-02	3.69E-02	3.94E-02
	Pu-240	5.86E-04	6.04E-04	1.17E-03	1.19E-03	1.27E-03
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0062	0.0065	0.0069	0.0072	0.0079
	H/X	788	756	699	682	627
	Experiment >	PU003-6	PU003-7	PU003-8	PU004-1	PU004-2
Concentration	Pu C (g/L)	44.09	35.98	36.81	26.27	26.31
Enrichment	Pu-239 (wt%)	96.88%	96.88%	96.88%	99.46%	99.46%
Density (g/cc)	Pu (fissile)	4.27E-02	3.49E-02	3.57E-02	2.61E-02	2.62E-02
	Pu (fissionable)	4.41E-02	3.60E-02	3.68E-02	2.63E-02	2.63E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	4.27E-02	3.49E-02	3.57E-02	2.61E-02	2.62E-02
	Pu-240	1.38E-03	1.12E-03	1.15E-03	1.42E-04	1.42E-04
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0085	0.0068	0.007	0.0052	0.0054
	H/X	563	738	714	987	977

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

Experiment >		PU004-3	PU004-4	PU004-5	PU004-6	PU004-7
Concentration	Pu C (g/L)	27.2	28.09	27.58	28.6	29.57
Enrichment	Pu-239 (wt%)	99.46%	99.46%	98.24%	96.88%	96.88%
Density (g/cc)	Pu (fissile)	2.71E-02	2.79E-02	2.71E-02	2.77E-02	2.86E-02
	Pu (fissionable)	2.72E-02	2.81E-02	2.76E-02	2.86E-02	2.96E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	2.71E-02	2.79E-02	2.71E-02	2.77E-02	2.86E-02
	Pu-240	1.47E-04	1.52E-04	4.85E-04	8.92E-04	9.23E-04
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0054	0.0056	0.0054	0.0056	0.0056
	H/X	935	889	942	927	892
Experiment >		PU004-8	PU004-9	PU04-10	PU04-11	PU04-12
Concentration	Pu C (g/L)	29.95	31.6	35.36	39.38	29.44
Enrichment	Pu-239 (wt%)	96.88%	96.88%	96.88%	96.88%	96.88%
Density (g/cc)	Pu (fissile)	2.90E-02	3.06E-02	3.43E-02	3.82E-02	2.85E-02
	Pu (fissionable)	3.00E-02	3.16E-02	3.54E-02	3.94E-02	2.94E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	2.90E-02	3.06E-02	3.43E-02	3.82E-02	2.85E-02
	Pu-240	9.34E-04	9.86E-04	1.10E-03	1.23E-03	9.19E-04
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0062	0.0062	0.0071	0.008	0.0059
	H/X	869	805	689	592	893

Experiment >		PU04-13	PU005-1	PU005-2	PU005-3	PU005-4

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

Concentration	Pu C (g/L)	29.27	29.65	30.54	31.43	33.54
Enrichment	Pu-239 (wt%)	96.57%	95.95%	95.95%	95.95%	95.95%
Density (g/cc)	Pu (fissile)	2.83E-02	2.84E-02	2.93E-02	3.02E-02	3.22E-02
	Pu (fissionable)	2.93E-02	2.96E-02	3.05E-02	3.14E-02	3.35E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	2.83E-02	2.84E-02	2.93E-02	3.02E-02	3.22E-02
	Pu-240	1.00E-03	1.20E-03	1.24E-03	1.27E-03	1.36E-03
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0058	0.0057	0.0059	0.0062	0.0066
	H/X	903	903	868	834	765

	Experiment >	PU005-5	PU005-6	PU005-7	PU005-8	PU005-9
Concentration	Pu C (g/L)	36.04	38.49	40.91	30.58	31.85
Enrichment	Pu-239 (wt%)	95.95%	95.95%	95.95%	95.60%	95.60%
Density (g/cc)	Pu (fissile)	3.46E-02	3.69E-02	3.93E-02	2.92E-02	3.04E-02
	Pu (fissionable)	3.60E-02	3.85E-02	4.09E-02	3.06E-02	3.18E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	3.46E-02	3.69E-02	3.93E-02	2.92E-02	3.04E-02
	Pu-240	1.46E-03	1.56E-03	1.66E-03	1.35E-03	1.40E-03
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0072	0.0077	0.0084	0.0059	0.0063
	H/X	694	633	581	869	825

	Experiment >	PU007-2	PU007-3	PU007-5	PU007-6	PU007-7
Concentration	Pu C (g/L)	232	221	100.2	101.5	100.1

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

Enrichment	Pu-239 (wt%)	95.01%	95.01%	95.01%	95.01%	95.01%
Density (g/cc)	Pu (fissile)	2.21E-01	2.11E-01	9.55E-02	9.67E-02	9.54E-02
	Pu (fissionable)	2.32E-01	2.21E-01	1.00E-01	1.02E-01	1.00E-01
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	1.40E-05	1.30E-05	6.00E-06	6.00E-06	6.00E-06
	Pu-239	2.20E-01	2.10E-01	9.52E-02	9.64E-02	9.51E-02
	Pu-240	1.08E-02	1.03E-02	4.68E-03	4.74E-03	4.67E-03
	Pu-241	7.07E-04	6.74E-04	3.06E-04	3.10E-04	3.05E-04
	Pu-242	2.10E-05	2.00E-05	9.00E-06	9.00E-06	9.00E-06
Flux Spectrum	AENCF (MeV)	0.0402	0.0393	0.0176	0.018	0.0178
	H/X	109	114	267	261	265

	Experiment >	PU007-8	PU007-9	PU07-10	PU10091	PU10092
Concentration	Pu C (g/L)	101.6	101.6	93.5	99.09	73.92
Enrichment	Pu-239 (wt%)	95.01%	95.01%	95.01%	97.15%	97.15%
Density (g/cc)	Pu (fissile)	9.68E-02	9.68E-02	8.91E-02	9.63E-02	7.18E-02
	Pu (fissionable)	1.02E-01	1.02E-01	9.35E-02	9.91E-02	7.39E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	6.00E-06	6.00E-06	6.00E-06	0.00E+00	0.00E+00
	Pu-239	9.65E-02	9.65E-02	8.88E-02	9.63E-02	7.18E-02
	Pu-240	4.74E-03	4.74E-03	4.37E-03	2.82E-03	2.11E-03
	Pu-241	3.10E-04	3.10E-04	2.85E-04	0.00E+00	0.00E+00
	Pu-242	9.00E-06	9.00E-06	8.00E-06	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0181	0.0182	0.0165	0.0168	0.013
	H/X	258	259	284	267	357

	Experiment >	PU10093	PU10111	PU10112	PU10113	PU10114
Concentration	Pu C (g/L)	54.53	54.53	47.21	47.21	41.73
Enrichment	Pu-239 (wt%)	97.15%	97.15%	97.15%	97.15%	97.15%

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

Density (g/cc)	Pu (fissile)	5.30E-02	5.29E-02	4.59E-02	4.59E-02	4.05E-02
	Pu (fissionable)	5.45E-02	5.44E-02	4.72E-02	4.72E-02	4.17E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	5.30E-02	5.29E-02	4.59E-02	4.59E-02	4.05E-02
	Pu-240	1.55E-03	1.55E-03	1.35E-03	1.35E-03	1.19E-03
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0099	0.01	0.0087	0.0085	0.0079
	H/X	484	485	558	558	606

	Experiment >	**PU10115**	**PU10116**	**PU10117**	**PU10121**	**PU10122**
Concentration	Pu C (g/L)	36.9	63.99	48.98	48.75	42.29
Enrichment	Pu-239 (wt%)	97.15%	97.10%	97.10%	97.10%	97.10%
Density (g/cc)	Pu (fissile)	3.58E-02	6.21E-02	4.76E-02	4.73E-02	4.11E-02
	Pu (fissionable)	3.69E-02	6.40E-02	4.90E-02	4.88E-02	4.23E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	3.58E-02	6.21E-02	4.76E-02	4.73E-02	4.11E-02
	Pu-240	1.05E-03	1.86E-03	1.42E-03	1.41E-03	1.23E-03
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0075	0.0111	0.0088	0.009	0.0078
	H/X	665	414	535	543	618

	Experiment >	**PU10123**	**PU10124**	**PU11161**	**PU11162**	**PU11163**
Concentration	Pu C (g/L)	36.52	31.14	34.96	36.22	38.13
Enrichment	Pu-239 (wt%)	97.10%	97.10%	95.83%	95.83%	95.83%
Density (g/cc)	Pu (fissile)	3.55E-02	3.02E-02	3.35E-02	3.47E-02	3.65E-02

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

	Pu (fissionable)	3.65E-02	3.11E-02	3.50E-02	3.62E-02	3.81E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	3.55E-02	3.02E-02	3.35E-02	3.47E-02	3.65E-02
	Pu-240	1.06E-03	9.03E-04	1.46E-03	1.51E-03	1.59E-03
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0069	0.0061	0.0074	0.0078	0.0083
	H/X	728	850	765	736	691

	Experiment >	PU11164	PU11165	PU11181	PU11182	PU11183
Concentration	Pu C (g/L)	38.16	43.43	22.35	23.27	23.1
Enrichment	Pu-239 (wt%)	95.83%	95.83%	95.80%	95.80%	95.80%
Density (g/cc)	Pu (fissile)	3.66E-02	4.16E-02	2.14E-02	2.23E-02	2.21E-02
	Pu (fissionable)	3.82E-02	4.34E-02	2.24E-02	2.33E-02	2.31E-02
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	3.66E-02	4.16E-02	2.14E-02	2.23E-02	2.21E-02
	Pu-240	1.59E-03	1.81E-03	9.39E-04	9.77E-04	9.70E-04
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.0085	0.0097	0.0051	0.0055	0.0051
	H/X	682	575	1208	1151	1158

	Experiment >	PU11184	PU11185	PU11186	PU11187	PUST1T1
Concentration	Pu C (g/L)	23.82	25.2	27.49	23.94	73
Enrichment	Pu-239 (wt%)	95.80%	95.80%	95.80%	95.80%	95.01%
Density (g/cc)	Pu (fissile)	2.28E-02	2.41E-02	2.63E-02	2.29E-02	6.96E-02
	Pu (fissionable)	2.38E-02	2.52E-02	2.75E-02	2.39E-02	7.30E-02

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.00E-06
	Pu-239	2.28E-02	2.41E-02	2.63E-02	2.29E-02	6.94E-02
	Pu-240	1.00E-03	1.06E-03	1.16E-03	1.01E-03	3.41E-03
	Pu-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.23E-04
	Pu-242	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.00E-06
Flux Spectrum	AENCF (MeV)	0.0055	0.0059	0.0063	0.0055	0.0125
	H/X	1100	1039	908	1103	370
	Experiment >	**PUST1T2**	**PUST1T3**	**PUST1T4**	**PUST1T5**	**PUST1T6**
Concentration	Pu C (g/L)	96	119	132	140	268.7
Enrichment	Pu-239 (wt%)	95.01%	95.01%	95.01%	95.01%	95.01%
Density (g/cc)	Pu (fissile)	9.15E-02	1.13E-01	1.26E-01	1.33E-01	2.56E-01
	Pu (fissionable)	9.60E-02	1.19E-01	1.32E-01	1.40E-01	2.69E-01
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	6.00E-06	7.00E-06	8.00E-06	8.00E-06	1.60E-05
	Pu-239	9.12E-02	1.13E-01	1.25E-01	1.33E-01	2.55E-01
	Pu-240	4.48E-03	5.56E-03	6.16E-03	6.54E-03	1.25E-02
	Pu-241	2.93E-04	3.63E-04	4.03E-04	4.27E-04	8.20E-04
	Pu-242	9.00E-06	1.10E-05	1.20E-05	1.30E-05	2.40E-05
Flux Spectrum	AENCF (MeV)	0.017	0.0216	0.024	0.0248	0.0481
	H/X	271	215	190	180	91

	Experiment >	**PUST9-1**	**PUST9-2**	**PUST9-3**
Concentration	Pu C (g/L)	10.02	9.539	9.457
Enrichment	Pu-239 (wt%)	97.39%	97.39%	97.39%
Density (g/cc)	Pu (fissile)	9.77E-03	9.30E-03	9.22E-03
	Pu (fissionable)	1.00E-02	9.54E-03	9.46E-03
Isotopes (g/cc)	Pu-237	0.00E+00	0.00E+00	0.00E+00

Table 2.1-2. Plutonium Nitrate Solution Laboratory Critical Experiment Characterizations

	Pu-238	0.00E+00	0.00E+00	0.00E+00
	Pu-239	9.76E-03	9.29E-03	9.21E-03
	Pu-240	2.53E-04	2.40E-04	2.38E-04
	Pu-241	8.00E-06	7.00E-06	7.00E-06
	Pu-242	1.00E-06	1.00E-06	1.00E-06
Flux Spectrum	AENCF (MeV)	0.0026	0.0027	0.0025
	H/X	2645	2776	2800

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	HEST1-1	HEST1-2	HEST1-3	HEST1-4	HEST1-5
Concentration	U C (g/L)	145.68	346.73	142.92	357.71	54.89
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	1.36E-01	3.23E-01	1.33E-01	3.33E-01	5.11E-02
	U (fissionable)	1.45E-01	3.45E-01	1.42E-01	3.56E-01	5.47E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.49E-03	3.54E-03	1.46E-03	3.66E-03	5.61E-04
	U-235	1.36E-01	3.23E-01	1.33E-01	3.33E-01	5.11E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.83E-03	1.86E-02	7.68E-03	1.92E-02	2.95E-03
Flux Spectrum	AENCF (MeV)	0.015759	0.038569	0.015461	0.040502	0.006505
	H/X	182	71	186	68	499
	Experiment >	**HEST1-6**	**HEST1-7**	**HEST1-8**	**HEST1-9**	**HEST110**
Concentration	U C (g/L)	59.65	137.4	145.68	357.71	63.95
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	5.56E-02	1.28E-01	1.36E-01	3.33E-01	5.96E-02
	U (fissionable)	5.94E-02	1.37E-01	1.45E-01	3.56E-01	6.37E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	6.10E-04	1.40E-03	1.49E-03	3.66E-03	6.54E-04
	U-235	5.56E-02	1.28E-01	1.36E-01	3.33E-01	5.96E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	3.20E-03	7.38E-03	7.83E-03	1.92E-02	3.44E-03
Flux Spectrum	AENCF (MeV)	0.006781	0.015014	0.0161	0.040991	0.007573
	H/X	459	193	182	68	427
	Experiment >	**HEST131**	**HEST132**	**HEST133**	**HEST134**	**HEST141**
Concentration	U C (g/L)	20.12	25.53	26.77	28.45	70
Enrichment	U-235 (wt%)	93.43%	93.43%	93.43%	93.43%	89.24%

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	Experiment >	HEST131	HEST132	HEST133	HEST134	HEST141
Density (g/cc)	U (fissile)	1.88E-02	2.19E-02	2.49E-02	2.65E-02	6.23E-02
	U (fissionable)	2.01E-02	2.35E-02	2.67E-02	2.84E-02	6.98E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	2.09E-04	2.45E-04	2.78E-04	2.96E-04	6.37E-04
	U-235	1.88E-02	2.19E-02	2.49E-02	2.65E-02	6.23E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.11E-03	1.30E-03	1.48E-03	1.57E-03	6.88E-03
Flux Spectrum	AENCF (MeV)	0.002654	0.003069	0.003605	0.003785	0.007269
	H/X	1375	1173	1030	971	405

	Experiment >	HEST142	HEST143	HEST151	HEST152	HEST153
Concentration	U C (g/L)	68.1	67.7	100.5	100.5	98.8
Enrichment	U-235 (wt%)	89.24%	89.24%	89.24%	89.24%	89.24%
Density (g/cc)	U (fissile)	6.06E-02	6.03E-02	8.95E-02	8.95E-02	8.80E-02
	U (fissionable)	6.79E-02	6.76E-02	1.00E-01	1.00E-01	9.86E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	6.20E-04	6.16E-04	9.15E-04	9.15E-04	8.99E-04
	U-235	6.06E-02	6.03E-02	8.95E-02	8.95E-02	8.80E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	6.69E-03	6.66E-03	9.88E-03	9.88E-03	9.71E-03
Flux Spectrum	AENCF (MeV)	0.007369	0.007908	0.01047	0.010092	0.011274
	H/X	418	421	278	278	283

	Experiment >	HEST154	HEST155	HEST161	HEST162	HEST163
Concentration	U C (g/L)	98.8	95.2	156.5	143.6	144.2
Enrichment	U-235 (wt%)	89.24%	89.24%	89.24%	89.24%	89.24%
Density (g/cc)	U (fissile)	8.80E-02	8.48E-02	1.39E-01	1.28E-01	1.28E-01
	U (fissionable)	9.86E-02	9.50E-02	1.56E-01	1.43E-01	1.44E-01
	Experiment >	HEST154	HEST155	HEST161	HEST162	HEST163

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	8.99E-04	8.66E-04	1.42E-03	1.31E-03	1.31E-03
	U-235	8.80E-02	8.48E-02	1.39E-01	1.28E-01	1.28E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	9.71E-03	9.36E-03	1.54E-02	1.41E-02	1.42E-02
Flux Spectrum	AENCF (MeV)	0.010771	0.011098	0.015165	0.015001	0.015973
	H/X	283	295	175	192	191
	Experiment >	**HEST171**	**HEST172**	**HEST173**	**HEST174**	**HEST175**
Concentration	U C (g/L)	202.4	202.4	202.4	196.2	192
Enrichment	U-235 (wt%)	89.24%	89.24%	89.24%	89.24%	89.24%
Density (g/cc)	U (fissile)	1.80E-01	1.80E-01	1.80E-01	1.75E-01	1.71E-01
	U (fissionable)	2.02E-01	2.02E-01	2.02E-01	1.96E-01	1.92E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.84E-03	1.84E-03	1.84E-03	1.79E-03	1.75E-03
	U-235	1.80E-01	1.80E-01	1.80E-01	1.75E-01	1.71E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.99E-02	1.99E-02	1.99E-02	1.93E-02	1.89E-02
Flux Spectrum	AENCF (MeV)	0.018899	0.020954	0.02004	0.019386	0.019935
	H/X	133	133	133	137	141
	Experiment >	**HEST176**	**HEST177**	**HEST178**	**HEST181**	**HEST182**
Concentration	U C (g/L)	192	192	186.2	300	300
Enrichment	U-235 (wt%)	89.24%	89.24%	89.24%	89.24%	89.24%
Density (g/cc)	U (fissile)	1.71E-01	1.71E-01	1.66E-01	2.67E-01	2.67E-01
	U (fissionable)	1.92E-01	1.92E-01	1.86E-01	2.99E-01	2.99E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.75E-03	1.75E-03	1.69E-03	2.73E-03	2.73E-03
	Experiment >	**HEST176**	**HEST177**	**HEST178**	**HEST181**	**HEST182**
	U-235	1.71E-01	1.71E-01	1.66E-01	2.67E-01	2.67E-01

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.89E-02	1.89E-02	1.83E-02	2.95E-02	2.95E-02
Flux Spectrum	AENCF (MeV)	0.022091	0.020445	0.022161	0.02844	0.031524
	H/X	141	141	147	86	86
	Experiment >	**HEST183**	**HEST184**	**HEST185**	**HEST186**	**HEST187**
Concentration	U C (g/L)	300	291.3	291.3	291.3	283.3
Enrichment	U-235 (wt%)	89.24%	89.24%	89.24%	89.24%	89.24%
Density (g/cc)	U (fissile)	2.67E-01	2.59E-01	2.59E-01	2.59E-01	2.52E-01
	U (fissionable)	2.99E-01	2.91E-01	2.91E-01	2.91E-01	2.83E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	2.73E-03	2.65E-03	2.65E-03	2.65E-03	2.58E-03
	U-235	2.67E-01	2.59E-01	2.59E-01	2.59E-01	2.52E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.95E-02	2.86E-02	2.86E-02	2.86E-02	2.78E-02
Flux Spectrum	AENCF (MeV)	0.029903	0.028945	0.032662	0.03066	0.029683
	H/X	86	89	89	89	92
	Experiment >	**HEST188**	**HEST189**	**HEST191**	**HEST192**	**HEST193**
Concentration	U C (g/L)	283.3	283.3	447.3	393.6	400
Enrichment	U-235 (wt%)	89.24%	89.24%	89.24%	89.24%	89.24%
Density (g/cc)	U (fissile)	2.52E-01	2.52E-01	3.98E-01	3.50E-01	3.56E-01
	U (fissionable)	2.83E-01	2.83E-01	4.46E-01	3.93E-01	3.99E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	2.58E-03	2.58E-03	4.07E-03	3.58E-03	3.64E-03
	U-235	2.52E-01	2.52E-01	3.98E-01	3.50E-01	3.56E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Experiment >	**HEST188**	**HEST189**	**HEST191**	**HEST192**	**HEST193**
	U-238	2.78E-02	2.78E-02	4.40E-02	3.87E-02	3.93E-02
Flux Spectrum	AENCF (MeV)	0.033348	0.030876	0.042621	0.039202	0.041469

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	H/X	92	92	55	63	61
	Experiment >	**HEST2-1**	**HEST2-2**	**HEST2-3**	**HEST2-4**	**HEST2-5**
Concentration	U C (g/L)	144.38	144.38	334.77	334.77	144.38
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	1.35E-01	1.35E-01	3.12E-01	3.12E-01	1.35E-01
	U (fissionable)	1.44E-01	1.44E-01	3.33E-01	3.33E-01	1.44E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.48E-03	1.48E-03	3.42E-03	3.42E-03	1.48E-03
	U-235	1.35E-01	1.35E-01	3.12E-01	3.12E-01	1.35E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.76E-03	7.76E-03	1.80E-02	1.80E-02	7.76E-03
Flux Spectrum	AENCF (MeV)	0.015512	0.015066	0.035869	0.034601	0.015802
	H/X	184	184	74	74	184
	Experiment >	**HEST2-6**	**HEST2-7**	**HEST2-8**	**HEST2-9**	**HEST210**
Concentration	U C (g/L)	144.38	334.77	334.77	59.65	59.65
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	1.35E-01	3.12E-01	3.12E-01	5.56E-02	5.56E-02
	U (fissionable)	1.44E-01	3.33E-01	3.33E-01	5.94E-02	5.94E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.48E-03	3.42E-03	3.42E-03	6.10E-04	6.10E-04
	U-235	1.35E-01	3.12E-01	3.12E-01	5.56E-02	5.56E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.76E-03	1.80E-02	1.80E-02	3.20E-03	3.20E-03
Flux Spectrum	AENCF (MeV)	0.014689	0.036593	0.034229	0.007065	0.006603
	Experiment >	**HEST2-6**	**HEST2-7**	**HEST2-8**	**HEST2-9**	**HEST210**
	H/X	184	74	74	460	460
	Experiment >	**HEST211**	**HEST212**	**HEST213**	**HEST214**	**HEST310**
Concentration	U C (g/L)	144.38	144.38	334.77	334.77	345.33

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	1.35E-01	1.35E-01	3.12E-01	3.12E-01	3.22E-01
	U (fissionable)	1.44E-01	1.44E-01	3.33E-01	3.33E-01	3.44E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.48E-03	1.48E-03	3.42E-03	3.42E-03	3.53E-03
	U-235	1.35E-01	1.35E-01	3.12E-01	3.12E-01	3.22E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.76E-03	7.76E-03	1.80E-02	1.80E-02	1.86E-02
Flux Spectrum	AENCF (MeV)	0.01551	0.014357	0.037033	0.033554	0.038165
	H/X	184	184	74	74	71

	Experiment >	HEST311	HEST312	HEST313	HEST314	HEST315
Concentration	U C (g/L)	345.33	60.32	60.32	60.32	66.33
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	3.22E-01	5.62E-02	5.62E-02	5.62E-02	6.18E-02
	U (fissionable)	3.44E-01	6.01E-02	6.01E-02	6.01E-02	6.60E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	3.53E-03	6.16E-04	6.16E-04	6.16E-04	6.78E-04
	U-235	3.22E-01	5.62E-02	5.62E-02	5.62E-02	6.18E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.86E-02	3.24E-03	3.24E-03	3.24E-03	3.56E-03
Flux Spectrum	AENCF (MeV)	0.035663	0.006511	0.006536	0.007036	0.007179
	H/X	71	454	454	454	412

	Experiment >	HEST316	HEST317	HEST318	HEST319	HEST710
Concentration	U C (g/L)	147.66	147.66	345.33	345.33	83.49
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	1.38E-01	1.38E-01	3.22E-01	3.22E-01	7.78E-02
	U (fissionable)	1.47E-01	1.47E-01	3.44E-01	3.44E-01	8.31E-02

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.51E-03	1.51E-03	3.53E-03	3.53E-03	8.53E-04
	U-235	1.38E-01	1.38E-01	3.22E-01	3.22E-01	7.78E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.93E-03	7.93E-03	1.86E-02	1.86E-02	4.49E-03
Flux Spectrum	AENCF (MeV)	0.015926	0.014981	0.038422	0.034143	0.008599
	H/X	180	180	71	71	325
	Experiment >	**HEST711**	**HEST712**	**HEST713**	**HEST714**	**HEST715**
Concentration	U C (g/L)	360.37	83.49	359.55	359.55	359.55
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	3.36E-01	7.78E-02	3.35E-01	3.35E-01	3.35E-01
	U (fissionable)	3.59E-01	8.31E-02	3.58E-01	3.58E-01	3.58E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	3.68E-03	8.53E-04	3.68E-03	3.68E-03	3.68E-03
	U-235	3.36E-01	7.78E-02	3.35E-01	3.35E-01	3.35E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.94E-02	4.49E-03	1.93E-02	1.93E-02	1.93E-02
Flux Spectrum	AENCF (MeV)	0.035134	0.008552	0.035199	0.036173	0.035741
	H/X	68	325	68	68	68
	Experiment >	**HEST716**	**HEST717**	**HEST813**	**HEUST31**	**HEUST32**
Concentration	U C (g/L)	359.55	359.55	355.94	60.32	60.32
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
	Experiment >	**HEST716**	**HEST717**	**HEST813**	**HEUST31**	**HEUST32**
Density (g/cc)	U (fissile)	3.35E-01	3.35E-01	3.32E-01	5.62E-02	5.62E-02
	U (fissionable)	3.58E-01	3.58E-01	3.54E-01	6.01E-02	6.01E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	3.68E-03	3.68E-03	3.64E-03	6.16E-04	6.16E-04
	U-235	3.35E-01	3.35E-01	3.32E-01	5.62E-02	5.62E-02

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.93E-02	1.93E-02	1.91E-02	3.24E-03	3.24E-03
Flux Spectrum	AENCF (MeV)	0.036319	0.035831	0.035577	0.006568	0.006768
	H/X	68	68	69	454	454
	Experiment >	**HEUST33**	**HEUST34**	**HEUST35**	**HEUST36**	**HEUST37**
Concentration	U C (g/L)	147.66	147.66	345.33	345.33	60.32
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	1.38E-01	1.38E-01	3.22E-01	3.22E-01	5.62E-02
	U (fissionable)	1.47E-01	1.47E-01	3.44E-01	3.44E-01	6.01E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.51E-03	1.51E-03	3.53E-03	3.53E-03	6.16E-04
	U-235	1.38E-01	1.38E-01	3.22E-01	3.22E-01	5.62E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.93E-03	7.93E-03	1.86E-02	1.86E-02	3.24E-03
Flux Spectrum	AENCF (MeV)	0.016279	0.015393	0.038043	0.03538	0.006852
	H/X	180	180	71	71	454
	Experiment >	**HEUST38**	**HEUST39**	**HEUST71**	**HEUST72**	**HEUST73**
Concentration	U C (g/L)	147.66	147.66	67.28	369.96	67.28
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	1.38E-01	1.38E-01	6.27E-02	3.45E-01	6.27E-02
	U (fissionable)	1.47E-01	1.47E-01	6.70E-02	3.68E-01	6.70E-02
	Experiment >	**HEUST38**	**HEUST39**	**HEUST71**	**HEUST72**	**HEUST73**
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.51E-03	1.51E-03	6.88E-04	3.78E-03	6.88E-04
	U-235	1.38E-01	1.38E-01	6.27E-02	3.45E-01	6.27E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.93E-03	7.93E-03	3.61E-03	1.99E-02	3.61E-03
Flux Spectrum	AENCF (MeV)	0.016389	0.01512	0.007028	0.036071	0.007132

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

	H/X	180	180	406	65	406
	Experiment >	**HEUST74**	**HEUST75**	**HEUST76**	**HEUST77**	**HEUST78**
Concentration	U C (g/L)	364.11	76.09	360.37	76.09	364.11
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	3.39E-01	7.09E-02	3.36E-01	7.09E-02	3.39E-01
	U (fissionable)	3.63E-01	7.58E-02	3.59E-01	7.58E-02	3.63E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	3.72E-03	7.78E-04	3.68E-03	7.78E-04	3.72E-03
	U-235	3.39E-01	7.09E-02	3.36E-01	7.09E-02	3.39E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.96E-02	4.09E-03	1.94E-02	4.09E-03	1.96E-02
Flux Spectrum	AENCF (MeV)	0.035101	0.008402	0.037673	0.008429	0.038245
	H/X	67	358	68	358	67
	Experiment >	**HEUST79**	**HEUST81**	**HEUST83**	**HEUST86**	**HEUST89**
Concentration	U C (g/L)	80.72	60.32	60.32	355.94	60.32
Enrichment	U-235 (wt%)	93.58%	93.58%	93.58%	93.58%	93.58%
Density (g/cc)	U (fissile)	7.52E-02	5.62E-02	5.62E-02	3.32E-01	5.62E-02
	U (fissionable)	8.04E-02	6.01E-02	6.01E-02	3.54E-01	6.01E-02
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	8.25E-04	6.16E-04	6.16E-04	3.64E-03	6.16E-04
	Experiment >	**HEUST79**	**HEUST81**	**HEUST83**	**HEUST86**	**HEUST89**
	U-235	7.52E-02	5.62E-02	5.62E-02	3.32E-01	5.62E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	4.34E-03	3.24E-03	3.24E-03	1.91E-02	3.24E-03
Flux Spectrum	AENCF (MeV)	0.008985	0.006661	0.006444	0.037853	0.006428
	H/X	337	454	454	69	454
	Experiment >	**HST1810**	**HST1811**	**HST1812**		
Concentration	U C (g/L)	285.3	285.3	279.6		

Table 2.1-3. High Enriched Uranium Nitrate Solution Laboratory Critical Experiment Characterizations

Enrichment	U-235 (wt%)	89.24%	89.24%	89.24%
Density (g/cc)	U (fissile)	2.54E-01	2.54E-01	2.49E-01
	U (fissionable)	2.85E-01	2.85E-01	2.79E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00
	U-234	2.60E-03	2.60E-03	2.54E-03
	U-235	2.54E-01	2.54E-01	2.49E-01
	U-237	0.00E+00	0.00E+00	0.00E+00
	U-238	2.80E-02	2.80E-02	2.75E-02
Flux Spectrum	AENCF (MeV)	0.034433	0.03182	0.032765
	H/X	91	91	94

Table 2.1-4. Intermediate Enriched Uranium Laboratory Critical Experiment Characterizations

	Experiment >	IECT101	IECT102	IECT103	IECT104	IECT105
Enrichment	U-235 (wt%)	29.83%	29.83%	29.83%	29.83%	29.83%
Density (g/cc)	U (fissile)	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U (fissionable)	3.10E+00	3.10E+00	3.10E+00	3.10E+00	3.10E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00
Flux Spectrum	AENCF (MeV)	0.2188	0.1576	0.105	0.0744	0.0455
	H/X	8	16	32	64	222
	Experiment >	IECT106	IECT107	IECT108	IECT109	IECT110
Enrichment	U-235 (wt%)	29.83%	29.83%	29.83%	29.83%	29.83%
Density (g/cc)	U (fissile)	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U (fissionable)	3.10E+00	3.10E+00	3.10E+00	3.10E+00	3.10E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00
Flux Spectrum	AENCF (MeV)	0.1077	0.1106	0.1192	0.1681	0.1571
	H/X	32	32	32	16	16
	Experiment >	IECT111	IECT112	IECT113	IECT114	IECT115
Enrichment	U-235 (wt%)	29.83%	29.83%	29.83%	29.83%	29.83%
Density (g/cc)	U (fissile)	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U (fissionable)	3.10E+00	3.10E+00	3.10E+00	3.10E+00	3.10E+00
	Experiment >	IECT111	IECT112	IECT113	IECT114	IECT115

Table 2.1-4. Intermediate Enriched Uranium Laboratory Critical Experiment Characterizations

Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00
Flux Spectrum	AENCF (MeV)	0.1577	0.1565	0.0739	0.0743	0.0732
	H/X	16	16	64	64	64
	Experiment >	**IECT116**	**IECT117**	**IECT118**	**IECT119**	**IECT120**
Enrichment	U-235 (wt%)	29.83%	29.83%	29.83%	29.83%	29.83%
Density (g/cc)	U (fissile)	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U (fissionable)	3.10E+00	3.10E+00	3.10E+00	3.10E+00	3.10E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00
Flux Spectrum	AENCF (MeV)	0.055	0.2072	0.1328	0.0655	0.1554
	H/X	64	8	16	64	8
	Experiment >	**IECT121**	**IECT122**	**IECT123**	**IECT124**	**IECT125**
Enrichment	U-235 (wt%)	29.83%	29.83%	29.83%	29.83%	29.83%
Density (g/cc)	U (fissile)	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U (fissionable)	3.10E+00	3.10E+00	3.10E+00	3.10E+00	3.10E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	9.25E-01	9.25E-01	9.25E-01	9.25E-01	9.25E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Experiment >	**IECT121**	**IECT122**	**IECT123**	**IECT124**	**IECT125**
	U-238	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00

Table 2.1-4. Intermediate Enriched Uranium Laboratory Critical Experiment Characterizations

Flux Spectrum	AENCF (MeV)	0.2125	0.1972	0.1277	0.133048	0.0601
	H/X	4	8	16	16	64
	Experiment >	IECT126	IECT127	IECT128	IECT129	
Enrichment	U-235 (wt%)	29.83%	29.83%	29.83%	29.83%	
Density (g/cc)	U (fissile)	9.25E-01	9.25E-01	9.25E-01	9.25E-01	
	U (fissionable)	3.10E+00	3.10E+00	3.10E+00	3.10E+00	
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
	U-235	9.25E-01	9.25E-01	9.25E-01	9.25E-01	
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
	U-238	2.18E+00	2.18E+00	2.18E+00	2.18E+00	
Flux Spectrum	AENCF (MeV)	0.0562	0.0559	0.159	0.1516	
	H/X	64	64	8	8	

Table 2.1-5. Low Enriched Uranium Laboratory Critical Experiment Characterizations

	Experiment >	LEUJA01	LEUJA14	LEUJA29	LEUJA30	LEUJA32
Concentration	U C (g/L)	310.1	313	290.4	290.7	270
Enrichment	U-235 (wt%)	9.97%	9.97%	9.97%	9.97%	9.97%
Density (g/cc)	U (fissile)	3.09E-02	3.12E-02	2.90E-02	2.90E-02	2.69E-02
	U (fissionable)	3.10E-01	3.13E-01	2.90E-01	2.91E-01	2.70E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	3.09E-02	3.12E-02	2.90E-02	2.90E-02	2.69E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.79E-01	2.82E-01	2.61E-01	2.62E-01	2.43E-01
Flux Spectrum	AENCF (MeV)	0.018964	0.02001	0.018058	0.018812	0.017567
	H/X	719	709	771	770	842
	Experiment >	**LEUJA33**	**LEUJA34**	**LEUJA36**	**LEUJA46**	**LEUJA49**
Concentration	U C (g/L)	270	253.6	253.9	241.9	241.9
Enrichment	U-235 (wt%)	9.97%	9.97%	9.97%	9.97%	9.97%
Density (g/cc)	U (fissile)	2.69E-02	2.53E-02	2.53E-02	2.41E-02	2.41E-02
	U (fissionable)	2.70E-01	2.54E-01	2.54E-01	2.42E-01	2.42E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	2.69E-02	2.53E-02	2.53E-02	2.41E-02	2.41E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.43E-01	2.28E-01	2.29E-01	2.18E-01	2.18E-01
Flux Spectrum	AENCF (MeV)	0.016621	0.015895	0.016651	0.015353	0.015933
	H/X	842	896	896	942	942
	Experiment >	**LEUJA51**	**LEUJA54**	**LEUST21**	**LEUST22**	**LEUST23**
Concentration	U C (g/L)	233.2	225.3	452.2	491.7	491.7
Enrichment	U-235 (wt%)	9.97%	9.97%	4.89%	4.89%	4.89%
	Experiment >	**LEUJA51**	**LEUJA54**	**LEUST21**	**LEUST22**	**LEUST23**

Table 2.1-5. Low Enriched Uranium Laboratory Critical Experiment Characterizations

Density (g/cc)	U (fissile)	2.33E-02	2.25E-02	2.21E-02	2.40E-02	2.40E-02
	U (fissionable)	2.33E-01	2.25E-01	4.52E-01	4.92E-01	4.92E-01
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	9.00E-05	9.80E-05	9.80E-05
	U-235	2.33E-02	2.25E-02	2.21E-02	2.40E-02	2.40E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	2.10E-01	2.03E-01	4.30E-01	4.68E-01	4.68E-01
Flux Spectrum	AENCF (MeV)	0.014792	0.014396	0.024872	0.028323	0.026654
	H/X	983	1018	1098	1001	1001

Table 2.1-6. ^{233}U Laboratory Critical Experiment Characterizations

	Experiment >	u2331a	u2332a	u2332b	u2333a	u2333b
Concentration	U C (g/L)	18424	18621	18644	18621	18644
Enrichment	U-235 (wt%)	0.03%	44.80%	61.66%	0.19%	0.25%
	U-233 (wt%)	98.11%	51.00%	33.23%	31.55%	9.73%
Density (g/cc)	U (fissile)	1.81E+01	1.79E+01	1.78E+01	5.96E+00	1.88E+00
	U (fissionable)	1.84E+01	1.87E+01	1.87E+01	1.88E+01	1.88E+01
Isotopes (g/cc)	U-233	1.81E+01	9.54E+00	6.23E+00	5.92E+00	1.83E+00
	U-234	2.29E-01	1.07E-01	6.98E-02	6.63E-02	2.05E-02
	U-235	5.57E-03	8.38E+00	1.16E+01	3.58E-02	4.77E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.13E-01	6.79E-01	8.88E-01	1.27E+01	1.69E+01
Flux Spectrum	AENCF (MeV)	1.773851	1.737015	1.707885	1.748316	1.762311
	H/X	0	0	0	0	0

	Experiment >	u2334a1	u2334b1	u2335a	u2335b	u2336a
Concentration	U C (g/L)	18621	18644	18621	18644	18420
Enrichment	U-235 (wt%)	0.00%	0.00%	0.00%	0.00%	0.72%
	U-233 (wt%)	98.20%	98.20%	98.20%	98.20%	0.50%
Density (g/cc)	U (fissile)	1.83E+01	1.83E+01	1.83E+01	1.83E+01	2.32E-01
	U (fissionable)	1.86E+01	1.86E+01	1.86E+01	1.86E+01	1.90E+01
Isotopes (g/cc)	U-233	1.83E+01	1.83E+01	1.83E+01	1.83E+01	9.58E-02
	U-234	2.05E-01	2.05E-01	2.05E-01	2.05E-01	1.21E-03
	U-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.36E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.30E-01	1.31E-01	1.30E-01	1.31E-01	1.88E+01
Flux Spectrum	AENCF (MeV)	1.611865	1.517767	1.619497	1.518707	1.77403
	H/X	0	0	0	0	0

Experiment >	u233s1	u233s2	u233s3	u233s4	u233s5

Table 2.1-6. ^{233}U Laboratory Critical Experiment Characterizations

Concentration	U C (g/L)	17.14	17.86	18.52	19.18	19.82
Enrichment	U-235 (wt%)	0.00%	0.04%	0.04%	0.04%	0.04%
	U-233 (wt%)	99.35%	97.70%	97.70%	97.70%	97.70%
Density (g/cc)	U (fissile)	1.67E-02	1.75E-02	1.81E-02	1.87E-02	1.94E-02
	U (fissionable)	1.69E-02	1.79E-02	1.85E-02	1.92E-02	1.98E-02
Isotopes (g/cc)	U-233	1.67E-02	1.75E-02	1.81E-02	1.87E-02	1.94E-02
	U-234	0.00E+00	2.89E-04	3.00E-04	3.11E-04	3.21E-04
	U-235	0.00E+00	7.00E-06	7.00E-06	8.00E-06	8.00E-06
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	1.10E-04	1.14E-04	1.19E-04	1.23E-04	1.27E-04
Flux Spectrum	AENCF (MeV)	0.03738	0.003903	0.004022	0.004325	0.004352
	H/X	1531	1471	1419	1369	1325

Experiment >		u233s6
Concentration	U C (g/L)	13.25
Enrichment	U-235 (wt%)	0.03%
	U-233 (wt%)	97.67%
Density (g/cc)	U (fissile)	1.29E-02
	U (fissionable)	1.33E-02
Isotopes (g/cc)	U-233	1.29E-02
	U-234	2.04E-04
	U-235	4.00E-06
	U-237	0.00E+00
	U-238	1.01E-04
Flux Spectrum	AENCF (MeV)	0.003012
	H/X	1984

2.2 Description of Lattice LCEs

The LCEs presented in this section represent moderated lattice configurations containing fissile oxide fuel. All of the LCEs in this section are fresh fuel experiments. The LCE lattice configurations are described in Reference 6.

Table 2.2-1. Mixed Oxide Lattice Laboratory Critical Experiment Characterizations

	Experiment >	exp22	exp23	exp24	exp25	exp26
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (P) (cm)	1.778	1.778	2.21	2.21	2.515
	Fuel Diameter (D) (cm)	1.283	1.283	1.283	1.283	1.283
	P/D Ratio	1.39	1.39	1.72	1.72	1.96
Enrichment	U-235 (wt%)	0.71%	0.71%	0.71%	0.71%	0.71%
	Pu-239 (wt%)	91.84%	91.84%	91.84%	91.84%	91.84%
Density (g/cc)	U (fissile)	5.81E-02	5.81E-02	5.81E-02	5.81E-02	5.81E-02
	U (fissionable)	8.21E+00	8.21E+00	8.21E+00	8.21E+00	8.21E+00
	Pu (fissile)	1.57E-01	1.57E-01	1.57E-01	1.57E-01	1.57E-01
	Pu (fissionable)	1.70E-01	1.70E-01	1.70E-01	1.70E-01	1.70E-01
	Total (fissile)	2.15E-01	2.15E-01	2.15E-01	2.15E-01	2.15E-01
	Total (fissionable)	8.38E+00	8.38E+00	8.38E+00	8.38E+00	8.38E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	4.84E-04	4.84E-04	4.84E-04	4.84E-04	4.84E-04
	U-235	5.81E-02	5.81E-02	5.81E-02	5.81E-02	5.81E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	8.15E+00	8.15E+00	8.15E+00	8.15E+00	8.15E+00
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05
	Pu-239	1.56E-01	1.56E-01	1.56E-01	1.56E-01	1.56E-01
	Pu-240	1.32E-02	1.32E-02	1.32E-02	1.32E-02	1.32E-02
	Pu-241	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04
	Pu-242	4.80E-05	4.80E-05	4.80E-05	4.80E-05	4.80E-05
	Am-241	6.00E-04	6.00E-04	6.00E-04	6.00E-04	6.00E-04

Table 2.2-1. Mixed Oxide Lattice Laboratory Critical Experiment Characterizations

	Experiment >	exp22	exp23	exp24	exp25	exp26
Flux Spectrum	AENCF (MeV)	0.255567	0.273969	0.161276	0.189442	0.131923
	Experiment >	**exp27**	**exp28**	**exp29**	**exp30**	**exp31**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	2.515	1.321	1.422	1.422	1.867
	Fuel Diameter (cm)	1.283	0.857	0.857	0.857	0.857
	P/D Ratio	1.96	1.54	1.66	1.66	2.18
Enrichment	U-235 (wt%)	0.71%	0.71%	0.71%	0.71%	0.71%
	Pu-239 (wt%)	91.84%	90.50%	90.50%	90.50%	90.50%
Density (g/cc)	U (fissile)	5.81E-02	5.96E-02	5.96E-02	5.96E-02	5.96E-02
	U (fissionable)	8.21E+00	8.39E+00	8.39E+00	8.39E+00	8.39E+00
	Pu (fissile)	1.57E-01	5.42E-01	5.42E-01	5.42E-01	5.42E-01
	Pu (fissionable)	1.70E-01	5.93E-01	5.93E-01	5.93E-01	5.93E-01
	Total (fissile)	2.15E-01	6.02E-01	6.02E-01	6.02E-01	6.02E-01
	Total (fissionable)	8.38E+00	8.98E+00	8.98E+00	8.98E+00	8.98E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	4.84E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	5.81E-02	5.96E-02	5.96E-02	5.96E-02	5.96E-02
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	8.15E+00	8.33E+00	8.33E+00	8.33E+00	8.33E+00
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	1.50E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-239	1.56E-01	5.37E-01	5.37E-01	5.37E-01	5.37E-01
	Pu-240	1.32E-02	5.08E-02	5.08E-02	5.08E-02	5.08E-02
	Pu-241	6.25E-04	5.28E-03	5.28E-03	5.28E-03	5.28E-03
	Pu-242	4.80E-05	2.34E-04	2.34E-04	2.34E-04	2.34E-04
	Am-241	6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.153718	0.229279	0.191841	0.200936	0.120431
	Experiment >	**exp32**	**exp33**	**exp34**		

Table 2.2-1. Mixed Oxide Lattice Laboratory Critical Experiment Characterizations

Geometry	Pitch Type	Square	Square	Triangular
	Rod Pitch (cm)	2.012	2.642	1.598
	Fuel Diameter (cm)	0.857	0.857	1.271
	P/D Ratio	2.35	3.08	1.26
Enrichment	U-235 (wt%)	0.71%	0.71%	2.58%
	Pu-239 (wt%)	90.50%	90.50%	91.84%
Density (g/cc)	U (fissile)	5.96E-02	5.96E-02	2.24E-01
	U (fissionable)	8.39E+00	8.39E+00	8.67E+00
	Pu (fissile)	5.42E-01	5.42E-01	7.96E-02
	Pu (fissionable)	5.93E-01	5.93E-01	8.63E-02
	Total (fissile)	6.02E-01	6.02E-01	3.04E-01
	Total (fissionable)	8.98E+00	8.98E+00	8.76E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	1.22E-03
	U-235	5.96E-02	5.96E-02	2.24E-01
	U-237	0.00E+00	0.00E+00	0.00E+00
	U-238	8.33E+00	8.33E+00	8.45E+00
	Pu-237	0.00E+00	0.00E+00	0.00E+00
	Pu-238	0.00E+00	0.00E+00	8.00E-06
	Pu-239	5.37E-01	5.37E-01	7.93E-02
	Pu-240	5.08E-02	5.08E-02	6.70E-03
	Pu-241	5.28E-03	5.28E-03	3.17E-04
	Pu-242	2.34E-04	2.34E-04	2.40E-05
	Am-241	0.00E+00	0.00E+00	3.12E-04
Flux Spectrum	AENCF (MeV)	0.107321	0.079640	0.377618

Table 2.2-2. Uranium Oxide Lattice Laboratory Critical Experiment Characterizations

	Experiment >	core2	core3	core4	core5	core6
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.63576	1.63576	1.63576	1.63576	1.63576
	Fuel Diameter (cm)	1.03	1.03	1.03	1.03	1.03
	P/D Ratio	1.59	1.59	1.59	1.59	1.59
Enrichment	U-235 (wt%)	2.46%	2.46%	2.46%	2.46%	2.46%
Density (g/cc)	U (fissile)	2.22E-01	2.22E-01	2.22E-01	2.22E-01	2.22E-01
	U (fissionable)	9.01E+00	9.01E+00	9.01E+00	9.01E+00	9.01E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	2.22E-01	2.22E-01	2.22E-01	2.22E-01	2.22E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	8.79E+00	8.79E+00	8.79E+00	8.79E+00	8.79E+00
Flux Spectrum	AENCF (MeV)	0.199882	0.180775	0.179075	0.169188	0.172157
	Experiment >	core7	core8	core9	core10	core11
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.63576	1.63576	1.63576	1.63576	1.63576
	Fuel Diameter (cm)	1.03	1.03	1.03	1.03	1.03
	P/D Ratio	1.59	1.59	1.59	1.59	1.59
Enrichment	U-235 (wt%)	2.46%	2.46%	2.46%	2.46%	2.46%
Density (g/cc)	U (fissile)	2.22E-01	2.22E-01	2.22E-01	2.22E-01	2.22E-01
	U (fissionable)	9.01E+00	9.01E+00	9.01E+00	9.01E+00	9.01E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	2.22E-01	2.22E-01	2.22E-01	2.22E-01	2.22E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	8.79E+00	8.79E+00	8.79E+00	8.79E+00	8.79E+00
	Experiment >	core7	core8	core9	core10	core11

Table 2.2-2. Uranium Oxide Lattice Laboratory Critical Experiment Characterizations

Flux Spectrum	AENCF (MeV)	0.159626	0.164962	0.155275	0.160364	0.178931
	Experiment >	core12	core13	core15	core16	core17
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.63576	1.63576	1.63576	1.63576	1.63576
	Fuel Diameter (cm)	1.03	1.03	1.03	1.03	1.03
	P/D Ratio	1.59	1.59	1.59	1.59	1.59
Enrichment	U-235 (wt%)	2.46%	2.46%	2.46%	2.46%	2.46%
Density (g/cc)	U (fissile)	2.22E-01	2.22E-01	2.22E-01	2.22E-01	2.22E-01
	U (fissionable)	9.01E+00	9.01E+00	9.01E+00	9.01E+00	9.01E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	2.22E-01	2.22E-01	2.22E-01	2.22E-01	2.22E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	8.79E+00	8.79E+00	8.79E+00	8.79E+00	8.79E+00
Flux Spectrum	AENCF (MeV)	0.166711	0.180752	0.183477	0.169517	0.18187
	Experiment >	core18	core19	core20	core21	exp1
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.63576	1.63576	1.63576	1.63576	2.032
	Fuel Diameter (cm)	1.03	1.03	1.03	1.03	1.1176
	P/D Ratio	1.59	1.59	1.59	1.59	1.82
Enrichment	U-235 (wt%)	2.46%	2.46%	2.46%	2.46%	2.35%
Density (g/cc)	U (fissile)	2.22E-01	2.22E-01	2.22E-01	2.22E-01	1.91E-01
	U (fissionable)	9.01E+00	9.01E+00	9.01E+00	9.01E+00	8.11E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.51E-04
	U-235	2.22E-01	2.22E-01	2.22E-01	2.22E-01	1.91E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Experiment >	core18	core19	core20	core21	exp1
	U-238	8.79E+00	8.79E+00	8.79E+00	8.79E+00	7.92E+00

Table 2.2-2. Uranium Oxide Lattice Laboratory Critical Experiment Characterizations

Flux Spectrum	AENCF (MeV)	0.16855	0.183538	0.169332	0.162252	0.120951
	Experiment >	**exp2**	**exp3**	**exp4**	**exp5**	**exp6**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	2.032	2.032	2.032	1.892	1.892
	Fuel Diameter (cm)	1.1176	1.1176	1.1176	1.2649	1.2649
	P/D Ratio	1.82	1.82	1.82	1.50	1.50
Enrichment	U-235 (wt%)	2.35%	2.35%	2.35%	4.31%	4.31%
Density (g/cc)	U (fissile)	1.91E-01	1.91E-01	1.91E-01	3.98E-01	3.98E-01
	U (fissionable)	8.11E+00	8.11E+00	8.11E+00	9.23E+00	9.23E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	4.51E-04	4.51E-04	4.51E-04	3.48E-03	3.48E-03
	U-235	1.91E-01	1.91E-01	1.91E-01	3.98E-01	3.98E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	7.92E+00	7.92E+00	7.92E+00	8.83E+00	8.83E+00
Flux Spectrum	AENCF (MeV)	0.124688	0.121718	0.120029	0.279679	0.176621
	Experiment >	**exp7**	**exp8**	**exp9**	**exp10**	**exp11**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.892	1.89	1.89	1.715	1.715
	Fuel Diameter (cm)	1.2649	1.2649	1.2649	1.2649	1.2649
	P/D Ratio	1.50	1.49	1.49	1.36	1.36
Enrichment	U-235 (wt%)	4.31%	4.31%	4.31%	4.31%	4.31%
Density (g/cc)	U (fissile)	3.98E-01	3.98E-01	3.98E-01	3.98E-01	3.98E-01
	U (fissionable)	9.23E+00	9.23E+00	9.23E+00	9.23E+00	9.23E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	3.48E-03	3.48E-03	3.48E-03	3.48E-03	3.48E-03
	U-235	3.98E-01	3.98E-01	3.98E-01	3.98E-01	3.98E-01
	Experiment >	**exp7**	**exp8**	**exp9**	**exp10**	**exp11**
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 2.2-2. Uranium Oxide Lattice Laboratory Critical Experiment Characterizations

	U-238	8.83E+00	8.83E+00	8.83E+00	8.83E+00	8.83E+00
Flux Spectrum	AENCF (MeV)	0.178401	0.177353	0.221705	0.223902	0.266427
	Experiment >	**exp12**	**exp13**	**exp14**	**exp15**	**exp17**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.891	1.891	1.526	2.21	1.422
	Fuel Diameter (cm)	1.265	1.265	1.1176	1.1176	0.907
	P/D Ratio	1.49	1.49	1.37	1.98	1.57
Enrichment	U-235 (wt%)	4.31%	4.31%	2.35%	2.35%	5.74%
Density (g/cc)	U (fissile)	3.97E-01	3.97E-01	1.93E-01	1.93E-01	5.09E-01
	U (fissionable)	9.22E+00	9.22E+00	8.21E+00	8.21E+00	8.87E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	2.03E-03	2.03E-03	1.13E-03	1.13E-03	0.00E+00
	U-235	3.97E-01	3.97E-01	1.93E-01	1.93E-01	5.09E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	8.82E+00	8.82E+00	8.02E+00	8.02E+00	8.36E+00
Flux Spectrum	AENCF (MeV)	0.194612	0.194207	0.209445	0.109843	0.156366
	Experiment >	**exp18**	**ugd1**	**ugd2**	**ugd3**	**ugd4**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	2.012	1.636	1.636	1.636	1.636
	Average Fuel Diameter (cm)	0.907	1.03	1.03	1.03	1.03
	P/D Ratio	2.22	1.59	1.59	1.59	1.59
Enrichment	U-235 (Avg. wt%)	5.74%	2.46%	2.46%	2.46%	2.46%
Density (g/cc)	U (fissile)	5.09E-01	2.33E-01	2.33E-01	2.32E-01	2.32E-01
	U (fissionable)	8.87E+00	9.46E+00	9.46E+00	9.46E+00	9.46E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Experiment >	**exp18**	**ugd1**	**ugd2**	**ugd3**	**ugd4**
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	5.09E-01	2.33E-01	2.33E-01	2.32E-01	2.32E-01

Table 2.2-2. Uranium Oxide Lattice Laboratory Critical Experiment Characterizations

	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	8.36E+00	9.23E+00	9.23E+00	9.23E+00	9.23E+00
Flux Spectrum	AENCF (MeV)	0.088632	0.201321	0.198281	0.199481	0.199852
	Experiment >	**ugd5**	**ugd6**	**ugd7**	**ugd8**	**ugd9**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.636	1.636	1.636	1.636	1.636
	Average Fuel Diameter (cm)	1.03	1.03	1.03	1.03	1.03
	P/D Ratio	1.59	1.59	1.59	1.59	1.59
Enrichment	U-235 (Avg. wt%)	2.46%	2.46%	2.46%	2.46%	2.46%
Density (g/cc)	U (fissile)	2.32E-01	2.32E-01	2.32E-01	2.32E-01	2.32E-01
	U (fissionable)	9.46E+00	9.46E+00	9.46E+00	9.46E+00	9.46E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	2.32E-01	2.32E-01	2.32E-01	2.32E-01	2.32E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	9.23E+00	9.23E+00	9.23E+00	9.23E+00	9.23E+00
Flux Spectrum	AENCF (MeV)	0.197517	0.197747	0.196752	0.197561	0.198726
	Experiment >	**ugd10**	**ugd12**	**ugd13**	**ugd14**	**ugd15**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.636	1.636	1.636	1.636	1.636
	Average Fuel Diameter (cm)	1.03	1.048	1.048	1.047	1.047
	P/D Ratio	1.59	1.56	1.56	1.56	1.56
Enrichment	U-235 (Avg. wt%)	2.46%	2.82%	2.82%	2.81%	2.81%
Density (g/cc)	U (fissile)	2.32E-01	2.67E-01	2.67E-01	2.65E-01	2.65E-01
	Experiment >	**ugd10**	**ugd12**	**ugd13**	**ugd14**	**ugd15**
	U (fissionable)	9.46E+00	9.46E+00	9.46E+00	9.46E+00	9.46E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 2.2-2. Uranium Oxide Lattice Laboratory Critical Experiment Characterizations

	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	2.32E-01	2.67E-01	2.67E-01	2.65E-01	2.65E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	9.23E+00	9.19E+00	9.19E+00	9.20E+00	9.20E+00
Flux Spectrum	AENCF (MeV)	0.201104	0.209648	0.208409	0.204162	0.2056
	Experiment >	**ugd16**	**ugd17**	**ugd18**	**ugd19**	**ugd20**
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch (cm)	1.636	1.636	1.636	1.636	1.636
	Average Fuel Diameter (cm)	1.047	1.047	1.05	1.05	1.049
	P/D Ratio	1.56	1.56	1.56	1.56	1.56
Enrichment	U-235 (Avg. wt%)	2.80%	2.80%	2.86%	2.85%	2.84%
Density (g/cc)	U (fissile)	2.65E-01	2.65E-01	2.70E-01	2.69E-01	2.69E-01
	U (fissionable)	9.46E+00	9.46E+00	9.46E+00	9.46E+00	9.46E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-235	2.65E-01	2.65E-01	2.70E-01	2.69E-01	2.69E-01
	U-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-238	9.20E+00	9.20E+00	9.19E+00	9.19E+00	9.19E+00
Flux Spectrum	AENCF (MeV)	0.20648	0.203413	0.208511	0.210113	0.20698

2.3 Description of CRCs

The CRCs discussed in this section represent Pressurized Water Reactor (PWR) critical state points. All of the PWR fuel is initially low enriched uranium oxide. The state points relate to various "burnup" points for various cycles in four different reactors as shown in Table 2.3-1 and Table 2.3-2. The CRC configurations are described in References 7 through 14 and are summarized in Table 2.3-3. (Note: EFPD = Effective Full Power Days)

Table 2.3-1. Commercial Reactor Criticals State Points

State Point	Reactor	Cycle	Time of Measurement EFPD
1	Crystal River, Unit #3	1a	0.0
2	Crystal River, Unit #3	1b	268.8
3	Crystal River, Unit #3	1b	411.0
4	Crystal River, Unit #3	2	0.0
5	Crystal River, Unit #3	3	0.0
6	Crystal River, Unit #3	3	168.5
7	Crystal River, Unit #3	3	250.0
8	Crystal River, Unit #3	4	0.0
9	Crystal River, Unit #3	4	228.1
10	Crystal River, Unit #3	4	253.0
11	Crystal River, Unit #3	5	0.0
12	Crystal River, Unit #3	5	388.5
13	Crystal River, Unit #3	6	0.0
14	Crystal River, Unit #3	6	96.0
15	Crystal River, Unit #3	6	400.0
16	Crystal River, Unit #3	7	0.0
17	Crystal River, Unit #3	7	260.3
18	Crystal River, Unit #3	7	291.0
19	Crystal River, Unit #3	7	319.0
20	Crystal River, Unit #3	7	462.3
21	Crystal River, Unit #3	7	479.0
22	Crystal River, Unit #3	8	0.0
23	Crystal River, Unit #3	8	97.6
24	Crystal River, Unit #3	8	139.8
25	Crystal River, Unit #3	8	404.0
26	Crystal River, Unit #3	8	409.6
27	Crystal River, Unit #3	8	515.5

Table 2.3-1. Commercial Reactor Criticals State Points

State Point	Reactor	Cycle	Time of Measurement EFPD
28	Crystal River, Unit #3	9	0.0
29	Crystal River, Unit #3	9	158.8
30	Crystal River, Unit #3	9	219.0
31	Crystal River, Unit #3	9	363.1
32	Crystal River, Unit #3	10	0.0
33	Crystal River, Unit #3	10	573.7
36	Sequoyah, Unit #2	1	0.0
37	Sequoyah, Unit #2	3	0.0
38	Sequoyah, Unit #2	3	210.9
46	McGuire, Unit #1	1	0.0
47	McGuire, Unit #1	6	0.0
48	McGuire, Unit #1	6	62.4
49	McGuire, Unit #1	7	0.0
50	McGuire, Unit #1	7	129.0
51	McGuire, Unit #1	7	282.3
59	Three Mile Island, Unit #1	1	0.0
60	Three Mile Island, Unit #1	5	0.0
61	Three Mile Island, Unit #1	5	114.4

Table 2.3-2. Commercial Reactor Criticals Fuel Characterizations

State Point	Initial Enrichment (wt% ^{235}U)	Burnup (GWd/MTU)		
		Minimum	Maximum	Core Average
1	2.445	0.00	0.00	0.00
2	2.447	3.81	10.81	8.09
3	2.447	6.57	16.08	12.34
4	2.670	0.00	17.03	8.67
5	2.693	0.00	19.65	7.51
6	2.693	2.80	25.29	12.54
7	2.693	4.31	27.91	14.98
8	2.648	0.00	17.50	6.92
9	2.648	6.11	25.30	13.99
10	2.648	6.79	26.16	14.76
11	2.915	0.00	17.26	7.07
12	2.915	9.18	28.19	19.12
13	3.210	0.00	21.89	12.01
14	3.210	3.24	24.88	14.99
15	3.210	13.16	34.67	24.41
16	3.554	0.00	25.11	10.02
17	3.554	6.25	32.91	18.09
18	3.554	6.97	33.87	19.04
19	3.554	7.63	34.73	19.91
20	3.554	11.11	39.16	24.35
21	3.554	11.53	39.67	24.87
22	3.755	0.00	27.41	12.26
23	3.755	2.69	32.40	15.28
24	3.755	3.83	32.88	16.59
25	3.755	10.84	35.97	24.78
26	3.755	10.99	36.04	24.96
27	3.755	13.86	39.15	28.24

Table 2.3-2. Commercial Reactor Criticals Fuel Characterizations

State Point	Initial Enrichment (wt% ^{235}U)	Burnup (GWd/MTU)		
		Minimum	Maximum	Core Average
28	3.892	0.00	34.78	14.18
29	3.892	5.08	36.52	19.11
30	3.892	6.95	37.20	20.97
31	3.892	11.41	40.25	25.44
32	4.015	0.00	35.25	15.27
33	4.015	17.64	49.22	33.06
36	2.535	0.00	0.00	0.00
37	3.430	0.00	26.91	11.10
38	3.430	7.36	34.42	19.20
46	2.602	0.00	0.00	0.00
47	3.472	0.00	28.12	11.74
48	3.472	2.11	30.56	14.34
49	3.618	0.00	27.22	10.79
50	3.618	4.13	31.66	16.17
51	3.618	8.95	38.11	22.56
59	2.633	0.00	0.00	0.00
60	2.820	0.00	24.86	10.33
61	2.820	2.26	27.84	13.87

Table 2.3-3. Commercial Reactor Criticals Summary Table

	State Point >	9	10	11	16	17
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch in Assembly (P) (cm)	1.44	1.44	1.44	1.44	1.44
	Average Rod Diameter (D) (cm)	0.94	0.94	0.94	0.94	0.94
	P/D Ratio	1.53	1.53	1.53	1.53	1.53
Enrichment	U-235 (wt%)	1.44	1.39	2.19	2.58	1.96
Density (g/cc)	U (fissile)	1.27E-01	1.22E-01	1.95E-01	2.29E-01	1.71E-01
	U (fissionable)	8.79E+00	8.78E+00	8.87E+00	8.83E+00	8.71E+00
	Pu (fissile)	4.23E-02	4.34E-02	2.48E-02	2.77E-02	4.67E-02
	Pu (fissionable)	5.39E-02	5.57E-02	3.06E-02	3.54E-02	6.00E-02
	Total (fissile)	1.69E-01	1.66E-01	2.20E-01	2.57E-01	2.18E-01
	Total (fissionable)	8.85E+00	8.84E+00	8.90E+00	8.87E+00	8.78E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	1.55E-03	1.53E-03	1.95E-03	2.33E-03	2.05E-03
	U-235	1.27E-01	1.22E-01	1.95E-01	2.29E-01	1.71E-01
	U-237	1.00E-05	4.00E-06	0.00E+00	0.00E+00	8.00E-06
	U-238	8.66E+00	8.66E+00	8.67E+00	8.60E+00	8.54E+00
	Np-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Np-236	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Np-237	1.43E-03	1.52E-03	6.82E-04	1.07E-03	1.98E-03
	Np-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	2.97E-04	3.28E-04	1.00E-04	2.13E-04	5.21E-04
	Pu-239	3.74E-02	3.82E-02	2.25E-02	2.46E-02	4.09E-02
	Pu-240	1.01E-02	1.07E-02	5.30E-03	6.74E-03	1.12E-02
	Pu-241	4.86E-03	5.14E-03	2.29E-03	3.09E-03	5.78E-03
	Pu-242	1.21E-03	1.34E-03	3.79E-04	7.08E-04	1.60E-03

Table 2.3-3. Commercial Reactor Criticals Summary Table

	State Point ➢	9	10	11	16	17
	Am-241	1.20E-04	1.43E-04	1.01E-04	3.50E-04	3.04E-04
	Am-242	2.00E-06	2.00E-06	1.00E-06	2.00E-06	6.00E-06
	Am-243	1.81E-04	2.04E-04	3.50E-05	9.00E-05	2.84E-04
	Cm-242	2.50E-05	2.60E-05	4.00E-06	9.00E-06	8.00E-05
	Cm-243	0.00E+00	1.00E-06	0.00E+00	0.00E+00	2.00E-06
	Cm-244	3.60E-05	4.20E-05	4.00E-06	1.40E-05	6.70E-05
	Cm-245	1.00E-06	1.00E-06	0.00E+00	0.00E+00	2.00E-06
	Cm-246	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cm-247	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cm-248	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.2576	0.2568	0.2475	0.2504	0.2583
	State Point ➢	18	19	23	24	25
Geometry	Pitch Type	Square	Square	Square	Square	Square
	Rod Pitch in Assembly (cm)	1.44	1.44	1.44	1.44	1.44
	Average Rod Diameter (cm)	0.94	0.94	0.94	0.94	0.94
	P/D Ratio	1.53	1.53	1.53	1.53	1.53
Enrichment	U-235 (wt%)	1.89	1.84	2.28	2.18	1.64
Density (g/cc)	U (fissile)	1.66E-01	1.60E-01	2.01E-01	1.92E-01	1.42E-01
	U (fissionable)	8.70E+00	8.69E+00	8.75E+00	8.74E+00	8.63E+00
	Pu (fissile)	4.81E-02	4.93E-02	4.19E-02	4.46E-02	5.59E-02
	Pu (fissionable)	6.23E-02	6.42E-02	5.34E-02	5.70E-02	7.52E-02
	Total (fissile)	2.14E-01	2.10E-01	2.43E-01	2.36E-01	1.98E-01
	Total (fissionable)	8.77E+00	8.76E+00	8.81E+00	8.80E+00	8.71E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	U-234	2.02E-03	1.99E-03	2.25E-03	2.20E-03	1.94E-03
	U-235	1.66E-01	1.60E-01	2.01E-01	1.92E-01	1.42E-01
	State Point ➢	18	19	23	24	25

Table 2.3-3. Commercial Reactor Criticals Summary Table

	U-237	1.00E-06	0.00E+00	1.00E-05	2.70E-05	1.00E-06
	U-238	8.54E+00	8.53E+00	8.55E+00	8.54E+00	8.49E+00
	Np-235	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Np-236	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Np-237	2.11E-03	2.23E-03	1.78E-03	1.92E-03	3.03E-03
	Np-238	0.00E+00	0.00E+00	0.00E+00	1.00E-06	0.00E+00
	Pu-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Pu-238	5.82E-04	6.55E-04	4.26E-04	4.83E-04	9.66E-04
	Pu-239	4.20E-02	4.29E-02	3.69E-02	3.91E-02	4.75E-02
	Pu-240	1.19E-02	1.24E-02	9.75E-03	1.05E-02	1.56E-02
	Pu-241	6.11E-03	6.37E-03	5.00E-03	5.45E-03	8.44E-03
	Pu-242	1.75E-03	1.88E-03	1.27E-03	1.43E-03	2.74E-03
	Am-241	3.36E-04	4.27E-04	4.08E-04	4.04E-04	4.64E-04
	Am-242	6.00E-06	7.00E-06	8.00E-06	8.00E-06	9.00E-06
	Am-243	3.17E-04	3.50E-04	2.06E-04	2.40E-04	5.47E-04
	Cm-242	7.30E-05	5.00E-05	5.50E-05	6.80E-05	9.60E-05
	Cm-243	2.00E-06	2.00E-06	1.00E-06	1.00E-06	3.00E-06
	Cm-244	7.80E-05	8.80E-05	4.10E-05	5.00E-05	1.51E-04
	Cm-245	3.00E-06	3.00E-06	1.00E-06	2.00E-06	6.00E-06
	Cm-246	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-06
	Cm-247	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Cm-248	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.2598	0.2587	0.2572	0.2582	0.2615

State Point >		26	27
Geometry	Pitch Type	Square	Square
	Rod Pitch in Assembly (cm)	1.44	1.44

State Point >	26	27

Table 2.3-3. Commercial Reactor Criticals Summary Table

	Average Rod Diameter (cm)	0.94	0.94
	P/D Ratio	1.53	1.53
Enrichment	U-235 (wt%)	1.63	1.45
Density (g/cc)	U (fissile)	1.42E-01	1.25E-01
	U (fissionable)	8.63E+00	8.59E+00
	Pu (fissile)	5.59E-02	5.83E-02
	Pu (fissionable)	7.53E-02	8.06E-02
	Total (fissile)	1.97E-01	1.83E-01
	Total (fissionable)	8.71E+00	8.67E+00
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00
	U-234	1.93E-03	1.84E-03
	U-235	1.41E-01	1.25E-01
	U-237	1.80E-05	3.20E-05
	U-238	8.49E+00	8.46E+00
	Np-235	0.00E+00	0.00E+00
	Np-236	0.00E+00	0.00E+00
	Np-237	3.03E-03	3.46E-03
	Np-238	1.00E-06	1.00E-06
	Pu-237	0.00E+00	0.00E+00
	Pu-238	9.77E-04	1.21E-03
	Pu-239	4.74E-02	4.87E-02
	Pu-240	1.57E-02	1.76E-02
	Pu-241	8.49E-03	9.60E-03
	Pu-242	2.78E-03	3.48E-03
	Am-241	4.70E-04	4.92E-04
	Am-242	9.00E-06	1.00E-05
	Am-243	5.55E-04	7.36E-04
State Point →		**26**	**27**

Table 2.3-3. Commercial Reactor Criticals Summary Table

	Cm-242	9.50E-05	1.19E-04
	Cm-243	3.00E-06	4.00E-06
	Cm-244	1.54E-04	2.24E-04
	Cm-245	6.00E-06	9.00E-06
	Cm-246	1.00E-06	1.00E-06
	Cm-247	0.00E+00	0.00E+00
	Cm-248	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.2610	0.2643

Note: Only 12 CRC output files were available for review at the time of this writing.

Table 2.3-4 is a summary of the data from all 45 CRCs. The gram density data in Table 2.3-4 is limited to the twelve CRCs described in Table 2.3-3. The AENCF data includes the six McGuire state points in addition to the twelve Crystal River state points described in Table 2.3-3.

Table 2.3-4. Commercial Reactor Critical Characterizations

		Minimum	Maximum
Geometry	Pitch Type	Square Pitch	
	Rod Pitch (cm)	1.26	1.44
	Rod Diameter (cm)	0.78	0.94
	P/D Ratio	1.53	1.61
Fuel	Initial Enrichment (wt% U-235)	1.93	4.17
	State Point Enrichment (wt% U-235)	1.39	2.58
	Burnup – Minimum	0.00	17.64
	Burnup – Maximum	0.00	49.22
	Burnup – Core Average	0.00	33.06
Density (g/cc)	U (fissile)	0.12	0.23
	U (fissionable)	8.59	8.87
	Pu (fissile)	0.02	0.06
	Pu (fissionable)	0.03	0.08
	Total (fissile)	0.17	0.26
	Total (fissionable)	8.67	8.90
Isotopes (g/cc)	U-233	0.00E+00	0.00E+00
	U-234	1.53E-03	2.33E-03
	U-235	1.22E-01	2.29E-01
	U-237	0.00E+00	3.20E-05
	U-238	8.46E+00	8.67E+00
	Np-235	0.00E+00	0.00E+00
	Np-236	0.00E+00	0.00E+00
	Np-237	6.82E-04	3.46E-03
	Np-238	0.00E+00	1.00E-06
	Pu-237	0.00E+00	0.00E+00
	Pu-238	1.00E-04	1.21E-03
	Pu-239	2.25E-02	4.87E-02

Table 2.3-4. Commercial Reactor Critical Characterizations

		Minimum	Maximum
	Pu-240	5.30E-03	1.76E-02
	Pu-241	2.29E-03	9.60E-03
	Pu-242	3.79E-04	3.48E-03
	Am-241	1.01E-04	4.92E-04
	Am-242	1.00E-06	1.00E-05
	Am-243	3.50E-05	7.36E-04
	Cm-242	4.00E-06	1.19E-04
	Cm-243	0.00E+00	4.00E-06
	Cm-244	4.00E-06	2.24E-04
	Cm-245	0.00E+00	9.00E-06
	Cm-246	0.00E+00	1.00E-06
	Cm-247	0.00E+00	0.00E+00
	Cm-248	0.00E+00	0.00E+00
Flux Spectrum	AENCF (MeV)	0.2475	0.2643

2.4 Summary of the Benchmark and Repository Calculations

The repository data presented in Table 2.4-1 and Table 2.4-2 are the expected values. These are taken from References 15 through 19. Table 2.4-1 is a comparison table for modeled materials. An "x" in the repository column represents the inclusion of the material in repository models. "N/A" in the Repository Calculations column indicates "not applicable." No attempt is made to quantify the gram densities for the repository models.

Table 2.4-1. Materials Modeled in Significant Quantities (i.e., ≥ 5x 10^{-7} atoms/b cm)

		LCEs		CRCs*	Repository Calculations
		Homogeneous	Lattice		
Total Number of Models >>		270	68	18	N/A
Materials	H-1	260	68	18	x
	H-3	0	0	17	
	He-4	0	0	13	

Table 2.4-1. Materials Modeled in Significant Quantities (i.e., ≥ 5x 10^{-7} atoms/b cm)

		LCEs		CRCs*	Repository Calculations
		Homogeneous	Lattice		
Materials (continued)	Li-6	13	0	0	
	Li-7	9	0	0	
	Be-9	2	0	0	
	B-10	24	47	18	x
	B-11	16	47	18	x
	C	58	8	18	x
	C-12	76	51	0	
	N-14	228	21	18	x
	O-16	262	68	18	x
	F-19	35	0	0	
	Na-23	49	1	0	
	Mg	49	56	0	
	Al-27	119	68	18	x
	Si	129	68	18	x
	P-31	67	34	18	x
	S-32	73	53	18	x
	Cl	27	0	0	
	K	49	0	0	
	Ca	49	10	0	
	Ti	80	68	18	x
	Cr	0	0	0	x
	Cr-50	163	68	18	
	Cr-52	163	68	18	
	Cr-53	163	68	18	
	Cr-54	163	68	18	
	Mn-55	124	68	18	x
	Fe	0	0	0	x

Table 2.4-1. Materials Modeled in Significant Quantities (i.e., $\geq 5 \times 10^{-7}$ atoms/b cm)

		LCEs		CRCs*	Repository Calculations
		Homogeneous	Lattice		
Materials (continued)	Fe-54	197	68	18	
	Fe-56	202	68	18	
	Fe-57	197	68	18	
	Fe-58	197	68	18	
	Co-59	0	10	18	x
	Ni	0	0	0	x
	Ni-58	173	41	18	
	Ni-60	173	41	18	
	Ni-61	173	41	18	
	Ni-62	173	41	18	
	Ni-64	173	41	18	
	Cu-63	29	68	18	
	Cu-65	29	68	18	
	Ga	3	0	0	
	As-75	0	0	17	
	Kr-80	0	0	0	
	Kr-82	0	0	17	
	Kr-83	0	0	17	
	Kr-84	0	0	17	
	Kr-86	0	0	17	
	Y-89	0	0	17	
	Zr	11	13	18	x
	Zr-93	0	0	17	
	Nb-93	0	0	17	x
	Mo	23	11	18	x
	Mo-95	0	0	17	x
	Tc-99	0	0	17	x

Table 2.4-1. Materials Modeled in Significant Quantities (i.e., ≥ 5x 10^{-7} atoms/b cm)

		LCEs		CRCs*	Repository Calculations
		Homogeneous	Lattice		
Materials (continued)	Ru-101	0	0	17	x
	Ru-103	0	0	17	
	Rh-103	0	0	17	x
	Rh-105	0	0	3	
	Pd-105	0	0	17	
	Pd-108	0	0	17	
	Ag-107	0	19	15	
	Ag-109	0	19	18	x
	Cd	28	19	18	
	In	0	19	18	
	Sn	0	13	18	x
	Xe-131	0	0	17	
	Xe-134	0	0	17	
	Xe-135	0	0	0	
	Cs-133	0	0	17	
	Cs-135	0	0	17	
	Ba-138	9	0	17	
	Pr-141	0	0	17	
	Nd-143	0	0	17	x
	Nd-145	0	0	17	x
	Nd-147	0	0	13	
	Nd-148	0	0	17	
	Pm-147	0	0	17	
	Pm-148	0	0	9	
	Pm-149	0	0	3	
	Sm-147	0	0	17	x
	Sm-149	0	0	17	x

Table 2.4-1. Materials Modeled in Significant Quantities (i.e., ≥ 5x 10^{-7} atoms/b cm)

		LCEs		CRCs*	Repository Calculations
		Homogeneous	Lattice		
Materials (continued)	Sm-150	0	0	17	x
	Sm-151	0	0	17	x
	Sm-152	0	0	17	x
	Eu-151	0	0	17	x
	Eu-152	0	0	17	
	Eu-153	0	0	17	x
	Eu-154	0	0	17	
	Eu-155	0	0	17	
	Gd-152	23	19	17	
	Gd-154	23	19	17	
	Gd-155	23	19	17	x
	Gd-156	23	19	17	
	Gd-157	23	19	17	
	Gd-158	23	19	17	
	Gd-160	23	19	17	
	Ho-165	0	0	8	
	Ta-181	0	0	18	x
	Pb	0	9	0	
	Th-232	6	0	0	
	Pa-233	0	0	0	
	U-233	16	0	0	x
	U-234	131	22	18	x
	U-235	195	68	18	x
	U-236	116	18	18	x
	U-237	0	0	11	
	U-238	197	68	18	x
	Np-235	0	0	0	

Table 2.4-1. Materials Modeled in Significant Quantities (i.e., ≥ 5x 10^{-7} atoms/b cm)

		LCEs		CRCs*	Repository Calculations
		Homogeneous	Lattice		
Materials (continued)	Np-236	0	0	0	
	Np-237	0	0	17	x
	Np-238	0	0	3	
	Pu-237	0	0	0	
	Pu-238	22	7	17	x
	Pu-239	107	13	17	x
	Pu-240	107	13	17	x
	Pu-241	48	13	17	x
	Pu-242	22	13	17	x
	Am-241	24	7	17	x
	Am-242	0	0	17	x
	Am-243	0	0	17	x
	Cm-242	0	0	16	
	Cm-243	0	0	11	
	Cm-244	0	0	17	
	Cm-245	0	0	8	
	Cm-246	0	0	0	
	Cm-247	0	0	0	
	Cm-248	0	0	0	
AENCF (MeV)	Maximum ➢	1.7739	0.3776	0.2643	0.3311
	Minimum ➢	0.0025	0.0796	0.2475	0.0016

* Only 18 CRC input files were available for review at the time of this writing.

Table 2.4-2. Expected Modeled Parametric Ranges For Repository Calculations

	Parameter	Minimum	Maximum
Fuel	Initial Enrichment (wt% U-235)	0.71	93.5
	Modeled System Enrichment (wt% U-235)	0.00	93.5
	Burnup (GWd/MTU)	0.00	56
Flux Spectrum	AENCF - active range (MeV)	0.0016	0.3311

3.0 Parameters of Significance

This section investigates the range of applicability for select parameters. These parameters are chosen, because they have a significant effect on reactivity. The figures on the following pages demonstrate the benchmarked range and distributions of the average energy of the neutrons causing fission (AENCF), enrichment and burnup. The figures include:

- Figure 3-1. AENCF – Thermal Systems
- Figure 3-2. AENCF – Fast U-233 Systems
- Figure 3-3. System Average Enrichment (for all experiments and state points)
- Figure 3-4. Core Average State Point Enrichment (for CRC and Lattice LCEs only)
- Figure 3-5. Core Average Burnup (for CRCs only)
- Figure 3-6. Assembly Burnup (for CRCs only)

Following these figures is an analysis of the data and a development of subcritical limits (SLs) for the lattice and non-lattice repository models. The SLs are plotted in Figures 3-7 and 3-8. The trends and the benchmarked range of the parameters are then combined to establish the range of applicability for the repository criticality analyses.

Figure 3-1. AENCF – Thermal Systems

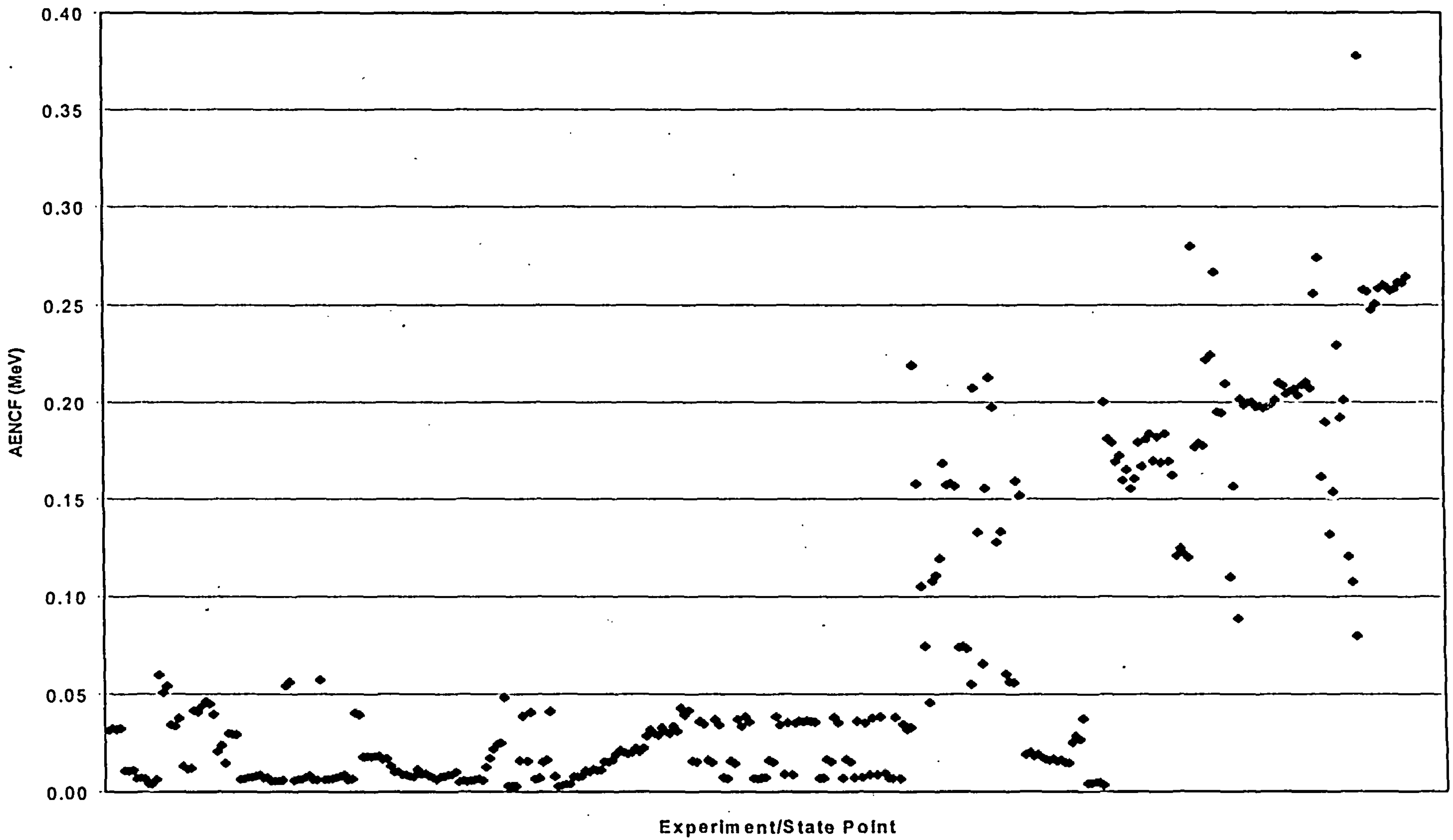

Figure 3-2. AENCF – Fast U-233 Systems

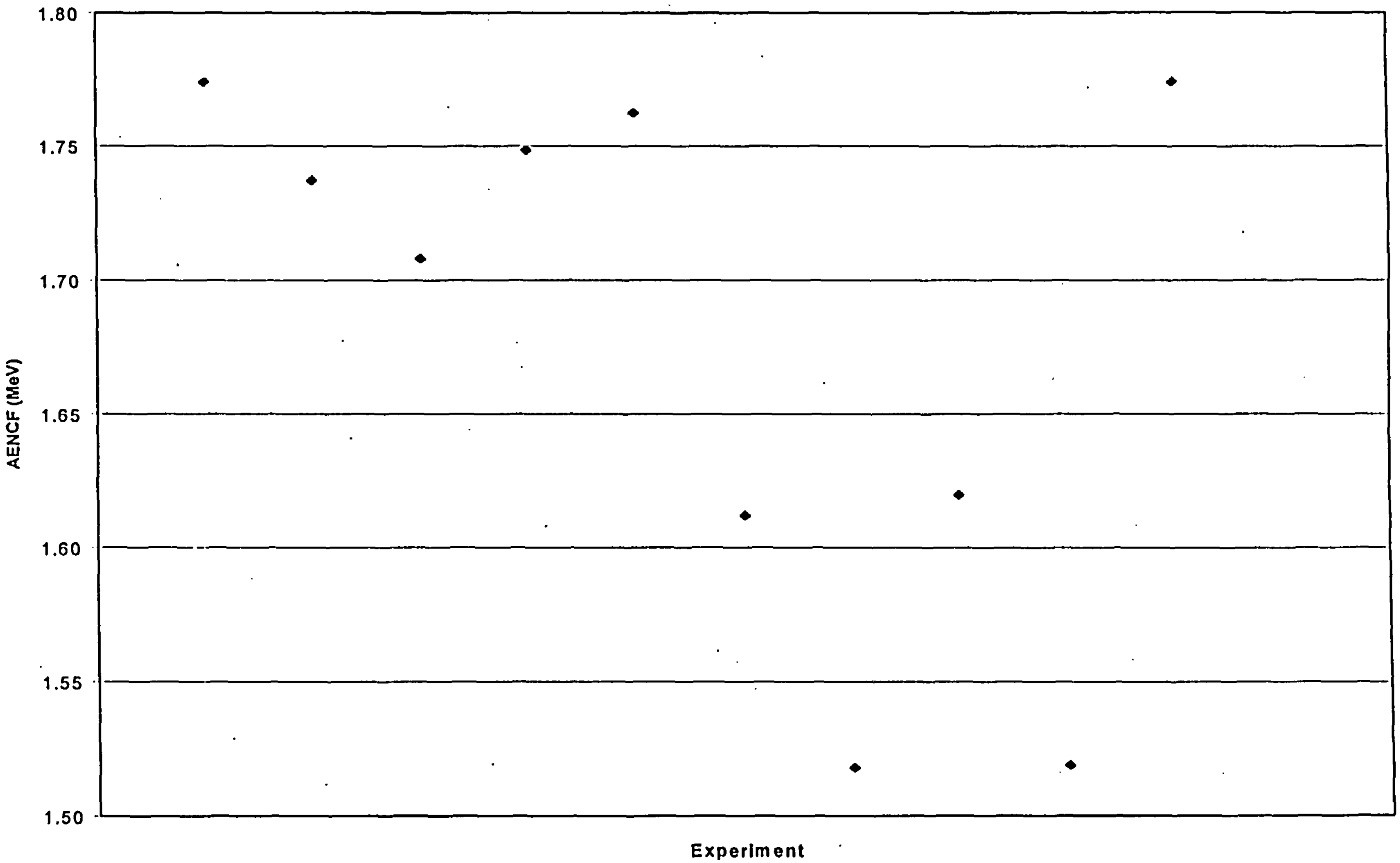

Figure 3-3. System Average Enrichment

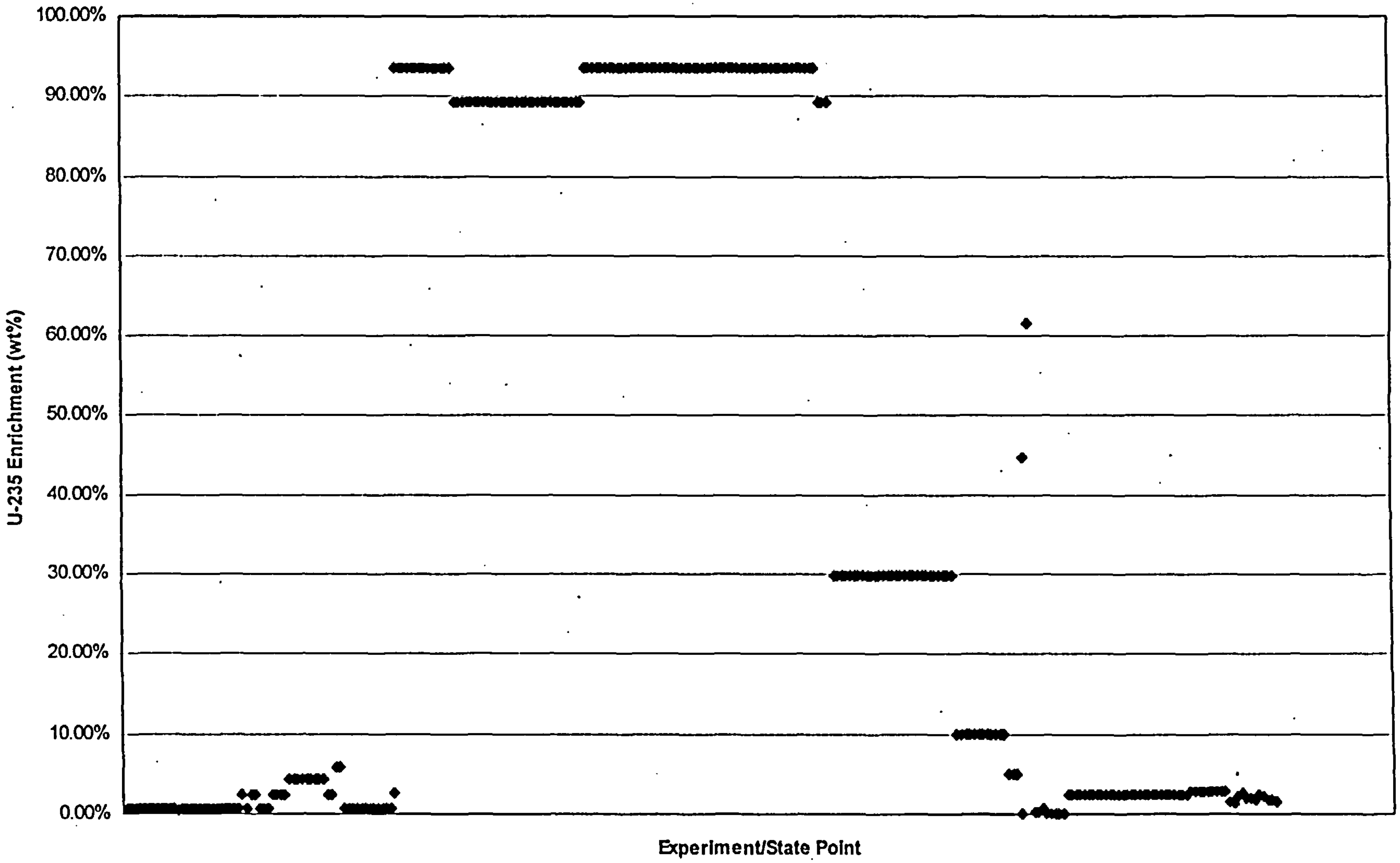

Figure 3-4. Core Average State Point Enrichment

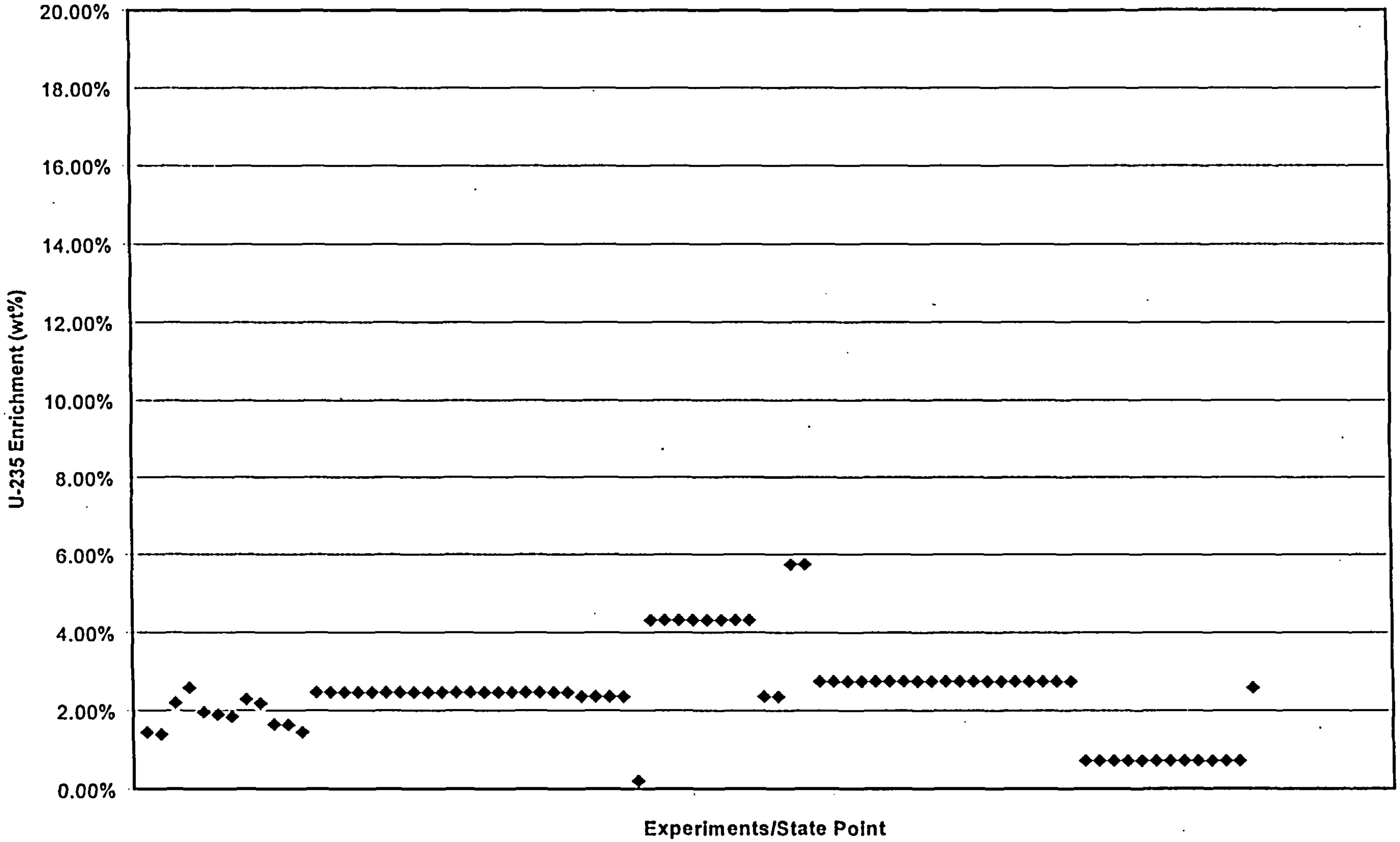

Figure 3-5. Core Average Burnup

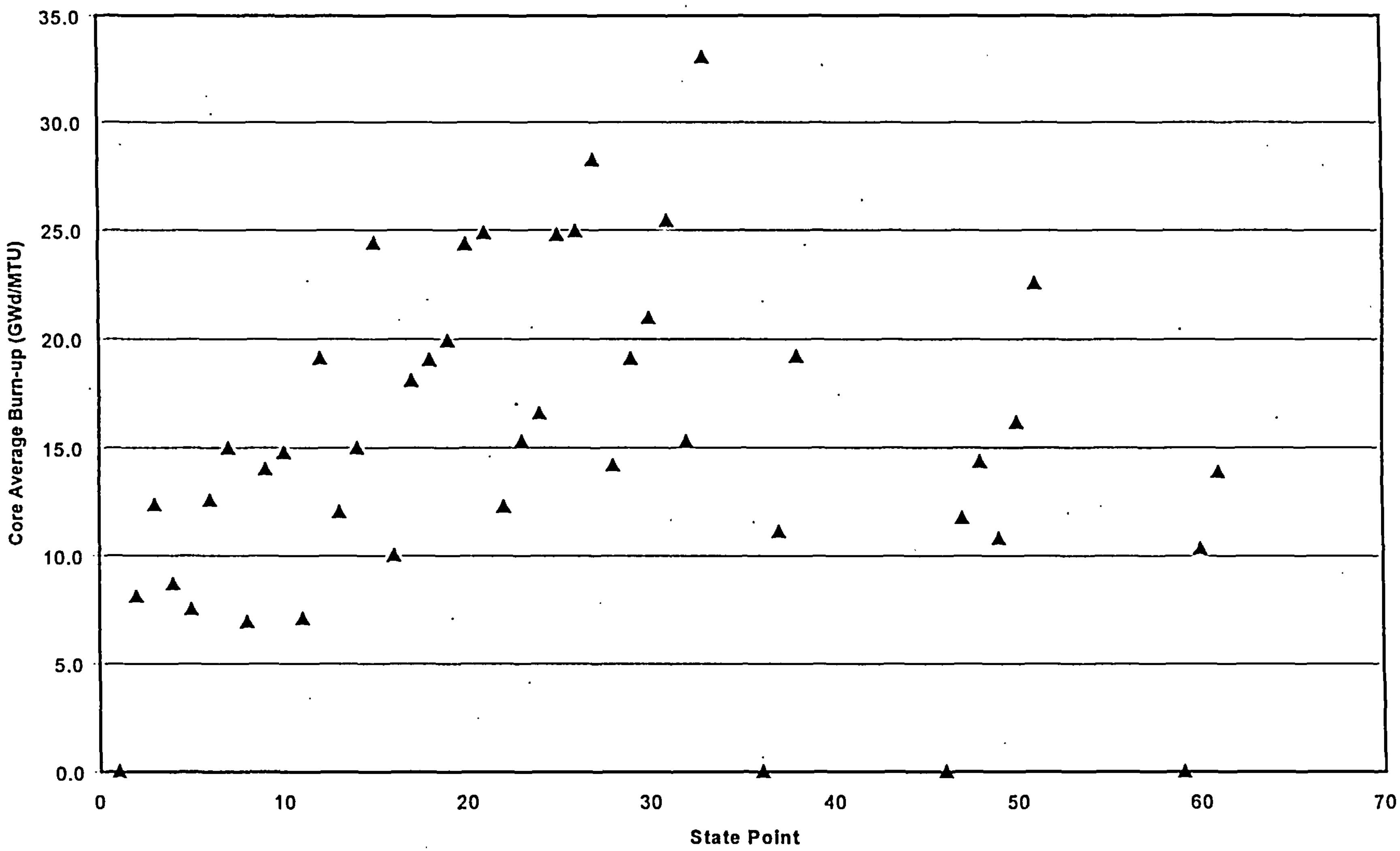

Figure 3-6. Assembly Burnup

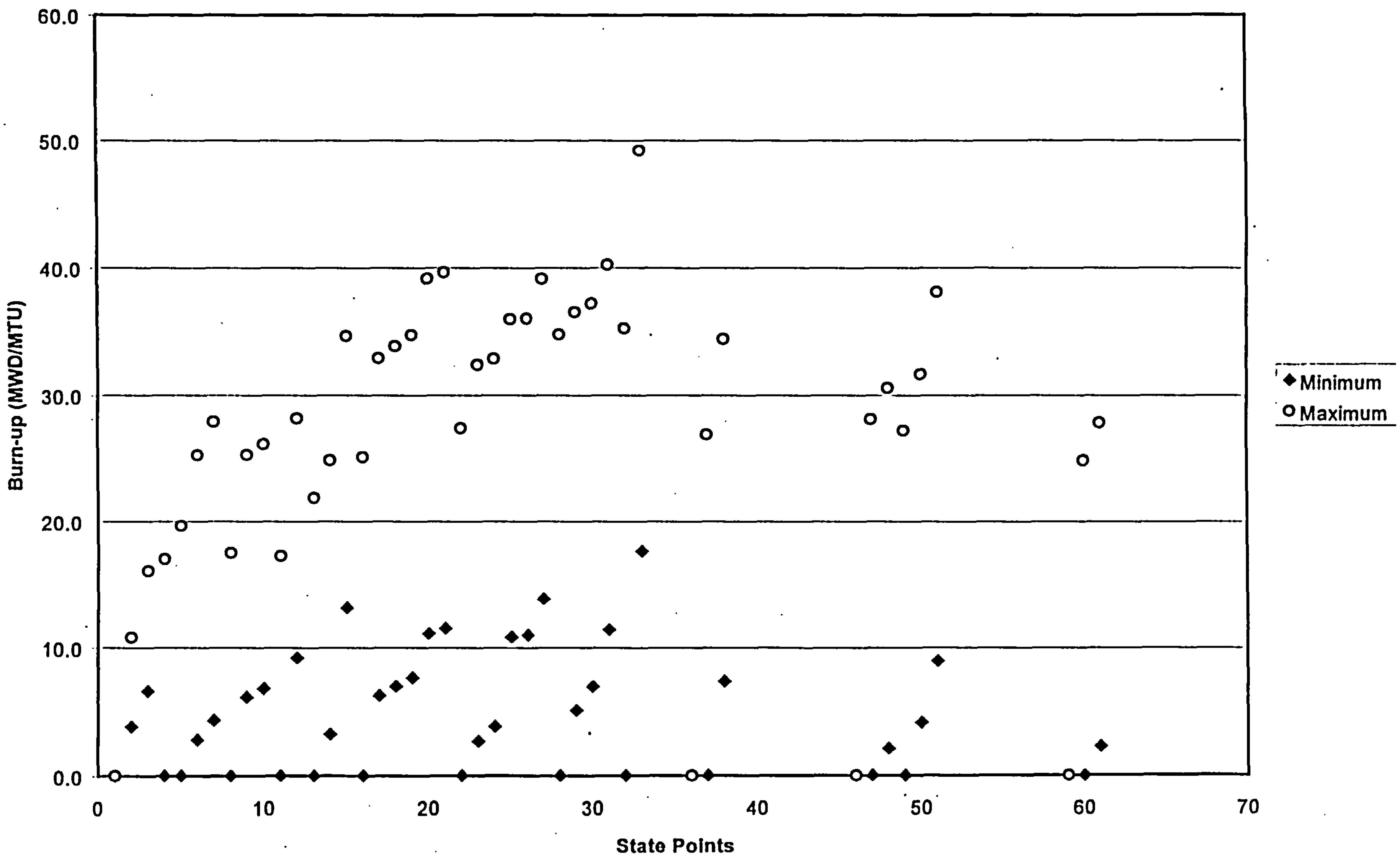

Figure 3-1 plots AENCF for the "thermal" LCEs and the CRCs. This plot includes all but six of the LCEs and the twelve CRCs described in Table 2.3-3. The figure shows a large number of AENCF data points from 0.0 MeV to 0.05 MeV. It also shows a significant number of AENCF data points, although fewer than in the previous range, from 0.05 MeV to 0.30 MeV. Only one data point appears between 0.30 MeV and 0.45 MeV. Without a significant number of data points in a large region, that region must be questioned. Because the data is almost exclusively limited to less than 0.30 MeV, AENCFs greater than 0.30 MeV are considered outside the benchmarked range of AENCF established by the benchmark calculations.

Figure 3-2 plots the six "fast" LCE systems. These six LCEs have AENCFs between 1.5 MeV and 1.8 MeV. All of these data points are for spheres of ^{233}U. Because materials such as ^{235}U occur only in a small number of these data points, and materials such as ^{239}Pu do not appear at all, these AENCF data points serve to validate only ^{233}U systems in this AENCF range. These data points also serve to enhance the validation of other materials included in significant quantities in the modeled reflectors (e.g., tungsten, aluminum, ^{235}U, ^{238}U) when combined with the rest of the data points reported in this document.

Figure 3-3 displays the ^{235}U enrichments included in the benchmark calculations. This data includes information from the homogeneous LCEs, lattice LCEs, and CRCs. The figure contains three noticeable sub-groupings: High Enriched (~89%-93.5%), Intermediate Enriched (~30%), and Low Enriched (<10%). Although there are significant gaps between the groupings, the benchmark calculations do "test" the cross sections for uranium in the three enrichment regions. This would allow identification of problems with the uranium cross sections. For example, a problem with ^{235}U cross sections would cause a greater calculational bias in high enriched cases, than in the low enriched cases. The number of uranium system calculations run in the different enrichment regions is sufficient to identify any correlation between the calculation bias and enrichment over the entire range of ^{235}U enrichment.

Figure 3-4 shows the benchmark data points for core average ^{235}U enrichment. This set of data is important for validating criticality analysis methodology for spent fuel lattice disposal. It includes the system ^{235}U enrichments for the LCE lattice calculations and the state point ^{235}U enrichments for the available CRCs. A significant number of data points occur under 4.5%. Only two data points appear above 4.5%; both at 5.74%. The data points below 4.5% are sufficiently distributed to validate the criticality analysis methodology applied to lattices.

Figure 3-5 exhibits the core average burnup for the available CRC state points. This looks at the burnup over an entire core, not just over a single assembly. The bulk of the data appears between 5.0 GWd/MTU and 25.0 GWd/MTU. However, the lattice LCEs provide an additional sixty-eight "zero burnup" data points not shown in Figure 3-5. Only three data points occur above 25.0 GWd/MTU, and they are distributed over a range of nearly 10 GWd/MTU. The core average burnup data is sufficient to validate the use of core average burnup up to 25.0 GWd/MTU. This may be extended if trending demonstrates that the higher values for core average burnup fit the trending curve.

Figure 3-6 reports the maximum and minimum assembly burnup for all of the CRC state points. All but one data point is below 40.3 GWd/MTU. The addition of all of the assembly burnup data (not just the minimum and maximum values) from the CRC state points listed in Table 2.3-1 would serve to further fill the range from 0.0 GWd/MTU to 40.0 GWd/MTU.

The following tables list the benchmarked ranges of the parameters for the repository criticality analyses. Table 3-1 is taken from Reference 5, and lists the approved cross-section set. Table 3-2 lists the ranges of applicability demonstrated in the previous figures and discussions.

Table 3-1. Validated Cross Section Set for Repository Calculations

Element/Isotope	MCNP ZAID	Element/Isotope	MCNP ZAID
H-1	1001.50c	Cr-53	24053.60c
H-3	1003.50c	Cr-54	24054.60c
He-4	2004.50c	Mn-55	25055.50c
Li-6	3006.50c	Fe-54	26054.60c
Li-7	3007.55c	Fe-56	26056.60c
Be-9	4009.50c	Fe-57	26057.60c
B-10	5010.50c	Fe-58	26058.60c
B-11	5011.56c	Co-59	27059.50c
C-natural	6000.50c	Ni-58	28058.60c
C-12	6012.50c	Ni-60	28060.60c
N-14	7014.50c	Ni-61	28061.60c
O-16	8016.50c	Ni-62	28062.60c
F-19	9019.50c	Ni-64	28064.60c
Na-23	11023.50c	Cu-63	29063.60c
Mg-natural	12000.50c	Cu-65	29065.60c
Al-27	13027.50c	Ga-natural	31000.50c
Si-natural	14000.50c	Zr-natural	40000.60c
P-31	15031.50c	Zr-93	40093.50c
S-32	16032.50c	Nb-93	41093.50c
Cl-natural	17000.50c	Mo-natural	42000.50c
K-natural	19000.50c	Mo-95	42095.50c
Ca-natural	20000.50c	Ag-107	47107.60c
Ti-natural	22000.50c	Ag-109	47109.60c
Cr-50	24050.60c	Cd-natural	48000.50c
Cr-52	24052.60c	In-natural	49000.60c

Table 3.-1. Validated Cross Section Set for Repository Calculations

Element/Isotope	MCNP ZAID	Element/Isotope	MCNP ZAID
Sn-natural	50000.35c	U-235	92235.50c
Ba-138	56138.50c	U-235	92235.53c
Gd-152	64152.50c	U-236	92236.50c
Gd-154	64154.50c	U-237	92237.50c
Gd-155	64155.50c	U-238	92238.50c
Gd-156	64156.50c	U-238	92238.53c
Gd-157	64157.50c	Pu-237	94237.35c
Gd-158	64158.50c	Pu-238	94238.50c
Gd-160	64160.50c	Pu-239	94239.55c
Ta-181	73181.50c	Pu-240	94240.50c
W-natural	74000.55c	Pu-241	94241.50c
Pb-natural	82000.50c	Pu-242	94242.50c
U-233	92233.50c	Am-241	95241.50c
U-234	92234.50c		

Table 3-2. Benchmarked Range of Parameters For Repository Calculations

Parameter	Minimum	Maximum
AENCF - active range (MeV)	0.0	0.3
Average Enrichment for Homogeneous Calculations (wt% U-235)	0.0	100.0
Average Enrichment for Lattices (wt% U-235)	0.0	4.5
Core Average Burnup (GWd/MTU)	0.0	25.0
Assembly Burnup (GWd/MTU)	0.0	40.0

To establish SLs, and ultimately the ROAs, for the repository calculations, the multiplication factor k_{eff} can be trended on several neutronic parameters to obtain a bias trend related to one of the candidate parameters. Table 3-3 shows a summary of the results taken from the benchmark calculations (References 5 through 14). The k_{eff} results represent the average combined collision, absorption, and track length estimate from the MCNP (see Reference 25) calculations.

Table 3-3. Summary Results of LCE and CRC k_{eff} Calculations

		k_{eff}		
Type of System	**Number**	**Average**	**Maximum**	**Minimum**
Homogeneous Thermal Systems	209			
Mixed Pu and Natural U	34	1.00431	1.01511	0.99318
Plutonium	73	1.01172	1.02390	1.00169
High-Enriched U-235	81	1.00504	1.02880	0.98345
Low-Enriched U-235	15	1.00078	1.00425	0.99469
High-Enriched U-233	6	0.99977	1.00153	0.99826
Homogeneous Fast Systems	10			
High-Enriched U-233	10	0.99818	1.00705	0.99297
Thermal Arrays	51			
High-Enriched U-235	22	1.00744	1.01399	0.99730
Intermediate-Enriched U-235	29	0.99923	1.00780	0.99300
Thermal Lattices	68			
Low-Enriched Mixed Oxide	13	1.00277	1.00835	0.98750
Low-Enriched Uranium Oxide	55	0.99896	1.00827	0.98895
Commercial Reactor Criticals	45	0.99220	1.00141	0.98541

Reference 20 describes three statistical methods used to determine the Subcritical Limit (SL), and discusses the statistical approaches used to characterize the benchmark data (the calculated values of k_{eff} for the LCEs and CRCs using the computer code MCNP). The three methods are the Lower Uniform Tolerance Band (LUTB) approach, the non-trending/Normal Distribution Tolerance Limit (NDTL) approach and the non-trending/Distribution Free Tolerance Limit (DFTL) approach.

The following contains the tables where k_{eff} is trended against the variables AENCF, Average Lethargy of a neutron causing Fission (ALF), Hydrogen to Fissile nuclide ratio (H/X), and Core

Average Burnup (BURNUP). The ALF is defined as the natural log of the ratio 10 MeV divided by AENCF (ALF ≡ ln (10 MeV/AENCF)).

To determine the most useful trending regression, a "goodness of fit" can be estimated by comparing various statistics of the trend. In general, no single statistic is sufficient to determine usefulness. Therefore, several are analyzed and judgment is made as to which variable gives the best "degree of linear association" using the Pearson correlation coefficient (r) as defined in Equation 3-1.

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \bullet \sum (y_i - \bar{y})^2}} \qquad \text{Eq. 3-1}$$

where:

x_i and y_i are the independent and dependent variables with average $\bar{x}$ and $\bar{y}$, respectively

$r^2 = 1$, if all observations fall under the regression line, that is x accounts for all variation in y

$r^2 = 0$, if the slope of the regression line is 0, that is there is no linear association between x and y.

As r^2 increases, the total variation of y decreases by virtue of introducing the independent variable x. For the purposes of this report, $x = k_{eff}$ and y is the other neutronic variables mentioned above; AENCF, H/X, etc.

Reference 20 also reports the Spearman rank correlation. Spearman rank correlations are computed using the same formula as Equation 3-1, but using the ranks of the observations rather than the observed values for the numerical inputs. A Spearman rank correlation is less sensitive to outliers, unequal variances, non-linearity, and non-normality.

The process of evaluation of calculation system biases and uncertainties begins with a set of k_{eff} values produced by MCNP for specific "experimental" conditions. This first set includes the 270 homogeneous experiments (homogeneous LCEs).

Table 3-4 displays the Pearson product-moment correlations and the Spearman rank correlations for this data set. These are edited portions of the Number Cruncher Statistical Systems 97 (NCSS 97) (see Reference 26) output taken from Reference 20. The Pearson correlations are those commonly displayed in regression routines in statistical analysis packages such as NCSS 97.

Table 3-4. Correlation Coefficients k_{eff}, AENCF, ALF, and H/X

Pearson Correlations				
	k_{eff}	AENCF	ALF	H/X
k_{eff}	1.000000	-0.412410	0.434119	0.265939
AENCF	-0.412410	1.000000	-0.847615	-0.446538
ALF	0.434119	-0.847615	1.000000	0.705121
H/X	0.265939	-0.446538	0.705121	1.000000
Spearman Correlations				
	k_{eff}	AENCF	ALF	H/X
k_{eff}	1.000000	-0.435239	0.435239	0.328738
AENCF	-0.435239	1.000000	-1.000000	-0.869735
ALF	0.435239	-1.000000	1.000000	0.869735
H/X	0.328738	-0.869735	0.869735	1.000000

As mentioned earlier, the Spearman rank correlation is less sensitive to outliers, unequal variances, non-linearity and non-normality. This is especially evident for the ALF and AENCF variables, which have a fixed mathematical relationship. For the Pearson results, the correlation of AENCF and ALF is -0.8476, and for the Spearman rank results, the correlation is -1.0. This demonstrates the ability of the Spearman technique to account for non-linearity.

Table 3-4 shows the correlations of the neutronic parameters to k_{eff} as well as to each other. If two parameters demonstrated a high correlation to keff, but a low correlation to each other, a better model would be to use both parameters for trending. However, this is not the case for the data in Table 3-4. AENCF and ALF show very similar Pearson Correlations, and equal Spearman Correlations. They also demonstrate a much higher correlation than H/X. AENCF and ALF also show a correlation to each other. Because of this, trending against one of these parameters is equivalent to trending against both.

At this point, the best candidate for trending the MCNP bias is either ALF or AENCF with equal basis. The decision to use ALF was made on the basis of a multiple regression of k_{eff} on ALF, AENCF, and H/X. Selected output from the NCSS 97 regression routine is displayed in Table 3-5. Further details are in Reference 20.

Table 3-5 shows, in the column labeled "Decision (5%)", that the only statistically significant slope, at the 5% level of significance, is the ALF slope. "Ho" refers to the hypothesis that the slope of the regression is 0. Therefore, a rejection of the hypothesis demonstrates a statistically non-zero regression coefficient.

Table 3-5. Multiple Regression of k_{eff} on AENCF, ALF, and H/X

Regression Equation					
Independent Variable	Regression Coefficient[1]	Standard Error[2]	T-Value (Ho: B=0)[3]	Prob Level[4]	Decision (5%)[5]
Intercept[6]	0.9910367	7.067051E-03	140.2334	0.000000	Reject Ho
AENCF	-0.0251856	2.143915E-02	-1.1747	0.241213	Accept Ho
ALF	2.548348E-03	1.087095E-03	2.3442	0.019852	Reject Ho
H/X	-5.834206E-07	1.317145E-06	-0.4429	0.658190	Accept Ho

Notes:
1. Regression Coefficient is defined in Reference 21 on page 33 and Reference 26 on page 320.
2. Standard Error is defined in Reference 26 on page 213.
3. T-Value (Ho: B=0) is defined in Reference 21 on pages 8 and 74 and Reference 26 on page 63.
4. Prob Level is defined in Reference 26 on page 88.
5. Decision (5%) is the probability level at which a decision on the validity of a hypothesis is made.
6. Intercept is defined in Reference 21 on page 33 and Reference 26 on page 1681.

Table 3-6 also contains data excerpts from the NCSS 97 regression fit of k_{eff} on ALF only. This is the resulting regression used for predicting the expected multiplication factor as a function of the ALF.

Table 3-6. Regression of k_{eff} on ALF

Regression Equation					
Independent Variable	**Regression Coefficient**	**Standard Error**	**T-Value (Ho: B=0)**	**Prob Level**	**Decision (5%)**
Intercept	0.991065	1.962644E-03	504.9642	0.000000	Reject Ho
ALF	2.366353E-03	3.101639E-04	7.6294	0.000000	Reject Ho
R-Squared	0.178436				
Regression Coefficient					
Independent Variable	**Regression Standardized Coefficient**	**Standard Error**	**Lower 95% C.L.[1]**	**Upper 95% C.L.[1]**	
Intercept	0.991065	1.962644E-03	0.9872183	0.9949117	
ALF	2.366353E-03	3.101639E-04	1.758443E-03	2.974263E-03	
Analysis of Variance					
Source	**DF[2]**	**Sum of Squares[3]**	**Mean Square[4]**	**F-Ratio[5]**	**Prob Level**
Intercept	1	273.0961	273.0961		
Model	1	2.571887E-03	2.571887E-03	58.2072	0.000000
Error	268	1.184159E-02	4.418505E-05		
Total (Adjusted)	269	1.441348E-02	5.358171E-05		
Root Mean Square Error[6]		**6.647184E-03**	**R-Squared[7]**		**0.1784**
Mean of Dependent[8]		**1.005717**	**Adj R-Squared[9]**		**0.1754**
Coefficient of Variation[10]		**6.609397E-03**	**Press Value[11]**		**1.199997E-03**
Sum|Press Residuals|[12]		**1.358394**	**Press R-Squared[13]**		**0.1674**

Notes:
1. C.L. represents "Confidence Limit" which is defined in Reference 26 on page 78.
2. DF represents the degrees of freedom which is defined in Reference 26 on page 214.
3. Sum of Squares is defined in Reference 21 on page 50 and Reference 26 on pages 292, 322.
4. Mean Square is defined in Reference 21 on page 50 and Reference 26 on pages 292, 322.
5. F-Ratio (or F*) is defined in Reference 21 on page 95 and Reference 26 on pages 292, 322.
6. Root Mean Square Error is defined in Reference 21 on page 50 and Reference 26 on page 323.
7. R-Squared is defined in Reference 21 on pages 100 and 101 and Reference 26 on pages 320, 323.
8. Mean of Dependent is defined in Reference 26 on page 323.

Notes (Continued):

9. Adj. R-Squared is defined in Reference 26 on page 324.
10. Coefficient of Variation is defined in Reference 26 on page 323.
11. Press Value is defined in Reference 21 on pages 450-452 and Reference 26 on page 324.
12. Sum|Press residuals| is defined in Reference 26 on page 325.
13. Press R-Squared is defined in Reference 26 on page 324.

Even though the regression relationship as reflected by r^2 is weak, it is statistically significant, as indicated by the F-Ratio data in Table 3-6, and could be applied in determining an SL using the LUTB method. The F-Ratio (or F*) is defined in Reference 21. For this data, the slope is positive, which indicates that as ALF increases, so does the regression model estimate for k_{eff}. This is a situation of positive bias, as described in Reference 22, and which is accounted for by limiting the regression predicted value to 1.0.

For the LUTB approach to computing a value for SL, the basic relationship is:

$$SL = 0.9911 + 2.3664E\text{-}03 * ALF - C_{\alpha/p} \bullet s_P \qquad \text{Eq. 3-2}$$

where:

ALF = ln (10 MeV / AENCF), with AENCF in MeV

$C_{\alpha/p} \bullet s_P$ is a function of the desired confidence and the variance on the pool of data (for this data set $C_{\alpha/p} \bullet s_P = 0.022$)

The basic relationship is explained in Reference 20, and the coefficients are taken from Table 3-6. The value for $C_{\alpha/p} \bullet s_P$ is dependent on the data set. Additions to or subtractions from the evaluated data set will change this value. Because calculation of $C_{\alpha/p} \bullet s_P$ is complicated, it is recommended that a computer program be developed for future determination of this value.

In this instance, the slope is positive, and that could lead to expected values from the regression contribution greater than 1.0, or equivalently, the insertion of a positive bias. To prevent this occurrence, the value of ALF used is restricted to those for which the regression contribution is less than or equal to 1.0. The value of ALF for which the regression solution is 1.0 is the breakpoint, ALF_{brkpt}. To compute the SL when ALF is less than ALF_{brkpt}, the ALF value is used in Equation 3-2, but for situations in which ALF is greater than ALF_{brkpt}, the ALF_{brkpt} value is used for ALF in Equation 3-2.

For this data set, $C_{\alpha/p}$ is determined such that the confidence is 95% and the proportion of the population protected is 99.5%. Here $\beta(x)$ is the regression model, and s_p is the pooled estimate of the standard deviation which accounts for the MCNP standard deviation and the regression standard error. These variables are described in greater detail in Reference 22.

Figure 3-7 compares the experimental data prediction (k_{eff}), the regression of k_{eff}, and the SL for the homogeneous LCE set of 270 experiments. Because no positive bias is allowed, the SL is constant over most of the range.

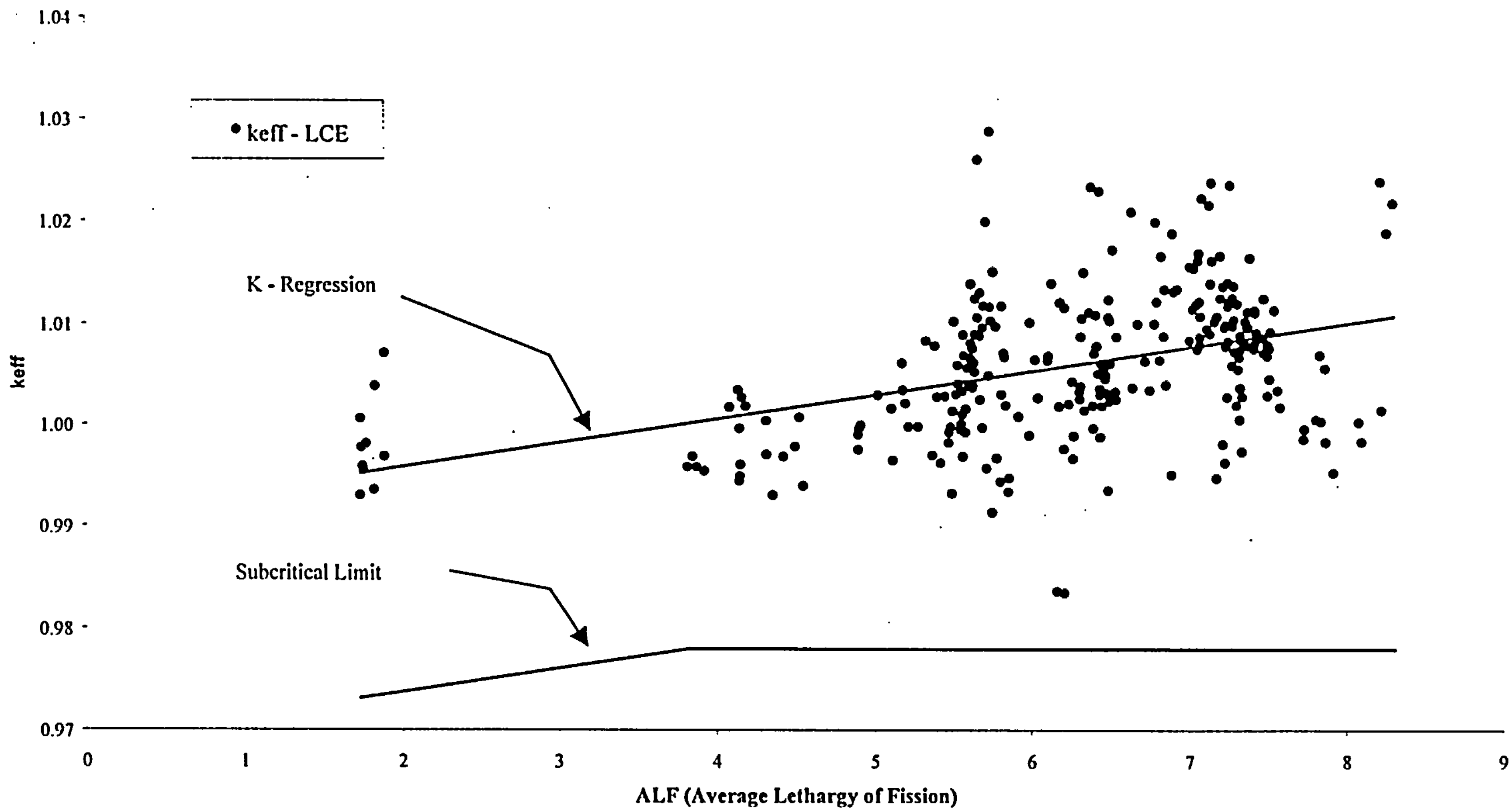

Figure 3-7. Comparison of k_{eff}, the Regression of k_{eff}, and the Subcritical Limit for LCEs

The next data set evaluated is comprised of the 45 evaluations of k_{eff} from the CRCs. The detailed calculations are described in Reference 11 through Reference 14. As for the previous data set, candidate trending variables were examined. Here the candidates were core average burnup (BURNUP), AENCF, and its transformed variable ALF. Table 3-7 shows the applicable data from Reference 20.

Table 3-7. Correlation Coefficients for k_{eff}, AENCF, ALF, and BURNUP

Pearson Correlations				
	k_{eff}	**AENCF**	**ALF**	**BURNUP**
k_{eff}	1.000000	-0.230240	0.227142	-0.577491
AENCF	-0.230240	1.000000	-0.999858	0.766388
ALF	0.227142	-0.999858	1.000000	-0.760713
BURNUP	-0.577491	0.766388	-0.760713	1.000000
Spearman Correlations				
	k_{eff}	**AENCF**	**ALF**	**BURNUP**
k_{eff}	1.000000	-0.243347	0.243347	-0.479012
AENCF	-0.243347	1.000000	-1.000000	0.840000
ALF	0.243347	-1.000000	1.000000	-0.84000
BURNUP	-0.479012	0.840000	-0.840000	1.000000

The comments in the discussion of the previous data set on the Pearson and Spearman rank correlations apply here also. According to the data in Table 3-7, BURNUP is highly correlated with the AENCF, and ALF, and has a stronger correlation with the MCNP k_{eff} values.

Similar to the previous process, the k_{eff} was regressed on BURNUP, AENCF and ALF. The summary is shown in Table 3-8. The table shows that the only statistically independent, significant variable in the regression is BURNUP. Therefore, this is the logical trending parameter for the CRC data.

Table 3-8. Regression of k_{eff} on AENCF, ALF, and BURNUP

Regression Equation					
Independent Variable	**Regression Coefficient**	**Standard Error**	**T-Value (Ho: B=0)**	**Prob Level**	**Decision (5%)**
Intercept	-3.860125	3.384521	-1.1405	0.260687	Accept Ho
AENCF	4.339246	2.92035	1.4859	0.144964	Accept Ho
ALF	1.022917	0.7196486	1.4214	0.162759	Accept Ho
BURNUP	-4.745053E-04	8.726973E-05	-5.4372	0.000003	Reject Ho
R-Squared	0.468933				

Regression Coefficient				
Independent Variable	**Regression Standardized Coefficient**	**Standard Error**	**Lower 95% C.L.[1]**	**Upper 95% C.L.[1]**
Intercept	-3.860125	3.384521	-10.6953	2.975055
AENCF	4.339246	2.92035	-1.558519	10.23701
ALF	1.022917	0.7196486	-0.4304433	2.476276
BURNUP	-4.745053E-04	8.726973E-05	-6.507501E-04	-2.982604E-04
T-Critical	2.019541			

Notes: 1. C.L. represents "Confidence Level"

The edited outputs from Reference 20 for this regression of k_{eff} on BURNUP are in Table 3-9. Although the regression relationship as reflected by r^2 is weak in this case, it is statistically significant, as indicated by the F-Ratio data in Table 3-9, and could be applied in determining a SL using the LUTB method. Observe that the slope is negative for this regression, which dictates that as BURNUP increases, the regression model estimate for k_{eff} will decrease. This is a situation of negative bias, as described in Reference 22.

For the LUTB method for computing a value for SL, the basic relationship is:

$$SL = 0.9959 - 2.4412E\text{-}04 * BURNUP - C_{\alpha/p} \bullet s_P \qquad \text{Eq. 3-3}$$

where:

BURNUP is the core averaged burnup in GWd/MTU,

$C_{\alpha/p} \bullet s_P$ is a function of the desired confidence and the variance on the pool of data (for this data set $C_{\alpha/p} \bullet s_P = 0.0083$) {see previous discussion of $C_{\alpha/p} \bullet s_P$}

The basic relationship is explained in Reference 20, and the coefficients are taken from

Table 3-9.

Table 3-9. Regression of k_{eff} on BURNUP

Regression Equation					
Independent Variable	**Regression Coefficient**	**Standard Error**	**T-Value (Ho: B=0)**	**Prob Level**	**Decision (5%)**
Intercept	0.9958596	8.828806E-04	1127.9664	0.000000	Reject Ho
BURNUP	-2.4412E-04	5.262901E-05	-4.6385	0.000033	Reject Ho
R-Squared	0.333496				

Regression Coefficient				
Independent Variable	**Regression Standardized Coefficient**	**Standard Error**	**Lower 95% C.L.[1]**	**Upper 95% C.L.[1]**
Intercept	0.9958596	8.828806E-04	0.9940791	0.9976401
BURNUP	-2.4412E-04	5.262901E-05	-3.502565E-04	-1.379835E-04

Analysis of Variance					
Source	**DF[2]**	**Sum of Squares**	**Mean Square**	**F-Ratio**	**Prob Level**
Intercept	1	44.30107	44.30107		
Model	1	1.532798E-04	1.532798E-04	21.5158	0.000033
Error	43	3.063352E-04	7.124075E-06		
Total (Adjusted)	44	4.596151E-04	1.04458E-05		
Root Mean Square Error		2.669096E-03	**R-Squared**	0.3335	
Mean of Dependent		0.9922038	**Adj R-Squared**	0.3180	
Coefficient of Variation		2.690069E-03	**Press Value**	3.356391E-04	
Sum|Press Residuals|		9.171949E-02	**Press R-Squared**	0.2697	

Notes: 1. C.L. represents "Confidence Level"
2. DF represents the degrees of freedom

In this instance, the slope is negative, and over the range of BURNUP, the regression estimates of the k_{eff} are less than 1.0. This simplifies the determination of the SL because there is no positive bias and the predicted SL for k_{eff} is always below 1.0. Figure 3-8 exhibits the results for the CRC calculation.

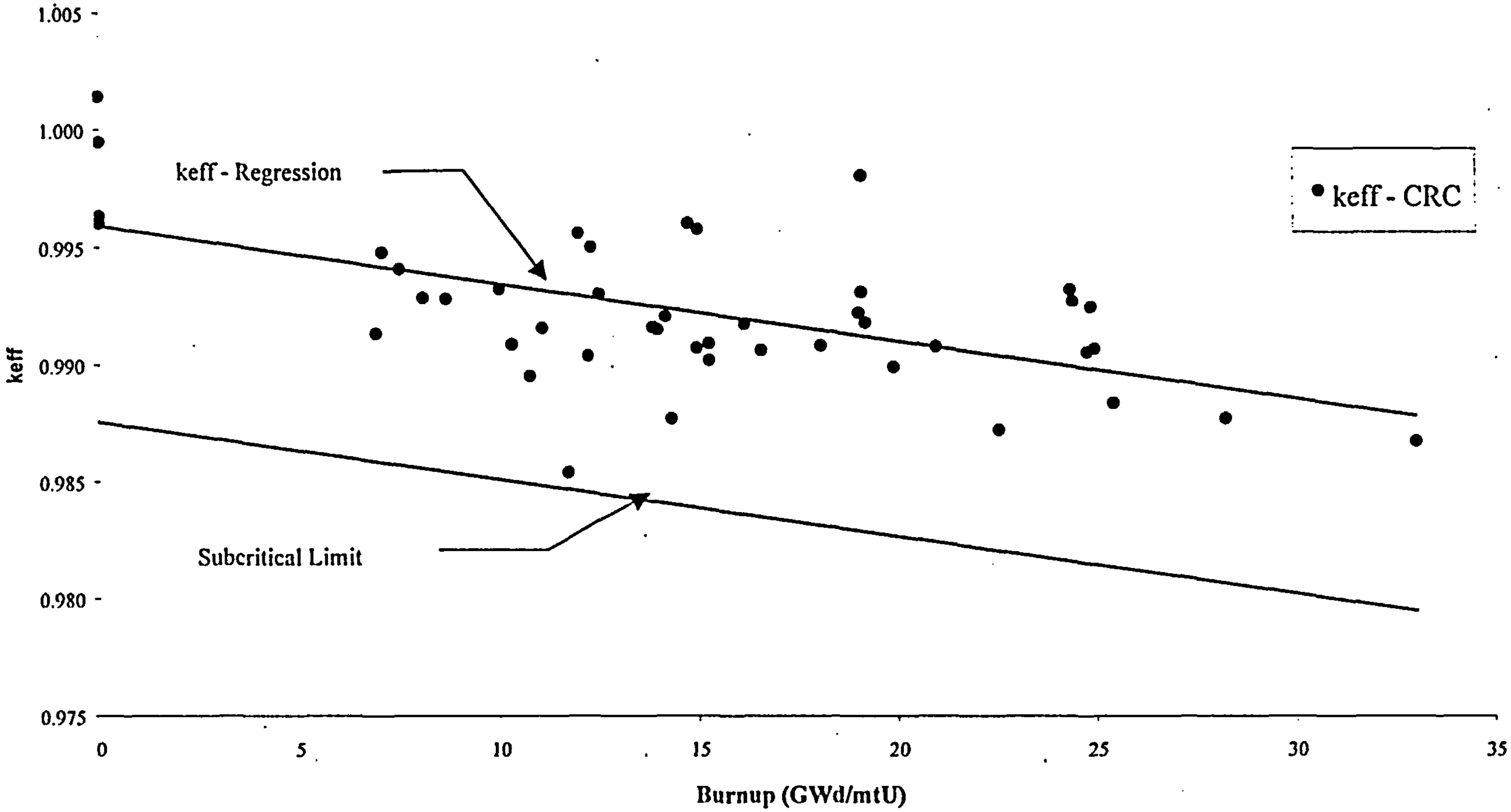

Figure 3-8. Comparison of k_{eff}, the Regression of k_{eff}, and the Subcritical Limit for CRCs

There may be sets of experiments for which the MCNP is used to establish estimates of k_{eff} which do not "trend" to a variable such as BURNUP, AENCF, or any other parameter. The following sample calculations are presented to illustrate the non-trending situations, described as NDTL and DFTL in earlier sections.

The two approaches that are available for the non-trending case exist in response to the question of the underlying probability distribution of the k_{eff} values. If the sample of k_{eff} values can be demonstrated, for example at the 1% level of significance, to be from a normal distribution, then the SL can be calculated easily from information contained in the sample of data on the k_{eff} and the corresponding MCNP uncertainties.

The 338 LCE (270 homogeneous; 68 lattice) k_{eff} values were tested for normality using the D' test (Reference 23). At the 5% level of significance, the hypothesis of normality is not rejected. The D' Test is statistical hypothesis-testing techniques designed to assist in the assessment of the assumption of normality by making use of all the individual observed values in a sample. The technique is based on the comparison of a "linear combination" estimator of the population variance with the conventional "sum of squared deviations" estimator of the population variance. The D' Test is most applicable to populations that are "not small" (i.e., > 50 observations). It is applicable to either "raw" or "transformed observations. "Raw" data are values obtained directly from an experiment; transformed data are values derived from "raw" data by subjecting them to numerical or mathematical manipulation (e.g., finding their logarithms). The D' Test is described in more detail in Reference 23.

For the LCE data set, the average of the 338 k_{eff} values is 1.0045. Because this is greater than 1.0, the value used for the average (k_c) should be 1.000 to eliminate positive bias. For the data set, the subcritical limit using the NDTL method (SL_N) is 0.9780. This value applies for all cases because there is no dependence on any parameter.

Assuming that the LCE data set does not trend to a neutronic parameter, and normality is rejected at a specified level of significance, the method to establish the SL is a Distribution-Free Statistical Tolerance Limit (DFTL). This approach assumes that the data is a random sample from a continuous distribution only. Normality is not required.

The basic need here is for an adequate data set, in terms of the desired confidence coefficient, and proportion of the population to protect.

There is an insufficient number of observations to have a 95% confidence that 99.5% of the population is above the limit. However, as also shown in Reference 24, there is a way to assess what portion of the population is above the smallest calculated k_{eff} at the desired confidence level ($k_{eff}s_1$). For the LCE data with 338 data points, that calculation allows the statement that there is at least 95% confidence that 99.1% of the population is above the smallest k_{eff} value in the available set of 338. Thus if $k_{eff}s_1$ equals 0.979, that would be the subcritical limit calculated using the DFTL (SL_D) for "experiments" categorized as covered by this data set. In other words:

> $SL_D = k_{eff}s_1 = 0.979$ at the confidence level of 95% that 99.1% of the population is covered.

To be 95% confident that 99.5% of the population is above some lower level, a data set containing approximately 600 critical experiments is required. This is not a concern here since the data for LCEs and CRCs show significant trends and pass reasonable tests for normality. Also, the population coverage of 99.1% may be sufficient, depending on the application.

The trends for the CRCs versus BURNUP are very strong when compared to other parameters and are unlikely to change. The trends for the other data are more complex since there are a large variety of waste forms that need to be included. The leading trending parameter for the LCEs, ALF, is more likely to change. For the repository calculations involving lattices, the CRC data will be used as a benchmark for purposes of determining bias and uncertainty.

Analysis has shown that the primary parameter used to define the applicable range for commercial fuel will be BURNUP. This parameter correlates better than the AENCF or ALF parameters. The form of burnup used is expressed as the core average burnup of the critical reactor benchmark state point. The modeled range of BURNUP for PWR fuel is 0 to 33.1 GWd/MTU based on a core-average value, but the benchmarked range of BURNUP is 0 to 25.0 GWd/MTU due to the limited number of data points beyond 25.0 GWd/MTU.

For a non-lattice or degraded state, the 270 LCEs are used as a benchmark. The data analyzed shows that the LCEs correlate well with the parameter ALF previously defined. The range of ALF values for this set is from 1.73 to 8.29 which corresponds to the energy range of 1.77 to 0.0025 MeV. The ALF and AENCF parameters correlate better than the ratio of hydrogen atoms to fissile atoms (H/X), which range from approximately 4 to 2,800 for this set.

Table 3-10 contains a summary of the SL development for the data sets defined in this report. As discussed previously, the LUTB method is the preferred method because the data does "trend" to a variable; ALF for the LCEs and BURNUP for the CRCs.

Table 3-10. Summary of SL Development

Method	LCE SL	CRC SL
LUTB	0.9911 + 2.36E-03 * ALF – 0.022	0.9959 -2.44E-04 * BURNUP – 0.0083
NDTL	0.978	0.978
DFTL	0.979	0.979

It is interesting to note, that over the trending range of ALF and BURNUP, the minimum calculated SL is between 0.97 and 0.98 for all three methods. Over the range of applicability for ALF and BURNUP, as defined in Table 3-11, the minimum calculated SL is approximately 0.98 for all three methods.

Table 3-11 shows the range of parameters for the benchmark calculations. It includes the benchmarked range, the trended range, and the range of applicability (ROA), which is a hybrid of the two other ranges. An "N/A" in the trended range indicates a parameter that was not trended against. For parameters that were not trended against, the ROA is the benchmark range.

Table 3-11. Range of Neutronic Parameters

Parameter	Benchmark Range	Trend Range	ROA
AENCF (MeV)	0 - 0.30	0.0025 – 1.77	0 - 0.22
Enrichment (wt% ^{235}U)	0 - 100	N/A	0 - 100
Avg. Enrichment (wt% ^{235}U)	0 - 4.5	N/A	0 - 4.5
Core Avg. Burnup (GWd/MTU)	0 - 25	0 - 33	0 - 33
Assembly Burnup (GWd/MTU)	0 - 40.0	N/A	0 - 40.0

For AENCF, the low ROA maximum results from two issues.

- The trend range does not include the LCE lattice data that makes up the bulk of the points in the benchmark range between 0.22 and 0.30.
- The "fast" ^{233}U system do not include sufficient other materials to claim validation for any system other than a ^{233}U system, as discuss previously.

The ROA encompasses the overlap between the benchmark range and the trend range for AENCF.

For core average burnup (BURNUP), the trend shows that the 33.1 GWd/MTU data point is consistent with the other BURNUP points. Because the 33.1 GWd/MTU point "trends" with the other data, the trend serves to extend the ROA past the benchmark range. The ROA for BURNUP becomes 0 GWd/MTU to 33 GWd/MTU.

4.0 Conclusions

This document presents an overall Range of Applicability for the MGR criticality control analyses. It is not a validation of the codes or methods for any specific waste form or waste package. The specific waste forms/packages will be addressed in future validation reports, which will be submitted as part of the License Application for the MGR.

Although this document establishes specific ROAs for the parameters, this does not limit the repository to only materials that fall in these ranges. Calculations for criticality analyses may include values outside of these ranges, but the reports evaluating these future repository calculations must include a justification for why the calculations are validated. If a repository waste is outside of the defined range of applicability, additional margin or uncertainty may be needed to insure subcriticality. The alternative is to add benchmark critical data that covers the extended range and calculate a revised subcritical limit.

Extension of the range of applicability should be based on trends in the bias as a function of system parameters and, if the extension is large, should be confirmed by alternate means. There is no available guidance on what constitutes a large extension, nor any guidance on how to extend trends in the bias. In all cases, extension of the bias and uncertainty requires the determination and understanding of the trends in the bias and uncertainty. If this extension is made, a detailed justification of the need for an extension, along with a thorough description of the method and procedure used to estimate the bias and uncertainty in this extended range shall be documented and approved.

The data reported herein are acceptable for quality affecting activities, but not for use in analyses affecting procurement, construction, or fabrication. The classification analysis for the repository (which includes the waste package) carries TBV-228 (To Be Verified) because of the preliminary status of the basis for the MGR design. This report conservatively assumes that the resolution of TBV-228 will find the waste package to be quality affecting; consequently, use of any of the data reported herein does not need to carry TBV-228. This report is a first of a kind report. There are no similar documents existing for the MGR project.

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