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Title CRITICAL LIMIT DEVELOPMENT FOR 21 PWR WASTE PACKAGE

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PURPOSE AND SUMMARY OF RESULTS:

This calculation uses regression (CLReg V1.0 computer code) and non-parametric statistical methods, as specified in References 1 and 12, to develop the critical limit (CL) for the 21 Pressurized Water Reactor (PWR) spent nuclear fuel (SNF) waste package (WP) in the proposed geologic repository at Yucca Mountain, Nevada. The CL is a limiting value of the effective neutron multiplication factor (k_{eff}) at which a WP configuration is considered potentially critical. The CL is derived from the bias and uncertainties associated with the employed criticality code (MCNP) and the modeling process.

The results of this calculation support the validation of the MCNP code to accurately predict k_{eff} for a range of conditions that are representative of potential configurations of commercial SNF in a degraded waste package in a geologic repository.

The CL, calculated for five subsets of experiments, applies to the various configurations that a 21 PWR waste package may take over time in the geologic repository. Specifically, the CL applies to configurations where the 21 PWR waste package and its internal structural components have degraded, but the fuel rods remain intact. Representative benchmark criticality experiments, e.g., Commercial Reactor Criticality (CRC) and Laboratory Critical Experiments (LCE), characterize the CL for these configurations and prescribe the basic range of applicability of the results.

Section 6 provides results of the CL calculations. Table 11 (p. 28) summarizes CL values for parameters associated with each subset of experiments. The lowest CL value of 0.96833 occurs with the average energy of the neutron causing fission (AENCF) as a trending parameter for the subset that combines the CRC and LCE experiments.

This engineering calculation supports the burnup credit methodology of the Yucca Mountain Site Characterization Project (Reference 12). The calculations are performed in accordance with the Framatome-ANP administrative procedure for preparing and processing calculations (Reference 8) and the Framatome Quality Management Manual (Reference 9). This calculation is subject to the Quality Assurance Requirements and Description (Reference 7) ~~per the activity evaluation under work package number AGRM02 in the technical work plan TWP-EBS-MD-000014 REV 00 (Reference 11)~~.

HLM 9/15/03

THE FOLLOWING COMPUTER CODES HAVE BEEN USED IN THIS DOCUMENT:	
CODE/VERSION/REV	CODE/VERSION/REV
CLREG V1.0	

THE DOCUMENT CONTAINS ASSUMPTIONS THAT MUST BE VERIFIED PRIOR TO USE ON SAFETY-RELATED WORK

☐ YES ☒ NO

RECORD OF REVISIONS

Revision Number	Date
00 (Initial)	September 2003

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1. PURPOSE

The purpose of this calculation is to develop the critical limit (CL) for the 21 Pressurized Water Reactor (PWR) spent nuclear fuel (SNF) waste package (WP) in the proposed geologic repository at Yucca Mountain, Nevada. The CL is a limiting value of the effective neutron multiplication factor (k_{eff}) at which a WP configuration is considered potentially critical. The CL is derived from the bias and uncertainties associated with the employed criticality code (MCNP) and the modeling process.

The results of this calculation support the validation of the MCNP code to accurately predict k_{eff} for a range of conditions that are representative of potential configurations of commercial SNF in a degraded waste package in a geologic repository.

This document is an engineering calculation that supports the burnup credit methodology of the Yucca Mountain Site Characterization Project (Reference 12). The calculations are performed in accordance with the Framatome-ANP administrative procedure for preparing and processing calculations (Reference 8) and the Framatome Quality Management Manual (Reference 9). This calculation is subject to the Quality Assurance Requirements and Description (Reference 7).

2. METHOD

The methods used for calculating the CL follow Section 2 of Reference 1. This section summarizes some main features of the methods as applied in this calculation.

For WP criticality evaluations, criticality is defined by the CL, which is the value of k_{eff} at which a waste package configuration is considered potentially critical. An essential element of validating the methods and models used for calculating k_{eff} for a WP is the determination of the CL. The value of the CL is established by applying the MCNP criticality model in evaluating critical experiments that are representative of the range of in-package and out-of-package configuration identified by the degradation analyses. The CL is derived from the bias and uncertainties associated with the MCNP criticality code and the modeling process.

The CL in this document is calculated for five subsets of experiments that are applicable to the various configurations that a 21 PWR waste package may take over time in the geologic repository. Specifically, the CL applies to a configuration where the 21 PWR waste package and its internal structural components have degraded, but the fuel rods remain intact. Representative benchmark criticality experiments, e.g., Commercial Reactor Criticality (CRC) and Laboratory Critical Experiments (LCE), characterize the CL for this configuration and prescribe the basic range of applicability of the results.

The CL method follows the process outlined in Figure 1. The process has two pathways for establishing the CL: (1) a regression-based pathway that reflects criticality code results over a set of critical experiments that can be trended, and (2) a random sample-based pathway that applies when trending does not provide an appropriate explanation of the data from criticality code calculations.

The regression approach addresses trending of calculated values of k_{eff} with either neutronic or physical parameters. Regression is applied to a set of k_{eff} values to identify trending with such parameters. Trends show the results of systematic errors or bias inherent in the calculation method used to estimate criticality. In some cases a data set may be valid but might not cover the full range of parameters used to characterize the waste form. The range of applicability of a calculation method may be extended beyond the range of experimental conditions that establishes the bias by making used of correlated trends in the bias.

If the regression path identifies no trend, the random sample route may establish a CL that provides the desired statistical properties. By treating the set of criticality code k_{eff} values as a random sample of data, this route chooses between two straightforward statistical methods to develop the CL. These methods are identified in Figure 1 as (1) the normal distribution tolerance limit (NDTL) method and (2) the distribution free tolerance limit (DFTL) Reference 12 calls these two methods "non-trending" techniques

Regression (trending) methods establish a CL function by using statistical tolerance values based on linear regression techniques. In this context, trending is the linear regression of k_{eff} on the predictor variable(s). The predictor variable may be a parameter such as enrichment or burnup, or it may be a parameter that indicates the distribution of neutrons within the system, such as the average energy of a neutron that causes either fission or absorption. Where multiple candidates exist for trending purposes, each regression model will be applied and the conservative model may be used to determine the value of the CL. The lower uniform tolerance band (LUTB) method trends a single parameter against k_{eff}. Multiple regression methods that trend multiple parameters against k_{eff} may also be used to establish the tolerance-limit CL function. This calculation only uses single parameter regression.

The CL is calculated by the CLReg code using the LUTB method only when a trending regression is identified as statistically significant. If no trend is identified, then either the NDTL or the DFTL method is implemented using Excel spreadsheets as discussed in Reference 1.

Section 5 provides a detailed description of the calculations performed and the exact flow of the calculations.

Control of electronic management of data follows Framatome-ANP procedures in Reference 8.

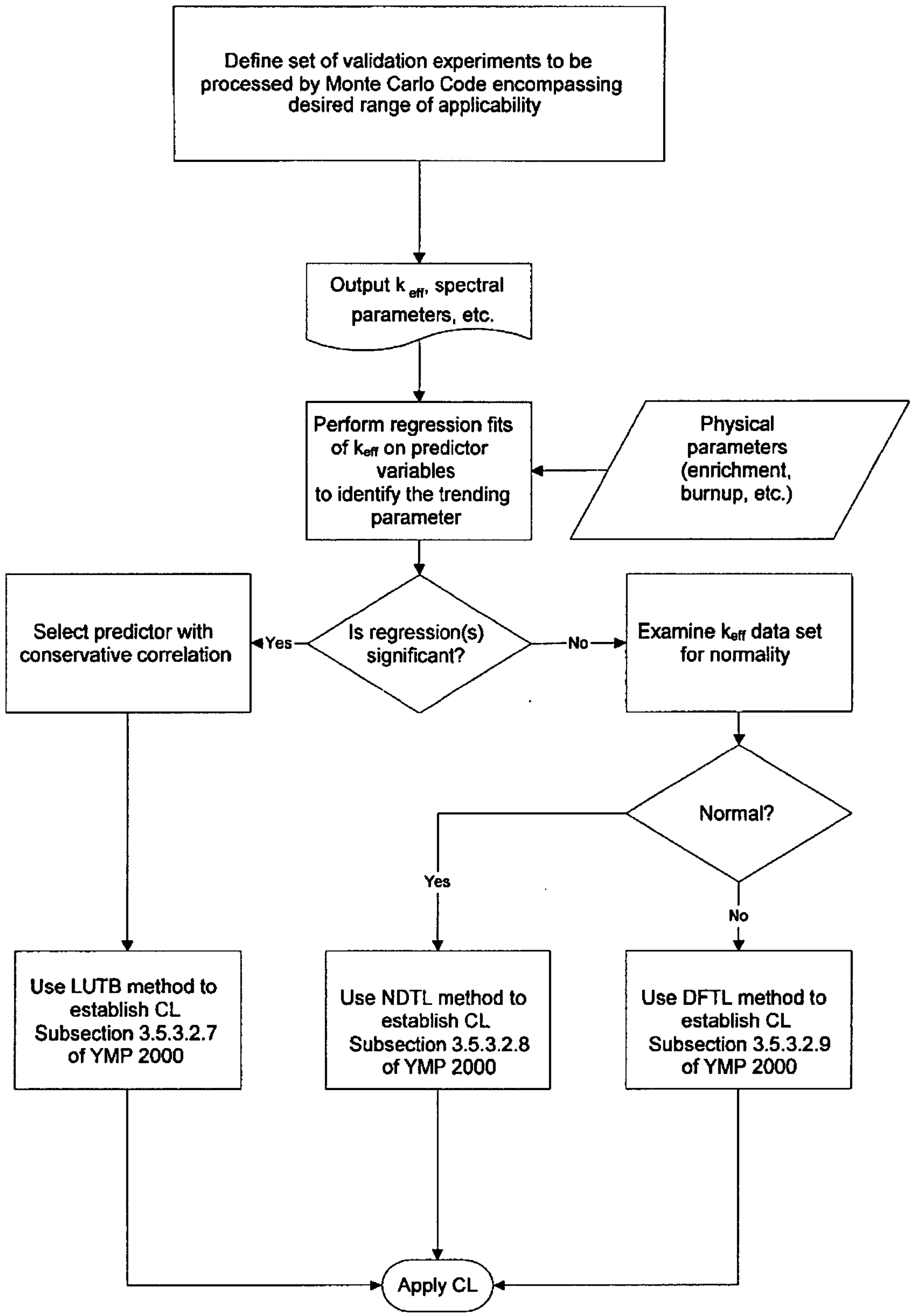


Figure 1. Process for Calculating Critical Limits (Reference 12)

3. ASSUMPTIONS

No specific assumptions are used in developing the current calculation.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE

In this calculation, a compiled version of the CLReg V1.0 (Reference 13) personal computer (PC) software code obtained from the YMP M&O is used in its executable form without modification. Reference 13 provides the following documentation for CLReg:

- Program Name: CLReg
- Version/Revision Number: V1.0
- Status/Operating System: Qualified/Windows 2000
- Software Tracking Number (STN) Number: 10528-1.0-01
- Computer Type: Personal Computer
- Computer processing unit: Software is installed on the Framatome-ANP PC Service Tag # JMTMB11 with the Windows XP operating system.

The identify and validity of the CLReg software and its qualification for use with the Windows XP operating system was confirmed for this calculation by re-executing the reference test cases and comparing the output to the original results in Reference 13. Documentation of the re-execution of the test cases is provided in Attachment I.

The CLReg computer program calculates sets of critical limits (critical limit functions) for waste packages under certain conditions. Each CL represents the value of k_{eff} at which a configuration is considered potentially critical. The CL accounts for the criticality analysis method bias and the uncertainty of the calculated k_{eff} values for a set of critical experiments that represent the waste package, as explained by linear regression trending analysis. Also inherent in each CL value is the statistical property of confidence for lower prediction limits and lower tolerance limits.

A FANPA listing of the input and output files for the CLReg calculations are documented in Attachment I such that an independent repetition of the software used could be performed. The CLReg software was: (1) appropriate for the calculation of critical limits, (2) used only within the range of validation as documented in Reference 13, and (3) obtained and used in accordance with Reference 8 (Section VII.C, p. 11).

5. CALCULATIONS

This section describes the calculations of CL for the 21 PWR waste package. The CL calculations are based on values of k_{eff} obtained with the MCNP code for appropriately selected groupings of data from the CRC and LCE benchmark experiments (References 4, 5, and 6). Section 5.1 describes the general inputs used in the CL evaluation. Section 5.2 gives a detailed description of the flow of the calculations that apply the CL method addressed in Section 2. Section 6 presents results of the calculations. The corresponding CLReg input and output files that are in FANPA are listed in Section 8. The supporting Excel spreadsheets that are stored in FANPA are listed in Section 9.

5.1 INPUTS

5.1.1 Selected Criticality Benchmark Experiments for CL Calculation

Neutronic parameters are selected from the CRC and LCE criticality benchmark experiments. The CRC and LCE state points for the trending analysis are selected from the following references:

CRC state points:

- State point identification from Reference 6 (Table 6.3-1, pp. 60-61)
- k_{eff} and sigma from Reference 4 (Table 4.1.1-1, pp. 40-41)
- Initial enrichment, and core average burnup from Reference 6 (Table 6.3-2, pp. 62-63)
- Ratio of rod pitch to average pellet diameter (P/D ratio) and average energy of the neutron causing fission (AENCF) from Reference 6 (Table. 6.3-3, pp. 64-66)

LCE state points:

- State point identification, k_{eff}, and sigma from Reference 5 (Table 6-1, pp. 21-23)
- Enrichment, AENCF, and P/D ratio from Reference 6 (Table 6.2-9, p. 55 and Table 6.2-10, pp. 55-59)
- Enrichment, AENCF, and P/D ratio for State Points 326 through 338 from Reference 6a (Table 6.2-1, pp. 49-51). Enrichment was derived from quotient of total fissile density over total fissionable density.

The CRC data contain results of criticality models for irradiated, burned SNF in an intact lattice geometry. The data cover a range of enrichments, lattice geometries, and fuel rod spacing that are representative of commercial PWR fuel in an intact configuration. The LCE data used in this calculation involve the results of criticality models for un-irradiated fresh fuel in various configurations that are representative of the range of potential configurations anticipated in the repository.

Tables 1 and 2 summarize parameters for CRC and LCE state points used in the trending analysis.

Table 1. Neutronic Parameters for CRC State Points

State Point	k_{eff}	sigma	enrichment	Burnup (GWD/MtU)	AENCF (MeV)	P/D Ratio
1	0.99601	0.00043	2.445	0	0.2344	1.53
2	0.99285	0.00040	2.446	8	0.2504	1.53
3	0.99502	0.00046	2.446	12	0.2518	1.53
4	0.99282	0.00044	2.670	9	0.2498	1.53
5	0.99408	0.00045	2.693	8	0.2489	1.53
6	0.99304	0.00045	2.693	13	0.2536	1.53
7	0.99073	0.00045	2.693	15	0.2547	1.53
8	0.99134	0.00047	2.648	7	0.2499	1.53
9	0.99152	0.00046	2.648	14	0.2576	1.53
10	0.99603	0.00047	2.648	15	0.2568	1.53
11	0.99479	0.00047	2.915	7	0.2475	1.53
12	0.99805	0.00045	2.915	19	0.2605	1.53
13	0.99561	0.00043	3.210	12	0.2513	1.53
14	0.99579	0.00047	3.210	15	0.2557	1.53
15	0.99273	0.00044	3.210	24	0.2612	1.53
16	0.99324	0.00052	3.554	10	0.2504	1.53
17	0.99083	0.00045	3.554	18	0.2583	1.53
18	0.99222	0.00049	3.554	19	0.2598	1.53
19	0.98993	0.00047	3.554	20	0.2587	1.53
20	0.99321	0.00042	3.554	24	0.2582	1.53
21	0.99247	0.00046	3.554	25	0.2616	1.53
22	0.99039	0.00043	3.755	12	0.2532	1.53
23	0.99021	0.00046	3.755	15	0.2572	1.53
24	0.99063	0.00049	3.755	17	0.2582	1.53
25	0.99054	0.00042	3.755	25	0.2615	1.53
26	0.99067	0.00047	3.755	25	0.2610	1.53
27	0.98772	0.00044	3.755	28	0.2643	1.53
28	0.99208	0.00044	3.892	14	0.2546	1.53
29	0.99311	0.00050	3.892	19	0.2584	1.53
30	0.99078	0.00048	3.892	21	0.2597	1.53
31	0.98837	0.00048	3.892	25	0.2635	1.53
32	0.99164	0.00052	4.015	15	0.2558	1.53
33	0.98725	0.00048	4.015	33	0.2660	1.53
59	1.00141	0.00042	2.633	0	0.2353	1.53
60	0.99088	0.00046	2.820	10	0.2476	1.53
61	0.99162	0.00048	2.820	14	0.2498	1.53
46	0.99946	0.00045	2.602	0	0.2390	1.62
47	0.98541	0.00050	3.472	12	0.2351	1.62
48	0.98771	0.00049	3.472	14	0.2375	1.62
49	0.98954	0.00047	3.618	11	0.2362	1.62
50	0.99175	0.00046	3.618	16	0.2388	1.62

51	0.98723	0.00049	3.618	23	0.2426	1.62
36	0.99631	0.00043	2.535	0	0.2374	1.54
37	0.99158	0.00044	3.427	11	0.2518	1.54
38	0.99180	0.00050	3.427	19	0.2555	1.54

Table 2. Neutronic Parameters for LCE State Points

State Point	k_{eff}	sigma	Enrichment (%)	AENCF (MeV)	P/D Ratio
271	1.00084	0.00088	2.350	0.12095	1.82
272	0.99842	0.00088	2.350	0.12469	1.82
273	0.99898	0.00089	2.350	0.12172	1.82
274	1.00104	0.00087	2.350	0.12003	1.82
275	1.00037	0.00107	4.310	0.27968	1.50
276	0.99675	0.00103	4.310	0.17662	1.50
277	0.99724	0.00111	4.310	0.17840	1.50
278	1.00719	0.00110	4.310	0.17735	1.49
279	1.00827	0.00099	4.310	0.22171	1.49
280	1.00660	0.00174	4.310	0.22390	1.36
281	1.00358	0.00157	4.310	0.26643	1.36
282	1.00546	0.00108	4.310	0.19461	1.49
283	1.00371	0.00113	4.310	0.19421	1.49
284	0.99593	0.00099	2.350	0.20945	1.37
285	1.00074	0.00087	2.350	0.10984	1.98
286	1.00218	0.00186	5.740	0.15637	1.57
287	1.00503	0.00167	5.740	0.08863	2.22
288	1.00058	0.00159	2.460	0.19988	1.59
289	1.00019	0.00148	2.460	0.18078	1.59
290	0.99480	0.00150	2.460	0.17908	1.59
291	0.99445	0.00153	2.460	0.16919	1.59
292	0.99556	0.00152	2.460	0.17216	1.59
293	0.99463	0.00151	2.460	0.15963	1.59
294	0.98895	0.00149	2.460	0.16496	1.59
295	0.99298	0.00144	2.460	0.15528	1.59
296	0.99511	0.00148	2.460	0.16036	1.59
297	0.99699	0.00148	2.460	0.17893	1.59
298	0.99549	0.00151	2.460	0.16671	1.59
299	0.99933	0.00151	2.460	0.18075	1.59
300	0.99107	0.00157	2.460	0.18348	1.59
301	0.99041	0.00150	2.460	0.16952	1.59
302	0.99365	0.00151	2.460	0.18187	1.59
303	0.99470	0.00150	2.460	0.16855	1.59
304	0.99383	0.00153	2.460	0.18354	1.59
305	0.99392	0.00151	2.460	0.16933	1.59
306	0.99160	0.00140	2.460	0.16225	1.59
307	0.99790	0.00144	2.460	0.20110	1.59
308	0.99940	0.00161	2.750	0.20965	1.56
309	1.00049	0.00155	2.750	0.20841	1.56
310	1.00066	0.00156	2.740	0.20416	1.56
311	1.00158	0.00151	2.740	0.20560	1.56
312	1.00335	0.00151	2.730	0.20648	1.56
313	0.99912	0.00151	2.730	0.20341	1.56

314	0.99876	0.00150	2.780	0.20851	1.56
315	1.00133	0.00153	2.770	0.21011	1.56
316	1.00033	0.00143	2.460	0.20132	1.59
317	1.00322	0.00153	2.760	0.20698	1.56
318	0.99945	0.00145	2.460	0.19828	1.59
319	1.00054	0.00147	2.460	0.19948	1.59
320	1.00193	0.00150	2.460	0.19985	1.59
321	0.99955	0.00154	2.460	0.19752	1.59
322	0.99996	0.00152	2.460	0.19775	1.59
323	1.00410	0.00148	2.460	0.19675	1.59
324	0.99929	0.00154	2.460	0.19756	1.59
325	1.00135	0.00156	2.460	0.19873	1.59
326	0.99624	0.00174	2.566	0.25557	1.39
327	1.00050	0.00169	2.566	0.27397	1.39
328	1.00302	0.00171	2.566	0.16128	1.72
329	1.00835	0.00161	2.566	0.18944	1.72
330	1.00709	0.00160	2.566	0.13192	1.96
331	1.00752	0.00155	2.566	0.15372	1.96
332	1.00318	0.00184	6.704	0.22928	1.54
333	1.00506	0.00166	6.704	0.19184	1.66
334	1.00003	0.00187	6.704	0.20094	1.66
335	1.00682	0.00181	6.704	0.12043	2.18
336	1.00626	0.00182	6.704	0.10732	2.35
337	1.00739	0.00171	6.704	0.07964	3.08
338	0.98750	0.00168	3.470	0.37762	1.26

For the 21 PWR waste package, five subsets of the criticality benchmark experiments are formed from the CRC and LCE state point data based on the anticipated range of parameters for intact fuel rods in a degraded waste package with degraded internal structural components. These five subsets of state points are identified in Table 3.

Table 3. Summary of Subsets of Critical Benchmark Experiments Used as Input

Description of Subset	Number of State Points	State Points	References
CRC	45	1-33, 36-38, 46- 51, 59-61	4, 6
LCE	68	271-338	5, 6, 6a
LCE & CRC (Cycle 1)	72	1, 36, 49, 59, 271-338	4, 5, 6, 6a
LCE & CRC (Fresh Batch)	85	1, 4, 5, 8, 11, 13, 16, 22, 28, 32, 36, 37, 46, 47, 49, 59, 60, 271-338	4, 5, 6, 6a
LCE &CRC	113	1-33, 36-38, 46-51, 59-61, 271-338	4, 5, 6,6a

5.2 DESCRIPTION AND FLOW OF CALCULATIONS

The CL calculations follow methods described in Section 2.

For critical benchmark experiments that are either slightly super- or sub-critical, the calculated k_{eff} value (k_{calc}) is normalized to the experimental value k_{exp} by using the formula

$$k_{norm} = k_{calc} / k_{exp} \quad (1)$$

The normalization does not affect inherent bias in the calculation due to very small differences in k_{eff}. Unless otherwise note, the normalized k_{eff} values (k_{norm}) are used in calculations of the CL.

Using the built-in regression analysis tool from Excel, each set of the normalized k_{eff} values is first tested for trending against available neutronic or physical parameters (e.g., average burnup, U-235 enrichment, average energy of a neutron causing fission (AENCF), and ratio of assembly pitch to fuel rod diameter (P/D ratio). Trending in this context is the linear regression of k_{eff} on each predictor variable. If a trend exists for a one set, the CLReg code is then used to calculate the CL function using the LUTB method (Reference 13).

The linear regression fitted equation has the form $y(x) = a + bx + \varepsilon$, where ε is the random error component (residuals). The test for trending uses well-established indicators or goodness-of-fit tests. As a first indicator, the coefficient of determination (r^2) from the linear regression analysis is evaluated for linear trending. This coefficient represents the proportion of the sum of the squares of deviations of the *y* values about their mean that can be attributed to a linear relation between *y* and *x*.

Another assessment of the linear model is done by checking the goodness-of-fit against a null hypothesis for the slope (*b*) by using the test statistic "*T*" calculated by the Excel regression analysis tool. The test statistic is compared to Student's t-distribution ($t_{\alpha/2,n-2}$) with 95% confidence and *n-2* degrees of freedom, where *n* is the number of points in the data set. Given a null hypothesis of "no statistically significant trending exists (slope = zero)", the hypothesis either is accepted if $|T| < t_{\alpha/2,n-2}$ or otherwise is rejected. Accepting linear trends supported by 95% confidence eliminates trends due to randomness of the data. The P-value probability calculated by the Excel regression tool provides a direct estimate of the probability of having linear trending due only to chance.

The last step in the regression analysis determines whether or not the simple linear regression model satisfies the final requirements of having a normally distributed error component (residuals) with a mean of zero. These requirements are verified in this calculation by calculating the mean of the residuals and applying a normality test to the residuals. If the data set shows no trending,

If the subset shows no trending, according to the methodology summarized in Figure 1, the subset is tested for normality by using an omnibus normality test. For subsets having between 10 and 50 points, the Shapiro-Wilk normality test is used. The steps required to apply the test are summarized in Reference 1 and implemented in Excel spreadsheets. For subsets of more than 50 points, the Anderson-Darling test is used to test the goodness-of-fit to a normal distribution constructed with the subset sample average and standard deviation. The steps required to apply this test are described in Reference 1 and are implemented in Excel spreadsheets.

Given that the k_{eff} values produced by the criticality code for the benchmark are shown to be normally distributed, the CL can be calculated using the NDTL as described in Reference 1 where

$$CL = k_{ave} - k\,(\gamma, P, df) * S_P \qquad (2)$$

where: k_{ave} is the average of the k_{eff} values, unless $k_{ave} > 1$, in which instance the appropriate value for k_{ave} should be 1 to disallow positive bas; k (γ, P, df) is a multiplier in which γ is the confidence level, P is the proportion of the population covered, and df is the number of degrees of freedom. The S_P term is the square root of the sum of the inherent variance of the critical experiment data set plus the average of the criticality code variance for the critical experiment data set. Lower tolerance limits (CL), at a minimum, should be calculated with 95% confidence that 95% of the data lies above the CL. This is quantified by using the multipliers in Table 4 (Reference 1, pp. 22-23). In cases where $n > 50$ the multiplier for $n = 50$ is used; this value of k is conservative for calculating the CL.

Table 4. Multiplier Used in Calculating CL Using NDTL

Number of Experiments (n)	Multiplier k (γ, P, df) for γ =95%; P= 95% and df = n
45	2.092
50	2.065

If the data set does not have a normal statistical distribution, the non-parametric DFTL statistical treatment be used. The DFTL method results in the determination of the degree of confidence that a fraction of the true population of data lies above the smallest value observed. The more data there are in a sample, the higher the degree of confidence. Non-parametric techniques do not require reliance upon distributions but are rather an analysis or ranks. Therefore, the k_{eff} values in sample are ranked from the smallest to the largest.

For a desired population fraction of 95% and a rank order of 1 (the smallest k_{eff} in the data sample), the following equation determines the percent confidence that the specified fraction of the population is above the lowest observed value:

$$\beta = 1 - q^n = 1 - 0.95^n \qquad (3)$$

Per Reference 1, for non-parametric data analysis, the CL is determined by:

CL = Smallest k_{eff} value – Uncertainty for smallest k_{eff} – Non-parametric Margin (NPM) (4)

where Non-parametric margin (NPM) is added to account for small sample size.

Table 5 (Reference 1) shows the recommended set of values of NPM based on the confidence level β calculated with equation (3) above.

Table 5. Non-parametric Margins

Degree of confidence (β) for 95% of population	Non-parametric margin
>90%	0.0
>80%	0.01
>70%	0.02
>60%	0.03
>50%	0.04
>40%	0.05
≤40%	Additional data needed

If the smallest k_{eff} value is greater than 1, then the non-parametric CL becomes:

$$CL = 1 - S_P - NPM \quad (4)$$

where S_P is the square root of the pooled variance.

All calculations described above have been applied, where appropriate, to each subset of k_{eff} data for the set of criticality benchmarks selected for the 21 PWR SNF group. The actual calculations are implemented in Excel spreadsheets. These spreadsheets are in files stored on FANPA. Section 12 provides a listing and description of the Excel files on FANPA.

6. RESULTS

The grouping of CL results based on benchmark subsets are presented in this section. For each subset, the results of the trending analysis are shown, and if a valid trending is identified, the CL function (LUTB method calculated with the CLReg code run at the 95% confidence level and 99.5% population coverage) is included in the corresponding figures together with the k_{eff} values of each subset. For data that show no trending, the results of the testing for normality are shown and the CL obtained either by the NDTL method or DFTL method is included in the corresponding figures.

The results of the linear trending analysis for each subset are summarized in separate tables in each of the following sections. Each table gives the number of k_{eff} state points (n), the intercept, the slope, the square of the correlation coefficient known as the coefficient of determination (r^2), the test statistic (T), the tabulated value of $t_{\alpha/2,n-2}$ (with $\alpha = 0.05$), and the probability (P-value) that the observed trending is due to chance. All of the above values have been calculated with the regression tool available in Excel and are included in the spreadsheets listed in Attachment III. For the purpose of these evaluations, the goodness-of-fit test for the linear model was judged to be passed when the coefficient of determination was greater than 0.1, the P-value was smaller than 0.001, and the residuals were found to be normally distributed with a mean of 0.

6.1 CALCULATED CL FOR CRC SUBSET

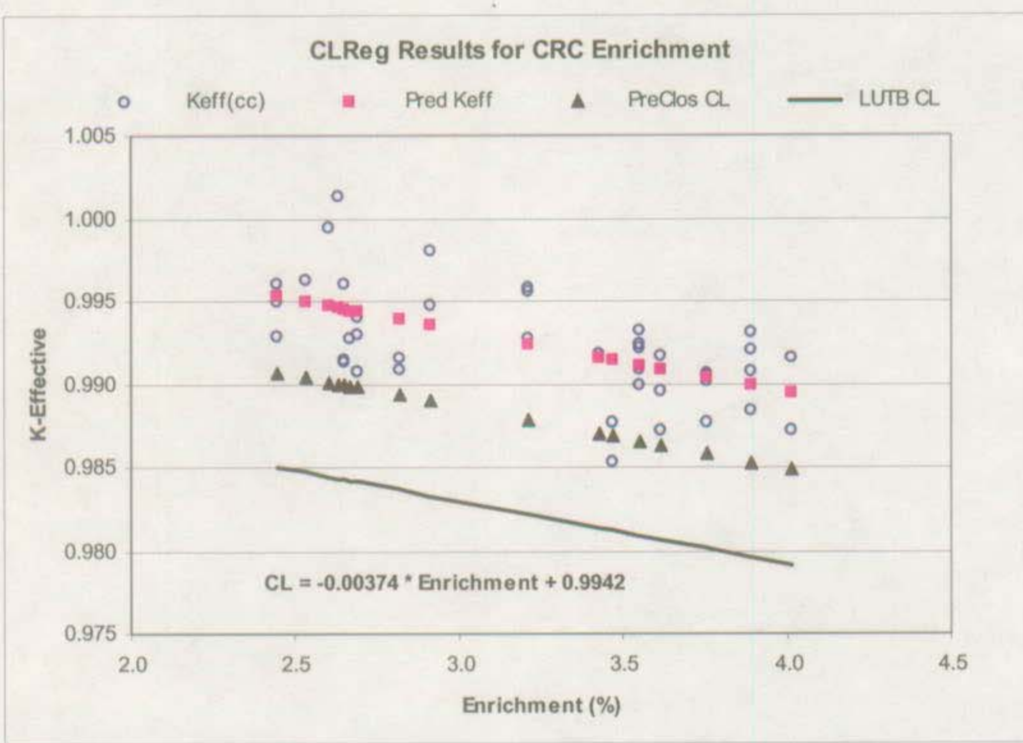
Table 6 shows results of the trending parameter analysis for the CRC subset.

Table 6. CRC Trending Parameter Results

Trend Parameter	n	Intercept	Slope	r^2	T	$t_{0.025,n-2}$	P-value	Goodness-of-fit Tests	Valid Trend
Burnup	45	0.9959	-2.4E-04	0.3312	-4.6149	2.016	3.53E-05	passed	yes
Enr (Fissile/ Fissionable)	45	1.0045	-0.0037	0.3609	-4.9281	2.016	1.28E-05	passed	yes
AENCF	45	1.0130	-0.0824	0.0511	-1.5211	2.016	0.1355	passed	no
P/D Ratio	45	1.0321	-0.0258	0.0613	-1.6759	2.016	0.1010	failed	no

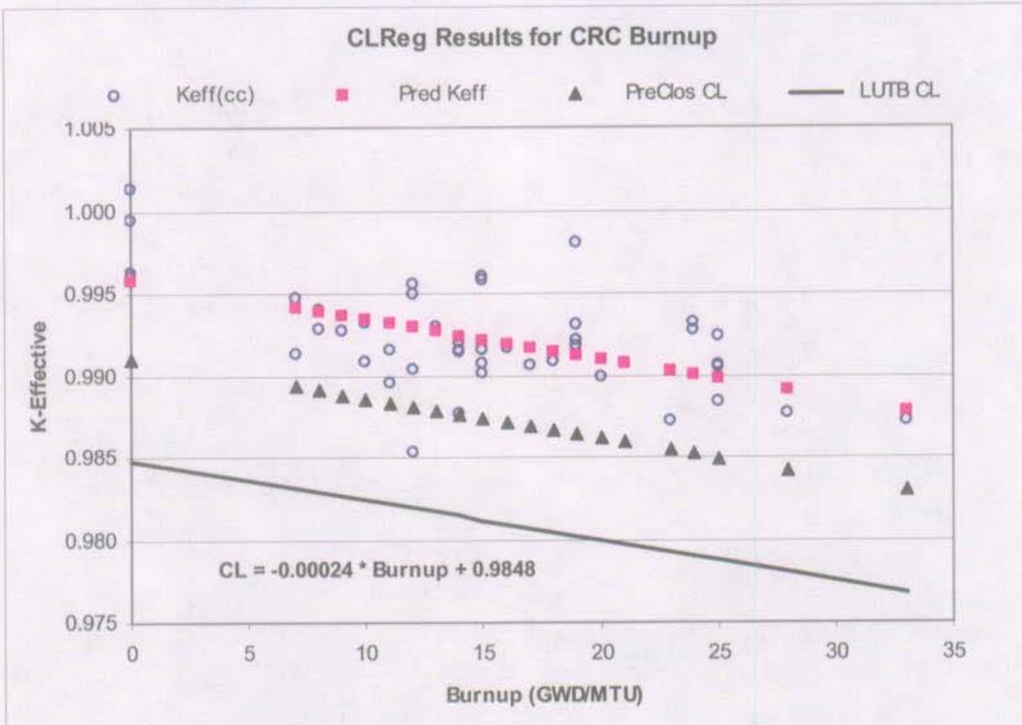
Source: Calculated in spreadsheet "crc_cl.xls", FANPA

Figures 2-5 are based on the results in Table 6.



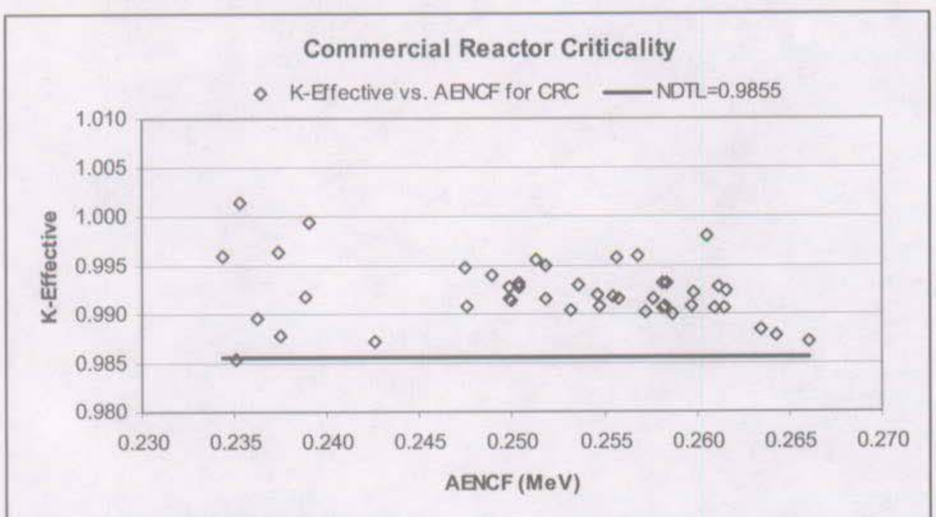
Source: Calculated (for 95% confidence level and 99.5% population coverage) in spreadsheet "crc_cl.xls", worksheet "crc_CLReg_enr", FANPA

Figure 2. CRC Critical Limit as a Function of Enrichment (CLReg Method)



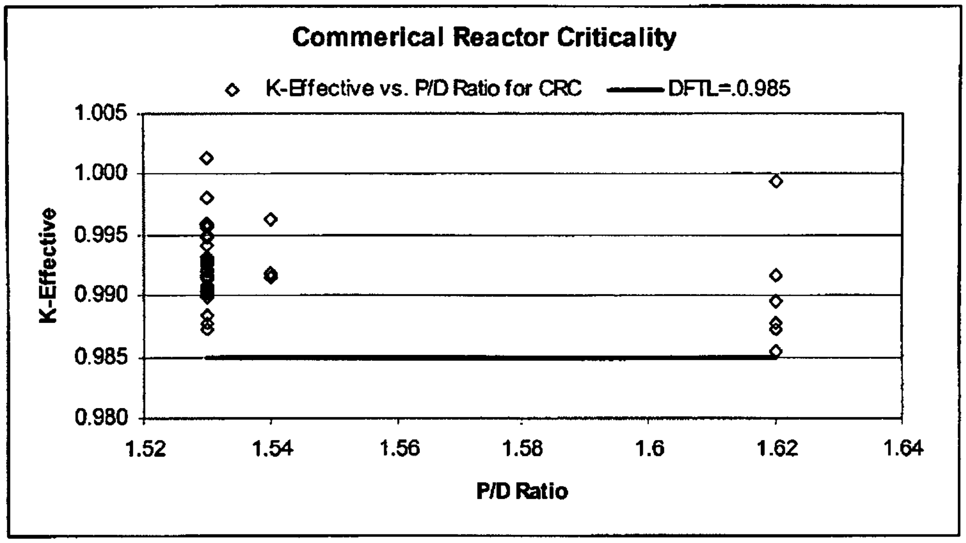
Source: Calculated (for 95% confidence level and 99.5% poulation coverge) in spreadsheet "crc_cl.xls", worksheet "crc_CLReg_burnup", FANPA

Figure 3. CRC Critical Limit as a Function of Burnup (CLReg Method)



Source: Calculated (for 95% confidence level and 95% population coverage) in spreadsheet "crc_cl.xls", worksheet "crc_NDTL_aencf", FANPA

Figure 4. CRC Critical Limit as Function of AENCF (NDTL Method)



Source: Calculated (for 90.1% confidence level and 95% population coverage) in spreadsheet "crc_cl.xls", worksheet "crc_DFTL_pd", FANPA

Figure 5. CRC Critical Limit as Function of P/D Ratio (DFTL Method)

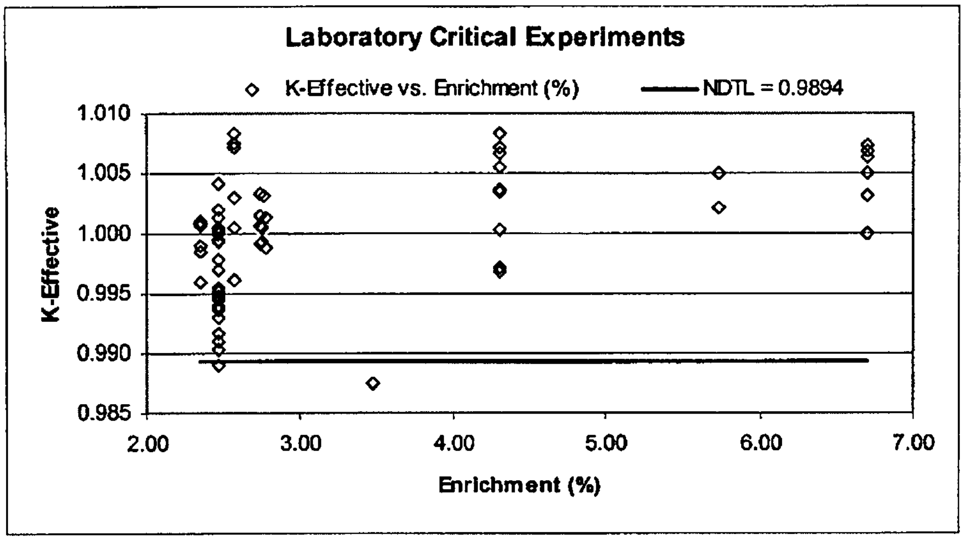
6.2 CALCULATED CL FOR LCE SUBSET

Table 7 shows the results of the trending parameter analysis for the LCE subset.

Table 7. LCE Trending Parameter Results

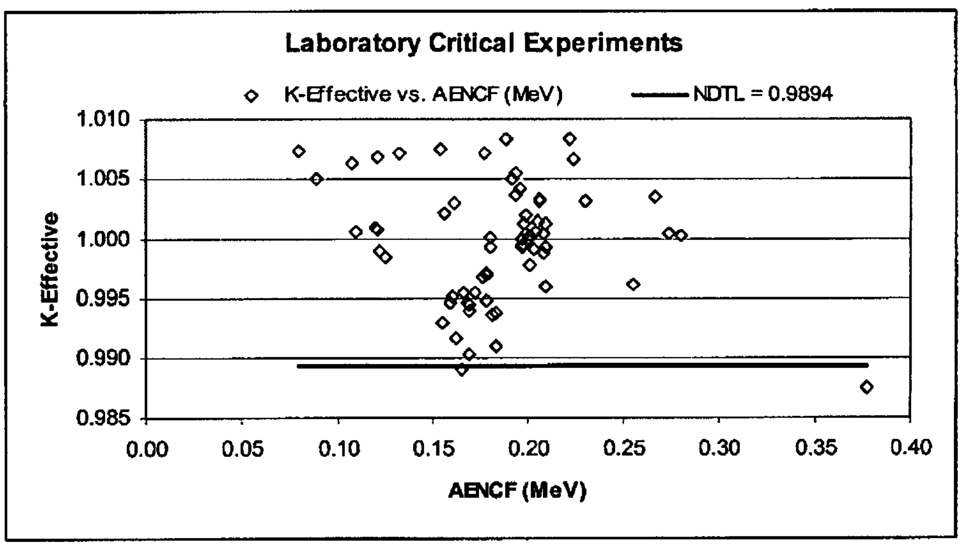
Trend Parameter	N	Intercept	Slope	r^2	T	$t_{0.025,n-2}$	P-value	Goodness-of-fit Tests	Valid Trend
Enr (Fissile / Fissionable)	68	0.9943	0.0017	0.2181	4.2904	1.997	5.96E-05	passed	no
AENCF	68	1.0033	-0.0195	0.0336	-1.5154	1.997	0.1344	passed	no
P/D Ratio	68	0.9879	0.0072	0.1458	3.3563	1.997	0.0013	passed	no

Figures 6-8 are based on the results in Table 7.



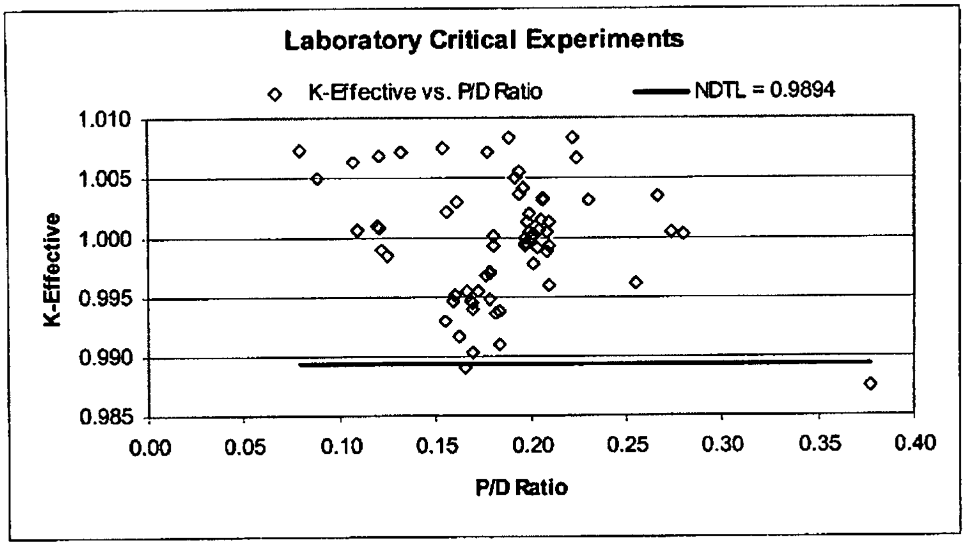
Source: Calculated (for 95% confidence level and 95% population coverage) in spreadsheet "lce_cl.xls", worksheet "lce_NDTL_enr", FANPA

Figure 6. LCE Critical Limit as Function of Enrichment (NDTL Method)



Source: Calculated (for 95% confidence level and 95% population coverage) in spreadsheet "lce_cl.xls", worksheet "lce_NDTL_aencf", FANPA

Figure 7. LCE Critical Limit as Function of AENCF (NDTL Method)



Source: Calculated (for 96.9% confidence level and 95% population coverage) in spreadsheet "lce_cl.xls", worksheet "lce_NDTL_pd", FANPA

Figure 8. LCE Critical Limit as Function of P/D Ratio (DFTL Method)

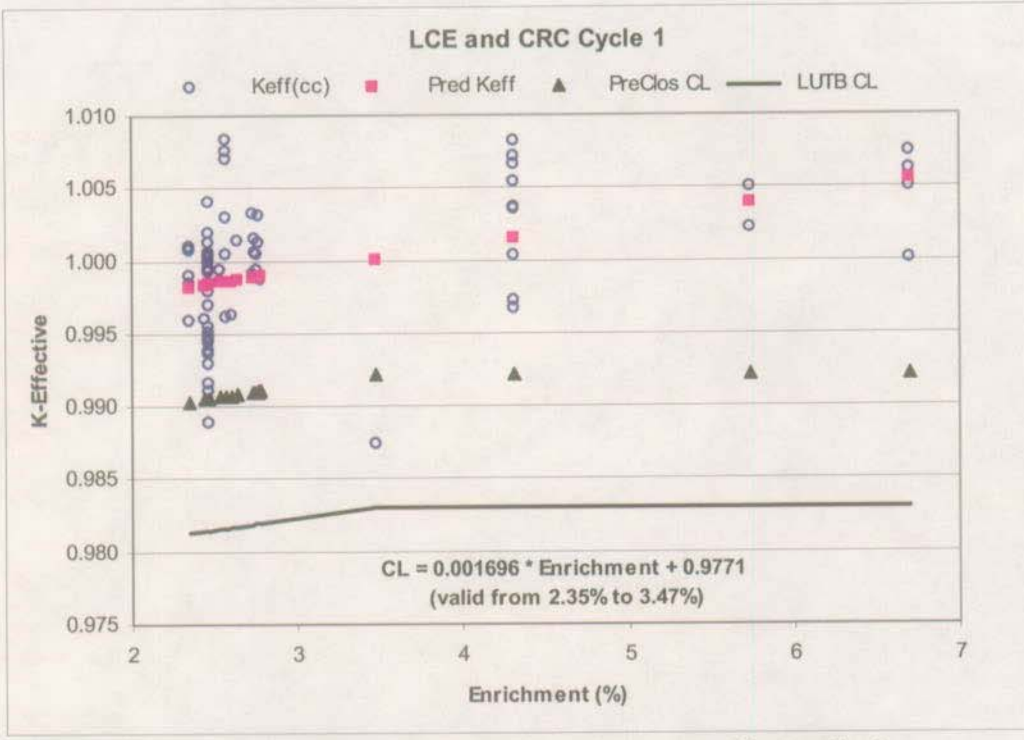
6.3 CALCULATED CL FOR LCE AND CRC (CYCLE 1) SUBSET

Table 8 shows the results of the trending parameter analysis for the LCE and CRC (Cycle 1) fuel subset.

Table 8. LCE and CRC (Cycle 1) Trending Parameter Results

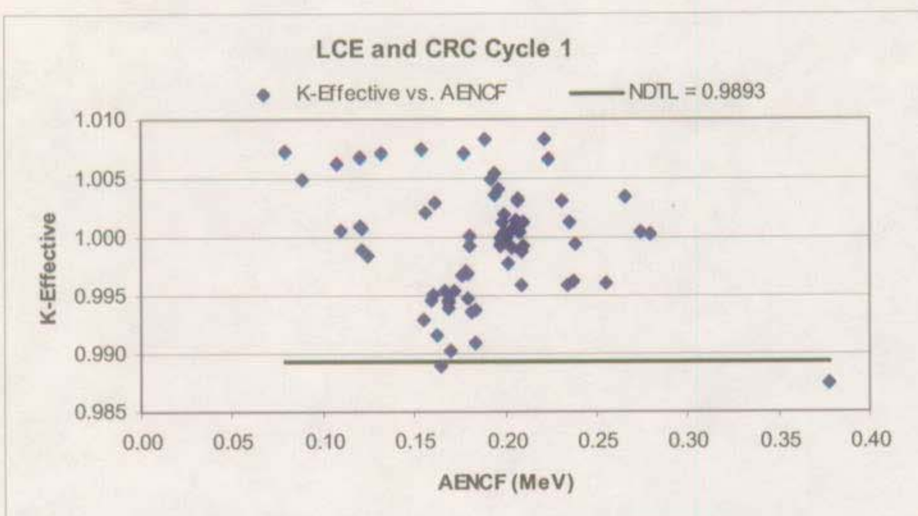
Trend Parameter	N	Intercept	Slope	r^2	T	$t_{0.025,n-2}$	P-value	Goodness-of-fit Tests	Valid Trend
Enr (Fissile / Fissionable)	72	0.9942	0.0017	0.2197	4.4391	1.996	3.29E-05	passed	yes
AENCF	72	1.0034	-0.0201	0.0374	-1.6490	1.996	0.1036	passed	no
P/D Ratio	72	0.9877	0.0073	0.1471	3.4749	1.996	8.81E-04	passed	no

Figures 9-11 are based on the results in Table 8.



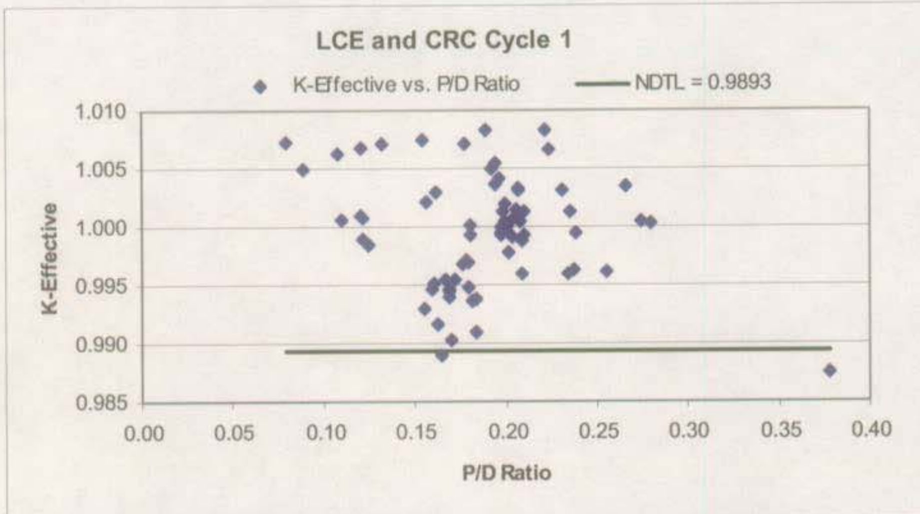
Source: Calculated (for 95% confidence level and 99.5% population coverage) in spreadsheet "lce&crc_cy1_cl.xls", worksheet "lce&crc_cy1_CLReg_enr", FANPA

Figure 9. LCE and CRC (Cycle 1) Critical Limit as Function of Enrichment (CLReg Method)



Source: Calculated (for 95% confidence level and 95% population coverage) in spreadsheet "lce&crc_cy1_cl.xls", worksheet "lce&crc_cy1_NDTL_aencf", FANPA

Figure 10. LCE and CRC (Cycle 1) Critical Limit as Function of AENCF (NDTL Method)



Source: Calculated (for 97.5% confidence level and 95% population coverage) in spreadsheet "lce&crc_cy1_cl.xls", worksheet "lce&crc_cy1_DFTL_pd", FANPA

Figure 11. LCE and CRC (Cycle 1) Critical Limit as Function of P/D Ratio (NDTL Method)

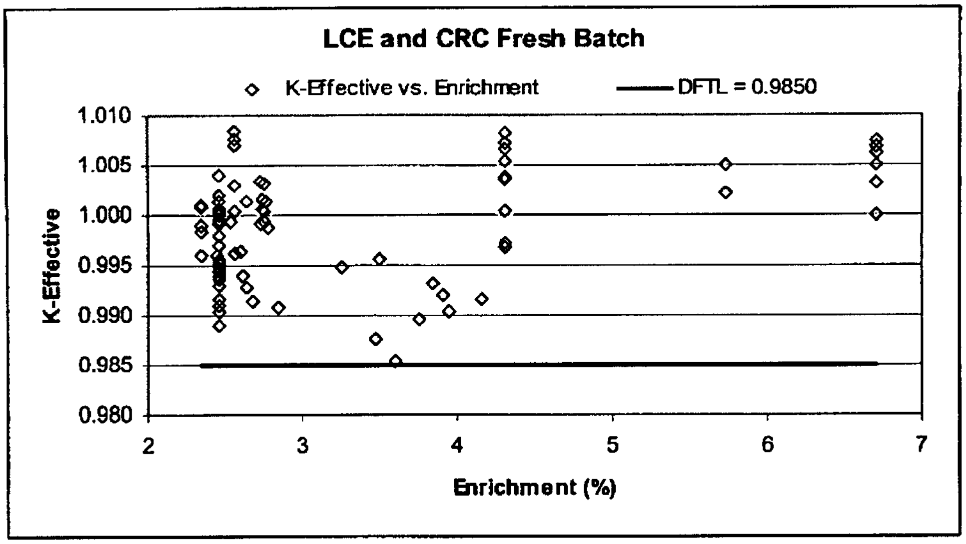
6.4 CALCULATED CL FOR LCE AND CRC (FRESH BATCH) SUBSET

Table 9 shows the results of the trending parameter analysis for the LCE and CRC (Fresh Batch) fuel subset.

Table 9. LCE and CRC (Fresh Batch) Trending Parameter Results

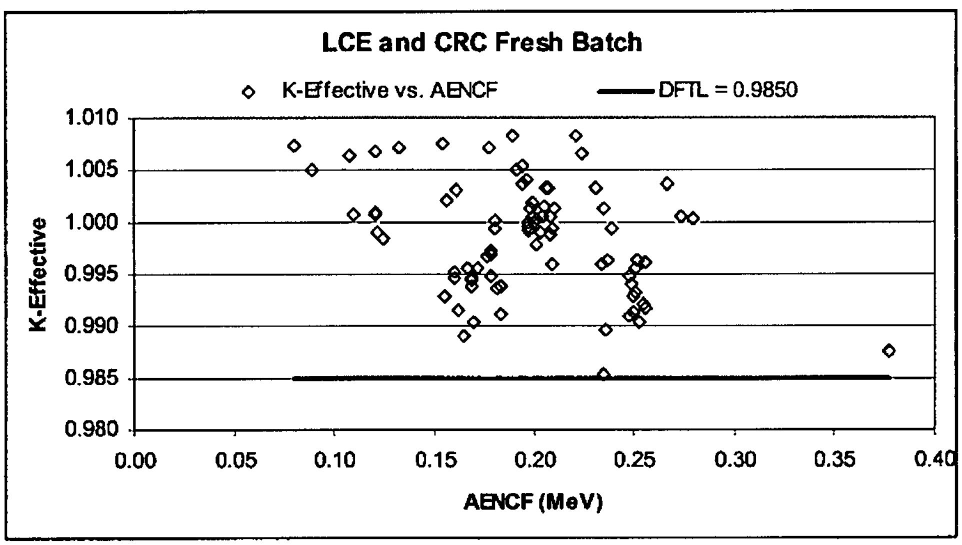
Trend Parameter	N	Intercept	Slope	r^2	T	$t_{0.025,n-2}$	P-value	Goodness-of-fit Tests	Valid Trend
Enr (Fissile / Fissionable)	85	0.9937	0.0015	0.1218	3.3921	1.992	0.0011	failed	no
AENCF	85	1.0066	-0.0412	0.1393	-3.6657	1.992	4.34E-04	passed	no
P/D Ratio	85	0.9846	0.0086	0.1452	-3.7553	1.992	3.20E-04	passed	no

Figures 12-14 are based on the results in Table 9.



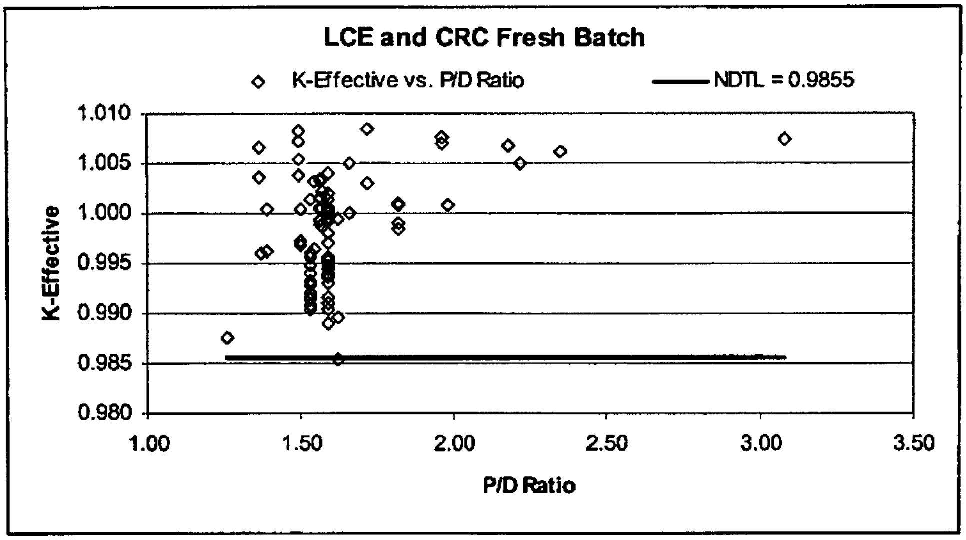
Source: Calculated (for 98.7% confidence level and 95% population coverage) in spreadsheet "lce&crc_freshbatch_cl.xls", worksheet "lce&crc_fb_DFTL_enr", FANPA

Figure 12. LCE and CRC (Fresh Batch) Critical Limit as Function of Enrichment (DFTL Method)



Source: Calculated (for 98.7% confidence level and 95% population coverage) in spreadsheet "lce&crc_freshbatch_cl.xls", worksheet "lce&crc_fb_DFTL_aencf", FANPA

Figure 13. LCE and CRC (Fresh Batch) Critical Limit as Function of AENCF (DFTL Method)



Source: Calculated (for 95% confidence level and 95% population coverage) in spreadsheet "lce&crc_freshbatch_cl.xls", worksheet "lce&crc_fb_NDTL_pd", FANPA

Figure 14. LCE and CRC (Fresh Batch) Critical Limit as Function of P/D Ratio (NDTL Method)

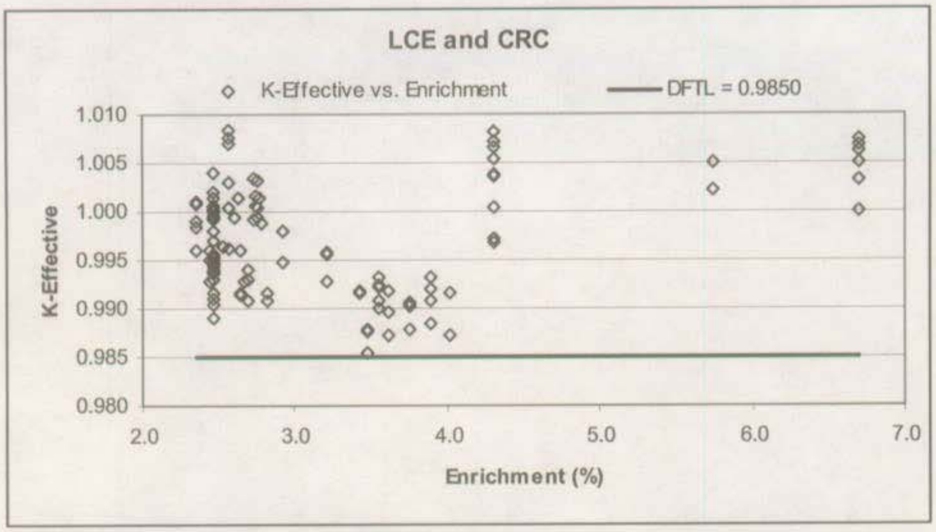
6.5 CALCULATED CL FOR LCE AND CRC SUBSET

Table 10 shows the results of the trending parameter analysis for the LCE and CRC fresh batch fuel subset.

Table 10. LCE and CRC Trending Parameter Results

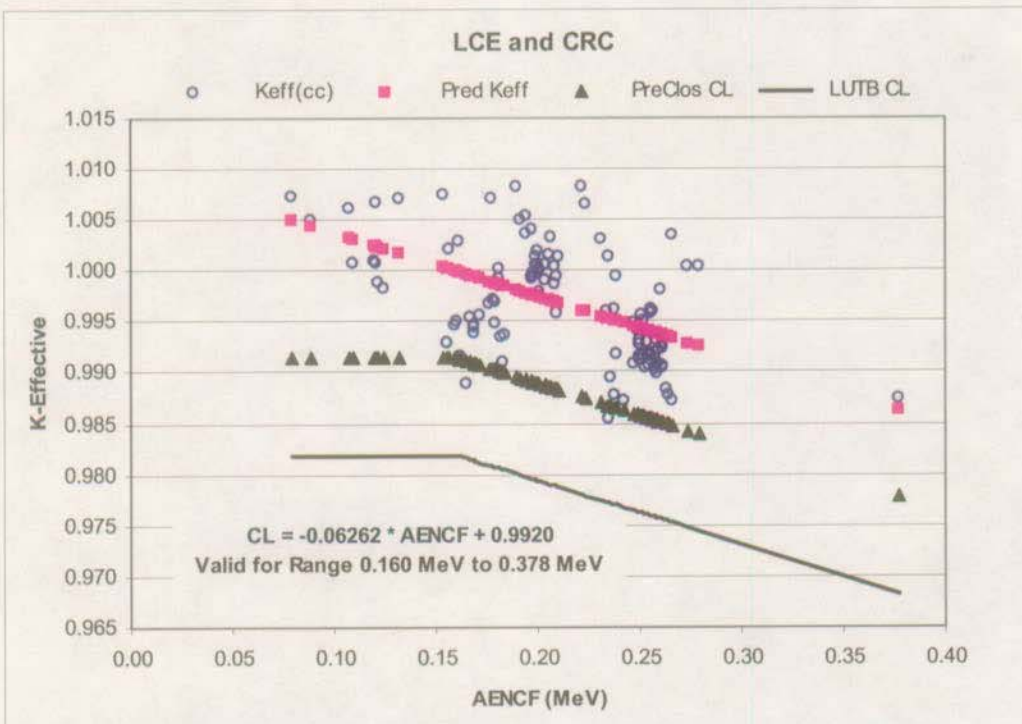
Trend Parameter	N	Intercept	Slope	r^2	T	$t_{0.025,n-2}$	P-value	Goodness-of-fit Tests	Valid Trend
Enr (Fissile / Fissionable)	113	0.9930	0.0012	0.0502	2.4174	1.982	0.0173	failed	no
AENCF	113	1.0100	-0.0627	0.2931	-6.7840	1.982	5.96E-10	passed	yes
P/D Ratio	113	0.9795	0.0107	0.1539	4.4940	1.982	1,72E-05	passed	no

Figures 15-16 are based on the results in Table 10.



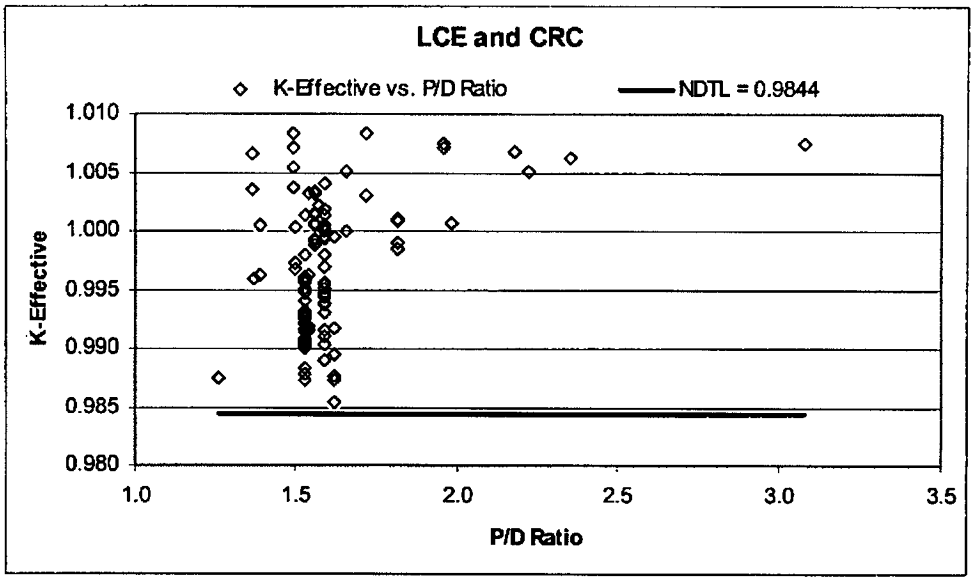
Source: Calculated (for 99.7% confidence level and 95% population coverage) in spreadsheet "lce&crc_cl.xls", worksheet "lce&crc_DFTL_enr", FANPA

Figure 15. LCE and CRC Critical Limit as Function of Enrichment (DFTL Method)



Source: Calculated (for 95% confidence level and 99.5% population coverage) in spreadsheet "lce&crc_cl.xls", worksheet "lce&crc_CLReg_aencf", FANPA

Figure 16. LCE and CRC Critical Limit as Function of AENCF (CLReg Method)



Source: Calculated (for 95% confidence level and 95% population coverage) in spreadsheet "lce&crc_cl.xls", worksheet "lce&crc_NDTL_pd", FANPA

Figure 17. LCE and CRC Critical Limit as Function of P/D Ratio (NDTL Method)

6.6 SUMMARY OF RESULTS

Table 11 provides a summary of the results of the analysis of the critical benchmark data and the calculated CL functions or values presented in the preceding tables and figures.

Table 11. Summary of Calculated CL Functions and CL Values for the 21 PWR WP

Data	Trend Parameter	Test for Normality of Residuals	Applied Calculation Method	CL or CL Function
CRC	enrichment	passed	CLReg	CL = -0.00374 * Enrichment + 0.9942
CRC	burnup	passed	CLReg	CL = -0.00024 * Burnup + 0.9848
CRC	AENCF	passed	NDTL	CL = 0.9855
CRC	P/D ratio	failed	DFTL	CL = 0.9850
LCE	enrichment	passed	NDTL	CL = 0.9894
LCE	AENCF	passed	NDTL	CL = 0.9894
LCE	P/D ratio	passed	NDTL	CL = 0.9894
LCE & CRC (Cycle 1)	enrichment	passed	CLReg	CL = 0.0017 * Enrichment + 0.9771 (Valid from 2.35% to 3.47%) CL = 0.9830 for Enrichment > 3.47%
LCE & CRC (Cycle 1)	AENCF	passed	NDTL	CL = 0.9893
LCE & CRC (Cycle 1)	P/D ratio	passed	NDTL	CL = 0.9893
LCE & CRC (fresh fuel)	enrichment	failed	DFTL	CL = 0.9850
LCE & CRC (fresh fuel)	AENCF	passed	DFTL	CL = 0.9850
LCE & CRC (fresh fuel)	P/D ratio	passed	NDTL	CL = 0.9855
LCE & CRC	enrichment	failed	DFTL	CL = 0.9850
LCE & CRC	AENCF	passed	CLReg	CL = -0.06262 * AENCF + 0.9920 (Valid from 0.160 MeV to 0.378 MeV) CL = 0.9820 for AENCF < 0.160 MeV
LCE & CRC	P/D ratio	passed	NDTL	CL = 0.9844

For the results summarized in Table 11, the lowest CL value (0.96833) is associated with a value of 0.378 for AENCF as a trending parameter in the CL function (CL = -0.6262 * AENCF + 0.9920) for the Commerical Reactor Criticality and Laboratory Critical Experiments subset of experiments.

7. REFERENCES

1. Framatome ANP Doc. 38-5032047-00, BSC, 2003. *Analysis of Critical Benchmark Experiments and Critical Limit Calculation for DOE SNF.* CAL-DSD-NU-000003 REV 00. Las Vegas, Nevada: Bechtel SAIC Company.

2. Not used.

3. Not used.

4. Framatome ANP Doc. 38-5032050-00, 1998. *Summary Report of Commercial Reactor Critical Analyses Performed for the Disposal Criticality Analysis Methodology.* B00000000-0717-5705-00075 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980825.0001.

5. Framatome ANP Doc.38-5032051-00, 1999. *Laboratory Critical Experiment Reactivity Calculations.* B00000000-01717-0210-00018 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990526.0294.

6. Framatome ANP Doc. 38-5032053-01, 1999. *Range of Neutronic Parameters Calculation File.* B00000000-01717-0210-00028 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990923.0231.

6a. Framatome ANP Doc. 38-5032053-00, 1999. *Range of Neutronic Parameters Calculation File.* B00000000-01717-0210-00028 REV 00. Las Vegas, Nevada: CRWMS M&O.

7. DOE 2002. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 12, Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20020814.0055.

8. Framatome ANP, Administrative Procedure, Number: 0402-01, Preparing and Processing FANP Calculations, February 2003, Framatome ANP, Lynchburg, VA 24506

9. Framatome ANP Inc., Quality Assurance, Quality Management Manual, 56-5015885, May 2002, Framatome ANP, Lynchburg, VA 24506

10. Lichtenwalter, J.J.; Bowman, S.M.; DeHart, M.D.; and Hopper, C.M. 1997. *Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages.* NUREG/CR-6361. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 233099.

11. Not used.

12. Framatome ANP Doc. 38-5032055-00, 2000. *Disposal Criticality Analysis Methodology Topical Report*, YMP/TR-004Q, Rev. 01. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20001214.0001.

13. 51-5021634-00, CLReg V1.0 Critical Limits Code for HLW YMP.

8. FILES ON FANPA

Excel File Name Excel Worksheet	File Description	Date
crc_cl.xls	CL calculations based on CRC data	9/10/03
crc_data	data for CRC CL calculations	
crc_trend_enr	CRC trend analysis for enrichment	
crc_CLReg_enr	CLReg output and CL function for CRC enrichment	
crc_trend_burnup	CRC trend analysis for burnup	
crc_CLReg _burnup	CLReg output and CL function for CRC burnup	
crc_trend_pd	CRC trend analysis for P/D ratio	
crc_DFTL_pd	CL from DFTL method for CRC P/D ratio	
crc_trend_aencf	CRC trend analysis for AENCF	
crc_NDTL_aencf	CL from NDTL method for CRC AENCF	
crc_normality_keff	Shapiro-Wilk normality test for CRC k_{eff} data	
lce_cl.xls	CL calculations based on LCE data	9/11/03
lce_data	data for LCE CL calculations	
lce_trend_enr	LCE trend analysis for enrichment	
lce_NDTL_enr	CL from NDTL method for LCE enrichment	
lce_trend_aencf	LCE trend analysis for AENCF	
lce_NDTL_aencf	CL from NDTL method for LCE AENCF	
lce_trend_pd	LCE trend analysis for P/D ratio	
lce_NDTL_pd	CL from NDTL method for LCE P/D ratio	
lce&crc_cy1_cl.xls	CL calculations based on LCE & CRC cycle 1 data	9/11/03
lce&crc_cy1_data	data for LCE & CRC cycle 1 CL calculations	
lce&crc_cy1_trend_enr	LCE & CRC cycle 1 trend analysis for enrichment	
lce&crc_cy1_CLReg_enr	CLReg output and CL function for LCE & CRC cycle 1 enrichment	
lce&crc_cy1_trend_aencf	LCE & CRC cycle 1 trend analysis for AENCF	
lce&crc_cy1_NDTL_aencf	CL from NDTL method for LCE & CRC cycle 1 AENCF	
lce&crc_cy1_trend_pd	LCE & CRC cycle 1 trend analysis for P/D ratio	
lce&crc_cy1_NDTL_pd	CL from NDTL method for LCE & CRC cycle 1 P/D ratio	
lce&crc_freshbatch_cl.xls	CL calculations based on LCE & CRC fresh batch data	9/11/03
lce&crc_fb_data	data for LCE & CRC fresh batch CL calculations	
lce&crc_fb_trend_enr	LCE & CRC fresh batch trend analysis for enrichment	
lce&crc_fb_trend_aencf	LCE & CRC fresh batch trend analysis for AENCF	
lce&crc_fb_DFTL_enr&aencf	CL from DFTL method for LCE & CRC fresh batch enrichment and AENCF	
lce&crc_fb_trend_pd	LCE & CRC fresh batch trend analysis for P/D ratio	
lce&crc_fb_NDTL_pd	CL from DFTL method for LCE & CRC fresh batch P/D ratio	
lce&crc_cl.xls	CL calculations based on LCE & CRC data	9/11/03
lce&crc_data	data for LCE & CRC CL calculations	
lce&crc_ trend_enr	LCE & CRC trend analysis for enrichment	
lce&crc_DFTL_enr	CL from DFTL method for LCE & CRC enrichment	
lce&crc_trend_aencf	LCE & CRC trend analysis for AENCF	
lce&crc_CLReg_aencf	CLReg output and CL function for LCE & CRC AENCF	
lce&crc_trend_pd	LCE & CRC trend analysis for P/D ratio	
lce&crc _NDTL_pd	CL from NDTL method for LCE & CRC P/D ratio	
CLRegTest01out.xls	CLReg Identification and Validation Test Case 1	8/13/03
CLRegTest02out.xls	CLReg Identification and Validation Test Case 2	8/12/03
CLRegTest03out.xls	CLReg Identification and Validation Test Case 3	8/13/03
CLRegTest04out.xls	CLReg Identification and Validation Test Case 4	8/13/03
CLRegTest05out.xls	CLReg Identification and Validation Test Case 5	8/13/03
CLRegTest06out.xls	CLReg Identification and Validation Test Case 6	8/13/03
CLRegTest01.csv	CLReg Input File for Test Case 1	8/28/01
CLRegTest02.csv	CLReg Input File for Test Case 2	8/31/01

CLRegTest03.csv	CLReg Input File for Test Case 3	9/7/01
CLRegTest04.csv	CLReg Input File for Test Case 4	8/30/01
CLRegTest05.csv	CLReg Input File for Test Case 5	8/28/01
CLRegTest06.csv	CLReg Input File for Test Case 6	8/31/01
CLReg_crc03.csv	CLReg input file for CRC enrichment case	7/2/03
CLReg_crc03out.csv	CLReg output file for CRC enrichment case	7/2/03
CLReg_crc01.csv	CLReg input file for CRC burnup case	8/25/03
CLReg_crc01out.csv	CLReg output file for CRC burnup case	8/25/03
CLReg_C1&L03.csv	CLReg input file for CRC (Cycle 1) and LCE enrichment case	8/26/03
CLREG_C1&L03out.csv	CLReg output file for CRC (Cycle 1) and LCE enrichment case	8/26/03
CLReg_C&L02.csv	CLReg input file for CRC and LCE AENCF case	7/25/03
CLReg_C&L02out.csv	CLReg output file for CRC and LCE AENCF case	7/25/03

Hyperlink to directory CL on FANPA:
\\fanpa\dfsroot\groups\FS\Home\Public\Technical\32-5029773-00

9. ATTACHMENTS

Attachment I: Documentation of CLReg V1.0. software validation and verification.

ATTACHMENT I

Tables A1 through A6 show software identification and validation results for the six CLReg test cases provided in Reference 13. The identity and validity of the CLReg software and its qualification for the Windows XP operating system is confirmed by the re-execution of the six test cases and the comparison of differences in CL, e.g., PreClos CL, LUTB CL, and Bonf LTL, to within ± 0.0005, as required by the installation test plan in Reference 13.

Table A1. Difference in Output for Re-Execution of CLReg V1.0 Test Case CLRegTest01

Ind Var	Keff(cc)	Pred Keff	PreClos CL	LUTB CL	Bonf LTL
0.00000	0.00001	-0.00004	0.00031	0.00041	-0.00013
-0.00500	0.00034	0.00000	0.00035	0.00045	-0.00009
0.00400	-0.00021	0.00000	0.00036	0.00045	-0.00009
-0.00300	0.00008	0.00000	0.00036	0.00045	-0.00008
0.00300	-0.00015	0.00001	0.00036	0.00046	-0.00008
-0.00200	-0.00018	0.00001	0.00037	0.00046	-0.00008
0.01100	-0.00039	0.00003	0.00039	0.00048	-0.00006
0.04200	0.00002	0.00003	0.00039	0.00048	-0.00006
0.04200	0.00004	0.00003	0.00039	0.00049	-0.00005
-0.01300	-0.00048	0.00004	0.00040	0.00049	-0.00004
-0.04200	0.00003	0.00004	0.00040	0.00050	-0.00004
-0.02300	-0.00027	0.00005	0.00040	-0.00050	-0.00004
-0.01300	-0.00021	0.00005	0.00040	-0.00050	-0.00004
0.01800	0.00005	0.00007	0.00043	-0.00048	-0.00001
0.01100	-0.00027	0.00010	0.00046	-0.00044	0.00002
ROA Calculations					
0.00000	0.00011	0.00011	-0.00014	-0.00014	-0.00014
0.00000	0.00011	0.00011	-0.00042	-0.00042	-0.00042
0.00000	0.00012	0.00012	0.00030	0.00030	0.00030

Table A2. Difference in Output for Re-Execution of CLReg V1.0 Test Case CLRegTest02

X1	X2	Keff	Pred Keff	Bonf CL
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
ROA Applications				
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000

Table A3. Difference in Output for Re-Execution of CLReg V1.0 Test Case CLRegTest03

Ind Var	Keff(cc)	Pred Keff	PreClos CL	LUTB CL	Bonf LTL
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table A4. Difference in Output for Re-Execution of CLReg V1.0 Test Case CLRegTest04

X1	X2	Keff	Pred Keff	Bonf CL
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	-0.00001
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000

Table A5. Difference in Output for Re-Execution of CLReg V1.0 Test Case CLRegTest05

Ind Var	Keff(cc)	Pred Keff	PreClos CL	LUTB CL	Bonf LTL
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table A6. Difference in Output for Re-Execution of CLReg V1.0 Test Case CLRegTest06

Ind Var	Keff(cc)	Pred Keff	PreClos CL	LUTB CL	Bonf LTL
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
ROA Calculations					
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Table A7. Test Log for CLReg V1.0 Software Identification and Validation

Date	Initials	Test Case	Pass (P) / Fail (F)	Comment
7/1/03	HLM	Test01	P	None
7/1/03	HLM	Test02	P	None
7/1/03	HLM	Test03	P	None
7/1/03	HLM	Test04	P	None
7/1/03	HLM	Test05	P	None
7/1/03	HLM	Test06	P	None

File ✓ 1/15/04 TV

OCRWM	SPECIAL INSTRUCTION SHEET	1. QA: QA Page 1 of 1

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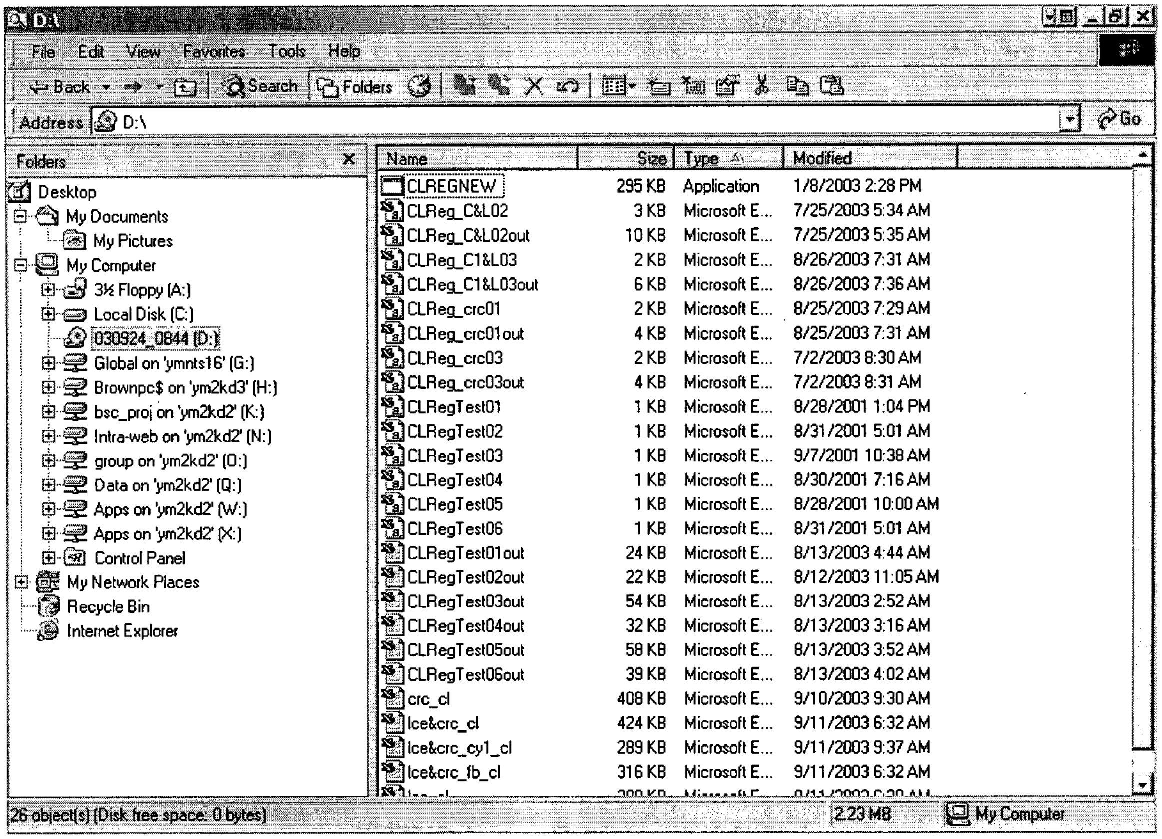
2. Record Date ~~12/11/03~~ 9.24.03 dc 030604	3. Accession Number ATT-TO: DOC.20031212.0004
4. Author Name(s) H. L. Massie	5. Authorization Organization FRAMATOME
6. Title/Description Critical Limit Development for 21 PWR Waste Package	
7. Document Number(s) 32-5029773-00	8. Version Designator 000
9. Document Type Calculation	10. Medium ~~DVD~~ CD Rom SC 1-15-04
11. Access Control Code PUB	
12. Traceability Designator DC# 37917	
13. Comments Excel files	THIS IS AN ELECTRONIC ATTACHMENT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Back Search Folders
Address D:\
Go
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My Computer
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Intra-web on 'ym2kd2' (N:)
group on 'ym2kd2' (O:)
Data on 'ym2kd2' (Q:)
Apps on 'ym2kd2' (W:)
Apps on 'ym2kd2' (X:)
Control Panel
My Network Places
Recycle Bin
Internet Explorer
Name Size Type Modified
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CLReg_C&L02out 10 KB Microsoft E... 7/25/2003 5:35 AM
CLReg_C1&L03 2 KB Microsoft E... 8/26/2003 7:31 AM
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CLRegTest02 1 KB Microsoft E... 8/31/2001 5:01 AM
CLRegTest03 1 KB Microsoft E... 9/7/2001 10:38 AM
CLRegTest04 1 KB Microsoft E... 8/30/2001 7:16 AM
CLRegTest05 1 KB Microsoft E... 8/28/2001 10:00 AM
CLRegTest06 1 KB Microsoft E... 8/31/2001 5:01 AM
CLRegTest01out 24 KB Microsoft E... 8/13/2003 4:44 AM
CLRegTest02out 22 KB Microsoft E... 8/12/2003 11:05 AM
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CLRegTest05out 58 KB Microsoft E... 8/13/2003 3:52 AM
CLRegTest06out 39 KB Microsoft E... 8/13/2003 4:02 AM
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lce&crc_fb_cl 316 KB Microsoft E... 9/11/2003 6:32 AM
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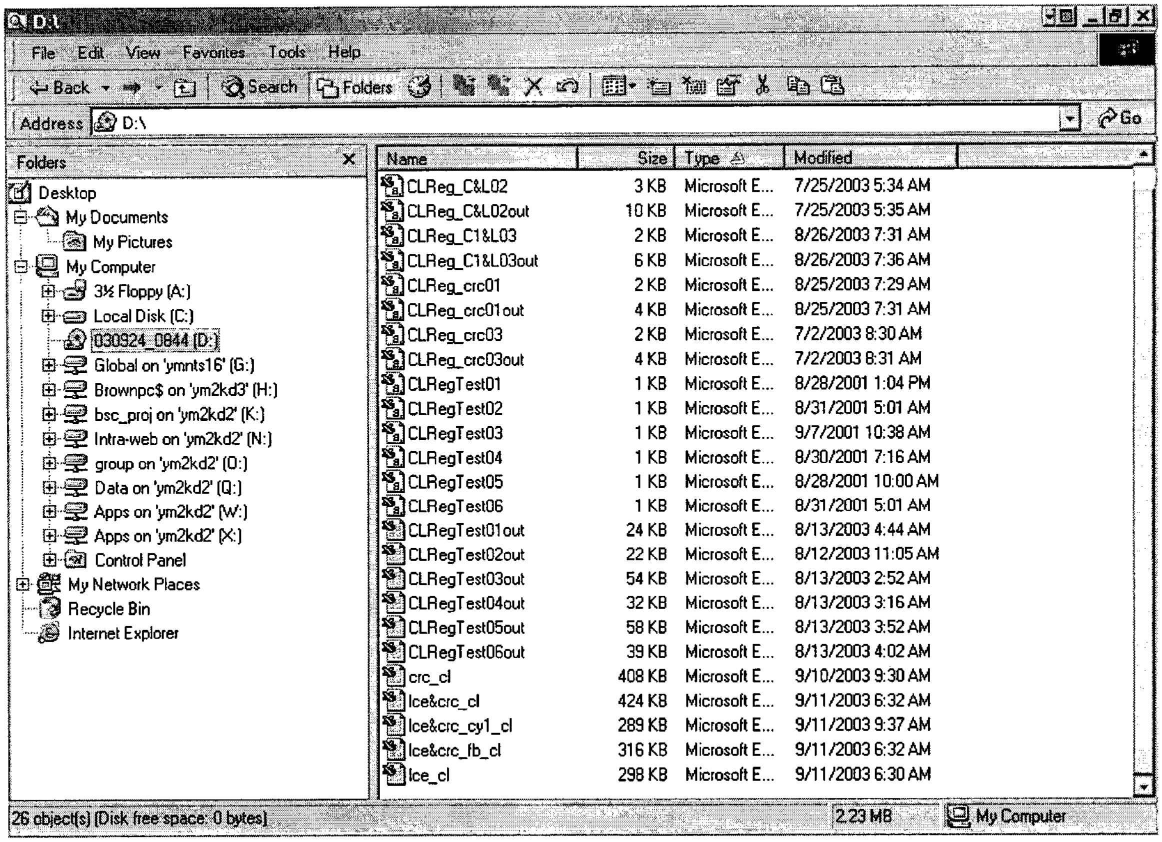
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Back
Search
Folders
Address D:\
Go
Folders
Desktop
My Documents
My Pictures
My Computer
3½ Floppy (A:)
Local Disk (C:)
030924_0844 (D:)
Global on 'ymnts16' (G:)
Brownpc$ on 'ym2kd3' (H:)
bsc_proj on 'ym2kd2' (K:)
Intra-web on 'ym2kd2' (N:)
group on 'ym2kd2' (O:)
Data on 'ym2kd2' (Q:)
Apps on 'ym2kd2' (W:)
Apps on 'ym2kd2' (X:)
Control Panel
My Network Places
Recycle Bin
Internet Explorer
Name Size Type Modified
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CLReg_C&L02out 10 KB Microsoft E... 7/25/2003 5:35 AM
CLReg_C1&L03 2 KB Microsoft E... 8/26/2003 7:31 AM
CLReg_C1&L03out 6 KB Microsoft E... 8/26/2003 7:36 AM
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CLRegTest05 1 KB Microsoft E... 8/28/2001 10:00 AM
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CLRegTest06out 39 KB Microsoft E... 8/13/2003 4:02 AM
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Ice&crc_cl 424 KB Microsoft E... 9/11/2003 6:32 AM
Ice&crc_cy1_cl 289 KB Microsoft E... 9/11/2003 9:37 AM
Ice&crc_fb_cl 316 KB Microsoft E... 9/11/2003 6:32 AM
Ice_cl 298 KB Microsoft E... 9/11/2003 6:30 AM
26 object(s) (Disk free space: 0 bytes)
2.23 MB
My Computer