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REANALYSIS OF THE CRYSTAL RIVER POOL B SPENT FUEL STORAGE RACKS WITH BORAFLEX DEGRADATION

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Summary of Revisions

Report HI-982056

Revision 1

Corrected typographical errors on Table 4.1.

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1.0 INTRODUCTION AND SUMMARY

The purpose of the present evaluation of the CR3 Pool B storage racks is threefold: (1) to update the analyses, incorporating the more modern and improved methodologies that have become available in the last few years, (2) to determine the potential effect of Boraflex degradation on criticality safety, and (3) to confirm configurations for acceptable storage of fuel with enrichments up to 5±0.05% U-235. The updated evaluation encompasses both Regions 1 and 2 of Pool B at the Crystal River Nuclear Plant, and it considered the potential effects of up to 20% loss of the Boraflex absorber.

The present analyses are based on the existing Technical Specifications of acceptable burnup-enrichment combinations for safe storage of fresh and spent fuel. Region 1 of Pool B uses a flux-trap design and is designed for fresh fuel of 5.0% enrichment positioned in a checkerboard pattern with spent fuel of specified enrichment-burnup combinations. The Region 1 storage cells are separated by two Boraflex panels with a flux-trap water gap between the two panels, while Region 2 consists of a uniform array of cells, designed for spent fuel of specified enrichment-burnup combinations. These cells have a single Boraflex absorber panel between cells.

The principal differences between the present analysis and the previous evaluation[1] are the following:

- The present analysis uses the full 238-group cross-section set based on the ENDF/BV cross-sections in contrast to the early 123-group set based on ENDF/BII cross-sections. This improvement is worth in excess of 1% in k.
- As permitted in the USNRC guidelines, parametric evaluations in the present analysis were performed for each of the manufacturing tolerances and the associated reactivity

uncertainties combined statistically. The previous analysis[1] had assumed that all tolerances were at their "worst" value simultaneously everywhere throughout the racks. This improvement reduces reactivity by about 2 to 3% in k.

- The previous evaluation acknowledged that the axial distribution in Boraflex gaps was random, but chose to assume 4-inch gaps on only two panels per cell, with all occurring at the fuel mid-plane. Since there is no known justification or rationale for this unnecessarily conservative assumption, the present analysis calculated the effect of a random distribution of 4-inch gaps in all Boraflex panels, consistent with effects observed in many rack blackness tests.

In contrast to the factors reducing the calculated reactivity, the USNRC guidelines require inclusion of an estimate of the uncertainty in depletion calculations (different from the plant's 5% penalty for uncertainty in knowing the burnup). As specified in the guidelines, this uncertainty was taken as 5% of the reactivity decrement from beginning of life to the burnup of interest.

Boraflex is now known to degrade under the influence of gamma radiation and chemical reaction with free radicals in the pool water. Over the first few years of use, the Boraflex will shrink, creating gaps distributed randomly in the axial direction. Over later years, as the gamma dose increases, the Boraflex panels will slowly begin to deteriorate, losing the neutron absorbing component (B_4C). The present analysis conservatively assumes the presence of 4-inch gaps in all Boraflex panels. The potential reactivity consequences of concurrent loss of up to 20% of the Boraflex was also evaluated.

Results of the analysis confirm that, for the existing Technical Specification limits, there is sufficient margin in both Region 1 and Region 2 of the CR3 Pool B storage racks to accommodate both the potential gaps in the Boraflex and the concurrent loss of up to 20%

of the Boraflex absorber material. In addition, Region 2 was evaluated with a 3-of-4 loading pattern, showing that, for this configuration, a significantly greater reactivity margin is available to accommodate more reactive fuel (lower burnup) or greater Boraflex degradation than is currently anticipated. Accident analyses were also performed, establishing that for the most serious fuel mis-loading accident (Region 2), criticality will not be reached, and that 350 ppm soluble boron is adequate to maintain the maximum k-effective below the regulatory limit. Recent USNRC Guidelines allow partial credit for soluble boron, and this would be more than adequate to protect against the most serious fuel handling accident.

2.0 ANALYSIS CRITERIA AND ASSUMPTIONS

To assure the true reactivity will always be less than the calculated reactivity, the following conservative analysis criteria or assumptions were used:

- The racks contain the most reactive fuel authorized to be stored, without any control rods or burnable poison.
- The moderator is pure, unborated water at a temperature within the design basis range corresponding to the highest reactivity.
- Criticality safety analyses are based upon an infinite radial array of cells; i.e., no credit is taken for radial neutron leakage.
- Neutron absorption in minor structural members is neglected; e.g., spacer grids are replaced by water.
- The analyses were based on the enrichment-burnup combinations in the current Technical Specifications and rack design details provided by Florida Power Corporation.
- The analyses assumed fresh Mark B-10F fuel in Region 1 checkerboarded with spent Mark B-10 fuel. Region 2 analyses assumed MARK B-10 fuel except for the accident analysis, which assumed Mark B10F fuel as the offending assembly. These two fuel types bound[1] all other fuel assemblies used at CR3 and now in storage. The analyses do not include burn B10F fuel.
- Mark B10 and Mark-B10F fuel assemblies have axial blankets of low-enriched fuel, which prevents the existence of higher reactivity fuel of lower-than-average burnup at the ends of the assembly. This precludes the penalty due to the axial distribution in burnup that might otherwise occur.

The remaining assumptions are defined in Section 4.0.

3.0 ACCEPTANCE CRITERIA

The CR3 Technical Specifications list the following enrichment-burnup combination limits for acceptable storage of spent fuel in Pool B. Region 1 assumes 5.0% enriched fuel in a checkerboard pattern, alternating with spent fuel of the enrichment-burnup combination listed below. Region 2 assumes all cells filled with spent fuel of the enrichment-burnup combinations listed below.

Region 1		Region 2	
Enrichment % U-235	**Burnup,** MWD/KgU	**Enrichment** % U-235	**Burnup,** MWD/KgU
2.08	0.0	1.63	0.0
3.00	11.2	2.04	8.0
4.00	20.2	2.31	15.0
5.00	30.3	3.20	25.0
		4.07	35.0
		5.20	45.0

Each of these combinations was analyzed with the 3-dimensional KENO5a code.

The primary acceptance criterion is that the maximum k_{eff} shall be less than 0.95, including calculation uncertainties and effects of mechanical tolerances. Applicable codes, standards, and regulations, or pertinent sections thereof, include the following:

- General Design Criterion 62, Prevention of Criticality in Fuel Storage and Handling.
- USNRC Standard Review Plan, NUREG-0800, Section 9.1.2, Spent Fuel Storage.

- USNRC letter of April 14, 1978, to all Power Reactor Licensees - OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications, including modification letter dated January 18, 1979.

- USNRC Regulatory Guide 1.13, Spent Fuel Storage Facility Design Basis, Rev. 2 (proposed), December, 1981.

- ANSI-8.17-1984, Criticality Safety Criteria for the Handling, Storage and Transportation of LWR Fuel Outside Reactors.

- L. Kopp, "Guidance On The Regulatory Requirements For Criticality Analysis Of Fuel Storage At Light-Water Reactor Power Plants", USNRC Internal Memorandum L. Kopp to Timothy Collins, August 19, 1998

4.0 DESIGN AND INPUT DATA

4.1 Fuel Assembly Design Specifications

Two fuel assembly designs were used in the analyses: the B&W Mark B-10 fuel and the Mark B10F, an enhanced version of the Mark B-10 fuel. Table 4.1 provides the pertinent design details for these assembly types. The Mark B-10 fuel bounds all fuel previously used at CR3[1], except the B-10F fuel which was used in the analyses of Region 1 and for all fuel mis-loading accidents. Enrichments used are those specified in the current Technical Specifications. Any boron burnable poison which may be in the fresh fuel assemblies in IFBA rods would reduce reactivity, but was not included in the analyses.

4.2 Pool B Region 1 Rack Design

The nominal spent fuel storage cell used for the criticality analyses of Region 1 storage cells is shown in Figure 4.1. The cell is composed of Boraflex absorber material mounted on the outside of a 0.060-inch-thick stainless steel box. The fuel assemblies are centrally located in each storage cell on a nominal lattice spacing of 10.60 inches, with a 1.20-inch water flux-trap between the two (thermal-neutron opaque) Boraflex absorber panels. The Boraflex absorber (as confirmed by measurement of representative coupons) has a thickness of 0.085 inch and a nominal B-10 areal density of 0.0269 g/cm^2 (0.023 g/cm^2 minimum).

4.3 Pool B Region 2 Rack Design

In Region 2, the storage cells are composed of a single Boraflex absorber panel between the stainless steel walls of adjacent storage cells. These cells, shown in Figure 4.2, are located on a lattice spacing of 9.17 inches. The Boraflex absorber (as confirmed by the measurement of representative samples) has a thickness of 0.058 inch and a nominal B-10 areal density of 0.0184 g/cm^2 (minimum of 0.015 g/cm^2).

5.0 METHODOLOGY

The primary criticality analyses were performed with the three-dimensional NITAWL-KENO5a Monte Carlo code package[2]. NITAWL was used with the 238-group SCALE-4.3 cross-section library and the Nordheim integral treatment for U-238 resonance shielding effects. Benchmark calculations, presented in Appendix A, indicate a bias of 0.0030 ± 0.0012 (95%/95%)[3]. Verification calculations for the principal cases were made with the MCNP code[4] (bias of 0.0009 ± 0.0011, as shown in Appendix A). CASMO4, a two-dimensional deterministic code[5] using transmission probabilities, was used to evaluate the small reactivity effects of manufacturing tolerances. Validity of the CASMO4 code was established by comparison with KENO5a and MCNP calculations.

In the geometric model used in the calculations, each fuel rod and each fuel assembly were explicitly described. The calculational model used a 4x4 array of cells with 4-inch gaps in the Boraflex randomly distributed axially. Reflecting boundary conditions effectively defined an infinite radial array of storage cells. In the axial direction, a 30-cm water reflector was used to conservatively describe axial neutron leakage. Each stainless steel box and all associated Boraflex panels were also explicitly described in the calculational model. The fuel cladding material was conservatively assumed to be zirconium; the actual Zircaloy, with a greater absorption cross-section, would slightly reduce reactivity.

Monte Carlo (KENO5a) calculations inherently include a statistical uncertainty due to the random nature of neutron tracking. To minimize the statistical uncertainty of the KENO5a calculated reactivities, a minimum of 1 million neutron histories was accumulated in each calculation, generally resulting in a statistical uncertainty of about $\pm 0.0006 \Delta k$ (1σ).

6.0 ANALYTICAL RESULTS

6.1 Code Comparison Calculations- KENO5a and MCNP

Two independent methods of analyses (KENO5a and MCNP) were used to verify the reference CASMO4 calculations . In addition, these calculations serve to validate the CASMO4 code, since CASMO4 is a two-dimensional code and cannot be directly validated against critical experiments. The USNRC guidelines, however, endorse CASMO and KENO5a as acceptable methods of criticality analysis. Results of these code comparison calculations are listed in Table 6.1, corrected for bias. These results are considered to be in reasonable agreement, confirming the basic KENO5a, MCNP and CASMO calculations.

6.2 Evaluation of Uncertainties

Calculations were made to determine the uncertainties in reactivity associated with manufacturing tolerances. Tolerances that would increase reactivity were calculated; negative values are expected to be of equal magnitude but opposite in sign. Results of these calculations are shown in Table 6.2. The reactivity effect was separately evaluated on a sensitivity study for each independent tolerance, and the results combined statistically.

Tolerances considered include the following:

- Tolerance in Boron loading in the Boraflex,
- Tolerance in Boraflex panel width,
- Tolerance in water gap (Region 1),

- Tolerance in box I.D. or lattice pitch (Region 2),
- Tolerance in stainless steel thickness,
- Tolerance in fuel enrichment and in UO_2 density, and
- Tolerance in depletion calculations.

These tolerance effects are relatively insensitive to enrichment or burnup. However, the tolerance on fuel enrichment is enrichment-dependent and is included in the summary tables.

6.3 Storage Rack Calculations

6.3.1 Region 1, Pool B

Region 1 of Pool B is designed to accommodate a checkerboard pattern of unburned 5% fuel intermixed with fuel of various enrichment-burnup combinations as specified in the Technical Specifications. Calculations for these specified cases are given in Table 6.3. As shown in the table, the maximum reactivity values are well below the regulatory limit and are therefore acceptable. The highest reactivity occurs for 4.0 % enriched fuel checker-boarded with unburned Mark B-10F fuel of 5.0 % enrichment.

6.3.2 Region 2, Pool B - Fully Loaded

Region 2 of Pool B is designed for fuel of various enrichment-burnup combinations as listed in the Technical Specifications. Calculations for the maximum reactivity for these cases is given in Table 6.4. The highest reactivity occurs for the 2.04 % enriched case, with the 5.2 % enrichment case slightly lower. In all cases the racks can safely accommodate 29% loss of Boraflex thickness (in addition to the 4-inch axial random gaps). Thus, Region 2 of Pool B is acceptable for storage of the Technical Specification fuel, with some margin remaining.

6.3.3 Region 2, Pool B - 3 of 4 Loading Pattern

The potential effect of a 3-of-4 loading pattern was also evaluated as an alternative loading pattern. Results are given in Table 6.5 and shows that a very substantial margin below the regulatory limit exists for this pattern.

6.4 Abnormal and Accident Conditions

The potential effect of abnormal and accident conditions were also considered as indicated in Table 6.6. Only the case of a mis-loaded fuel assembly was found to have more than a negligible impact. The mis-loading of a unburned Mark B-10F assembly into a Region 1 cell intended for spent fuel did not result in a k-effective that exceeded the 0.95 limit. In Region 2, however, the inadvertent loading of an unburned Mark B-10F assembly of 5.0% enrichment into an otherwise fully loaded rack, could potentially exceed the regulatory limit on k-effective, although criticality would not be reached. For this condition, calculations indicate that credit for 350 ppm soluble boron would maintain the maximum reactivity below the regulatory limit. A lower concentration would be required for protection in the 3 of 4 loading pattern so the fully loaded case (350 ppm) is controlling.

Temperature effects were also evaluated in the temperature range from 4°C to 120°C. Results, given in Table 6.7 show that the temperature coefficient of reactivity is negative and that 4°C (maximum water density) corresponds to the highest reactivity.

7.0 REFERENCES

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2. R.M. Westfall, et. al., "NITAWL-S: Scale System Module for Performing Resonance Shielding and Working Library Production" in SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation., NUREG/CR-0200, 1979.

   L.M. Petrie and N.F. Landers, "KENO Va. An improved Monte Carlo Criticality Program with Subgrouping" in SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation., NUREG/V-0200, 1979.

3. M.G. Natrella, Experimental Statistics, National Bureau of Standards, Handbook 91, August 1963.

4. J.F. Briesmeister, Ed., "MCNP - A General Monte Carlo N-Particle Transport Code, Version 4A", Los Alamos National Laboratory, LA-12625-M (1993).

5. A. Ahlin, M. Edenius, H. Haggblom, "CASMO- A Fuel Assembly Burnup Program," AE-RF-76-4158, Studsvik report (proprietary).

   A. Ahlin and M. Edenius, "CASMO- A Fast Transport Theory Depletion Code for LWR Analysis," ANS Transactions, Vol. 26, p. 604, 1977.

   D. Knott, "CASMO4 Benchmark Against Critical Experiments", Studsvik Report SOA-94/13 (Proprietary).

   M. Edenius et al., "CASMO4, A Fuel Burnup Program, Users Manual" Studsvik Report SOA/95/1.

Table 4.1

DESIGN BASIS FUEL ASSEMBLY SPECIFICATIONS

FUEL ROD DATA	MARK B10		MARK B10F
Outside diameter, in.	0.4300		0.428
Cladding inside diameter, in.	0.3770		0.382
Cladding Material		Zr-4	
Stack density, gms UO_2/cc	10.208		10.522
Pellet diameter, in.	0.3700		0.3742
Maximum enrichment, wt. % U-235		5.00 ± 0.05	
FUEL ASSEMBLY DATA			
Fuel rod array		15 x 15	
Number of fuel rods		208	
Fuel rod pitch, in.		0.568	
Number of control rod guide and instrument thimbles		17	
Thimble O.D., in. (nominal)	0.530		0.528
Thimble I.D., in. (nominal)	0.498		0.500

Table 6.1

COMPARISON OF CALCULATIONS

Case		CASMO	KENO*	MCNP*
1) Reg 1	all 5% fuel, k_∞	0.9589	0.9570 ± 0.0014	0.9541 ± 0.0014
2) Reg 1	all 2.08% E	0.7854	0.7834 ± 0.0014	0.7817 ± 0.0014
3) Reg 1	Checkerboard, 5% & 2.08%	-	0.8860 ± 0.0014	0.8823 ± 0.0014
4) Reg 2	1.63%E (4 of 4)	0.9099	0.9136 ± 0.0014	0.9160 ± 0.0014
5) Reg 2	1.63% (3 of 4)	-	0.8088 ± 0.0014	0.8165 ± 0.0014

*Includes Bias

Table 6.2

REACTIVITY UNCERTAINTIES DUE TO

MANUFACTURING TOLERANCES

(Limiting Reactivity Cases)

Region 1

Quantity	Nominal Value	Tolerance	Δk*
Boron loading	0.0269 g/cm^2	± 0.0039 g/cm^2	± 0.0041
Boraflex width	7.500 inches	± 1/16 inches	± 0.0011
Water Gap	1.20 inches	± 0.088 inches	± 0.0097
Cell Box I.D.	9.00 inches	± 0.088 inches	±0.0020
SS thickness	0.060/0.020	± 0.006 inches	± 0.0002
Statistical combination of tolerance uncertainties			± 0.0108
Fuel enrichment	@ 2.08% U-235	± 0.05% U-235	± 0.0055
Fuel density	10.208 g/cm^2	± 0.20 g/cm^2	± 0.0019

Region 2

Quantity	Nominal Value	Tolerance	Δk
Boron loading	0.0184 g/cm^2	± 0.0034 g/cm^2	± 0.0088
Boraflex width	7.600 inches	± 1/16 inches	± 0.0014
Min. Pitch	9.17 inches	± 0.120 inches	± 0.0069
SS thickness	0.060/0.0020	± 0.008 inches	± 0.0004
Statistical combination of tolerance uncertainties			± 0.0113
Fuel enrichment	@ 2.04% U-235	± 0.05% U-235	± 0.0073
Fuel density	10.208 g/cm^2	± 0.20 g/cm^2	± 0.0009

* Most conservative values used (fresh fuel).

Table 6.3

REACTIVITY SUMMARY

REGION 1 (checkerboard w/5%E fuel)

Enrichment Chkbd w/5%	2.08	3.0	4.0	5.0
Temp.	4°C	4°C	4°C	4°C
Burnup, MWD/Kgu	0	11.2	20.2	30.3
CASMO4 Case	F1-ENR	F1-B30	F1-B40	F1-B50
Reference k-inf.	0.7877	0.7847	0.7902	0.7853
KENO/CASMO** Corr.	0.1068	0.1068	0.1068	0.1068
Uncert. in Corr.	± 0.0014	± 0.0014	± 0.0014	± 0.0014
KENO5a Statistics	± 0.0007	± 0.0007	± 0.0007	± 0.0007
Mechanical Tolerances***	± 0.0108	± 0.0108	± 0.0108	± 0.0108
Enrichment*** &Dens Tol	± 0.0058	± 0.0058	± 0.0058	± 0.0058
Depletion Uncert.	0	± 0.0041	± 0.0066	± 0.0087
Total Uncert	± 0.0124	± 0.0130	±0.0140	± 0.0151
Reactivity	0.8945 ± 0.0124	0.8915 ± 0.0130	0.8970 ± 0.0140	0.8921 ± 0.0151
Maximum Reactivity	0.9069	0.9045	0.9110	0.9072
w/5% loss	0.9079	0.9055	0.9120	0.9082
w/10% loss	0.9095	0.9071	0.9136	0.9098
w/15% loss	0.9115	0.9091	0.9156	0.9118
w/20% loss	0.9138	0.9114	0.9179	0.9141

** KENO-CASMO correction includes temperature correction to 4°C, the KENO bias, and the reactivity facts for checkerboarding with 5% fuel.

*** Conservative values for fresh fuel used.

Table 6.4

REACTIVITY SUMMARY
REGION 2 (Fully Loaded)

Enrichment	1.63	2.04	2.31	3.20	4.07	5.20
Temp.	4°C	4°C	4°C	4°C	4°C	4°C
Burnup, MWD/Kgu	0	8	15	25	35	45
Reference k-inf.	0.9128	0.9114	0.8861	0.8977	0.8976	0.9095
KENO/ CASMO Corr.	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
Uncert. in Corr.	±0.0013	± 0.0013	± 0.0013	± 0.0013	± 0.0013	± 0.0013
Mechanical Tolerances	±0.0120	± 0.0113	± 0.0106	± 0.0098	± 0.0091	±0.0083
Enrichment &Dens Tol	±0.0095	± 0.0074	± 0.0062	± 0.0036	± 0.0026	± 0.0029
Depletion Uncert.	0	± 0.0039	± 0.0069	± 0.0106	± 0.0135	± 0.0153
Total Uncert	0.0154	± 0.0141	±0.0141	± 0.0149	± 0.0165	±0.0177
Reactivity	0.9177 ±0.0154	0.9163 ± 0.0141	0.8910 ± 0.0141	0.9026 ± 0.0149	0.9025 ± 0.0165	0.9144 ± 0.0177
Maximum Reactivity	0.9331	0.9304	0.9051	0.9175	0.9190	0.9321
w/5% loss	0.9354	0.9327	0.9074	0.9198	0.9213	0.9344
w/10% loss	0.9367	0.9340	0.9087	0.9211	0.9226	0.9357
w/15% loss	0.9395	0.9278	0.9115	0.9239	0.9254	0.9385
w/20% loss	0.9410	0.9383	0.9130	0.9254	0.9269	0.9400

Table 6.5

REACTIVITY SUMMARY

REGION 2 (3 of 4 Loading)

Enrichment Chkbd w/5%	1.63	2.04	2.31	3.20	4.07	5.20
Temp.	4°C	4°C	4°C	4°C	4°C	4°C
Burnup, MWD/Kgu	0	8	15	25	35	45
CASMO4 Case	F2-ENR	F2-B204	F2-B231	F2-B320	F2-B407	F2-B520
Reference k-inf.	0.9128	0.9114	0.8861	0.8977	0.8976	0.9095
KENO/ CASMO Corr.	-0.0994	-0.0994	-0.0994	-0.0994	-0.0994	-0.0994
Uncert. in Corr.	± 0.0013	± 0.0013	± 0.0013	± 0.0013	± 0.0013	± 0.0013
KENO5a Statistics	± 0.0007	± 0.0007	± 0.0007	± 0.0007	± 0.0007	± 0.0007
Mechanical Tolerances	± 0.0120	± 0.0113	± 0.0106	± 0.0098	± 0.0091	±0.0083
Enrichment &Dens Tol	± 0.0095	± 0.0074	± 0.0062	± 0.0036	± 0.0026	± 0.0029
Depletion Uncert.	0	± 0.0039	± 0.0069	± 0.0106	± 0.0135	± 0.0153
Total Uncert	± 0.0154	± 0.0141	±0.0141	± 0.0149	± 0.0165	±0.0177
Reactivity	0.8134 ± 0. 0154	0.8120 ± 0.0141	0.7867 ± 0.0141	0.7983 ± 0.0149	0.7982 ± 0.0165	0.8101 ± 0.0177
Maximum Reactivity	0.8288	0.8261	0.8008	0.8132	0.8147	0.8278
w/5% loss	0.8306	0.8279	0.8026	0.8150	0.8165	0.8296
w/10% loss	0.8327	0.8300	0.8047	0.8171	0.8186	0.8317
w/15% loss	0.8347	0.8320	0.8067	0.8191	0.8206	0.8337
w/20% loss	0.8367	0.8340	0.8087	0.8211	0.8226	0.8357

Table 6.6

REACTIVITY EFFECTS OF ABNORMAL AND ACCIDENT CONDITIONS

Accident/Abnormal Conditions	Reactivity Effect
Temperature increase	Negative
Void (Boiling)	Negative
Assembly dropped on top of rack	Negligible
Seismic movement	Negligible
Misplacement of a fuel assembly	Worst Case Requires minimum 350 ppm soluble boron

Table 6.7

EFFECT OF TEMPERATURE AND VOID ON CALCULATED REACTIVITY OF STORAGE RACK

Case	Incremental Reactivity Change, Δk	
	Region 1*	Region 2
4°C (39°F)		Reference
20°C (68°F)	-0.0011/-0.0014	-0.0011
40°C (104°F)	-0.0035/-0.0042	-0.0041
80°C (176°F)	-0.0103/-0.0120	-0.0086
120°C (248°F)	-0.0192/-0.0226	-0.0151
120°C + 10% void	- 0.0442/-0.0504	-0.0342

* Region 1 uses fuel of 5% enrichment burned to 30 MWD/KgU in a checkerboard arrangement with unburned fuel of 5% enrichment. The two values in this column are the temperature effects at 30 MWD/KgU and for unburned fuel, both of which show a negative coeffient of reactivity.

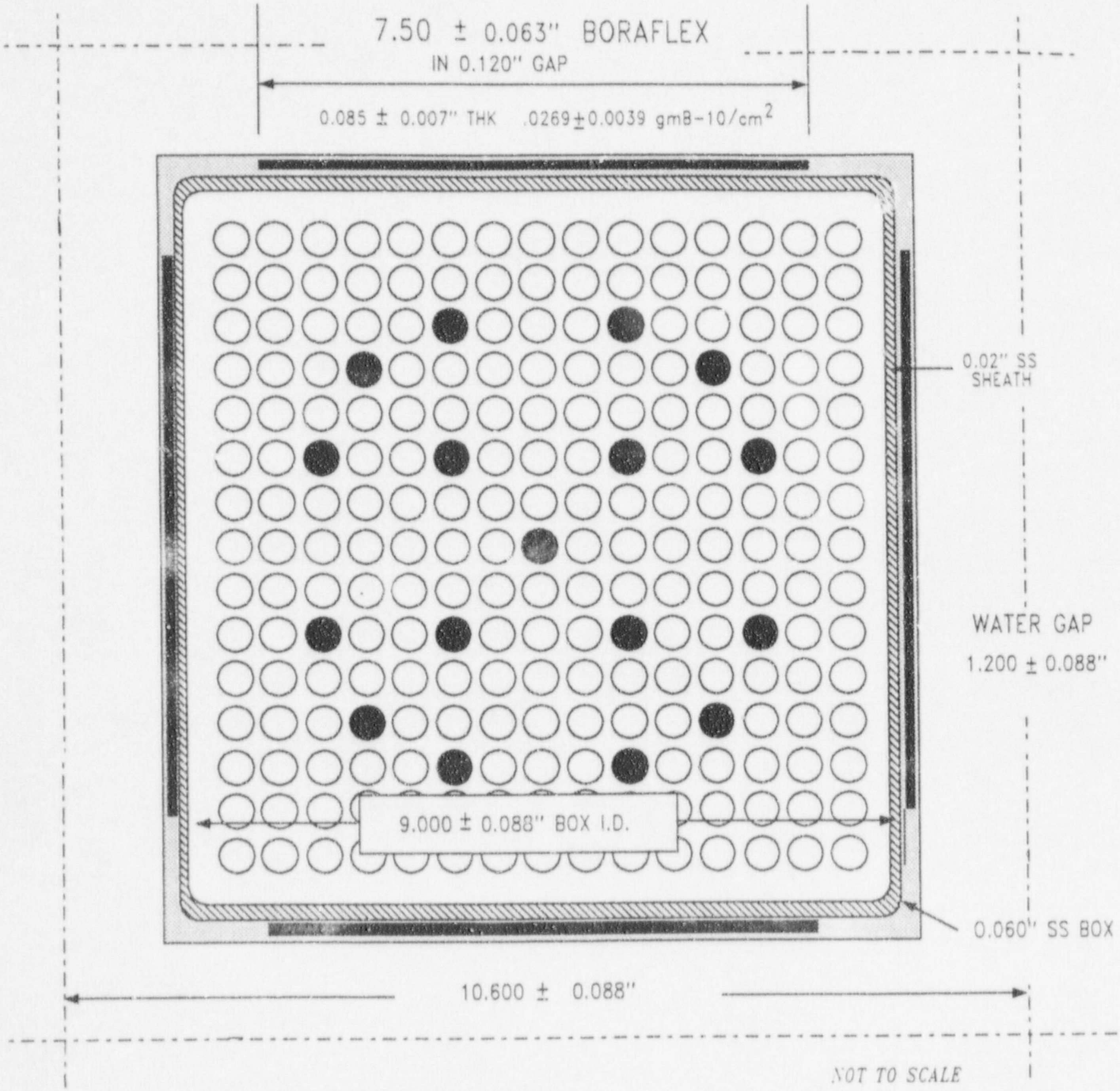

Fig. 4.1 REGION 1 FUEL STORAGE CELL

Appendix A to Chapter 5
of the Holtec Report, HI-98056
"Benchmark Calculations"

Provided to FPC as PROPRIETARY.

Therefore not included; will be provided
or can be viewed on-site upon request.