XN-NF-83-85
Issue Date: 10/24/83

D. C. COOK UNIT 2, CYCLE 5

SAFETY ANALYSIS REPORT

Written by: PDWimpy
P. D. Wimpy, Engineer
PWR Neutronics

Reviewed by: FBSkogen 18 Oct 83
F. B. Skogen, Manager
PWR Neutronics

Prepared by:
H. E. Williamson, Manager
Neutronics and Fuel Management

Prepared by: R. B. Stout 19 OCT 83
R. B. Stout, Manager
Licensing and Safety Engineering

Approved by: 10/20/83
G. J. Busselman, Manager
Fuel Design

Approved by:
G. A. Sofer, Manager
Fuel Engineering and Technical Services

Concurred by: 10/20/83
J. N. Morgan, Manager
Proposals and Customer Services Engineering

csk

EXXON NUCLEAR COMPANY, Inc.

8403080220 840302
PDR ADOCK 05000316
P PDR

NUCLEAR REGULATORY COMMISSION DISCLAIMER

IMPORTANT NOTICE REGARDING CONTENTS AND USE OF THIS DOCUMENT

PLEASE READ CAREFULLY

This technical report was derived through research and development programs sponsored by Exxon Nuclear Company, Inc. It is being submitted by Exxon Nuclear to the USNRC as part of a technical contribution to facilitate safety analyses by licensees of the USNRC which utilize Exxon Nuclear-fabricated reload fuel or other technical services provided by Exxon Nuclear for light water power reactors and it is true and correct to the best of Exxon Nuclear's knowledge, information, and belief. The information contained herein may be used by the USNRC in its review of this report, and by licensees or applicants before the USNRC which are customers of Exxon Nuclear in their demonstration of compliance with the USNRC's regulations.

Without derogating from the foregoing, neither Exxon Nuclear nor any person acting on its behalf:

A. Makes any warranty, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document will not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this document.

TABLE OF CONTENTS

Section Page

LIST OF TABLES

LIST OF FIGURES

D. C. COOK UNIT 2 CYCLE 5

SAFETY ANALYSIS REPORT

PROLOGUE

This report is the fourth in a series of five reports which address the neutronics characteristics of the Cycle 5 core and provides the safety evaluation for Cycle 5. Preliminary analyses were performed in response to the Tentative Scheduled Delivery Date (TSDD) notice and were provided in letter report PWR:41:82. Subsequently, a final reload was established in response to the Final Scheduled Delivery Date (FSDD) notice and was documented in letter report PWR:04:83. The Fuel Cycle Design Report (XN-NF-83-75(P)), which provides the Reference Design for the safety evaluation was issued in September, 1983. This Safety Analysis Report will be followed by a Cycle 5 Startup and Operations Report.

D. C. COOK UNIT 2 CYCLE 5
SAFETY ANALYSIS REPORT

1.0 INTRODUCTION

The results of the Safety Analysis for Cycle 5 of the D. C. Cook Unit 2 nuclear plant are presented in this report. The topics addressed include operating history of the reference cycle, power distribution considerations, control rod reactivity requirements, temperature coefficient considerations, and control rod ejection accident analysis.

2.0 SUMMARY

The D. C. Cook Unit 2 nuclear plant is scheduled to operate in Cycle 5 beginning in April of 1984 with ninety-two (92) fresh assemblies (Reload Batch XN-2) supplied by Exxon Nuclear Company (ENC). The composition of the core during Cycle 5 will be ninety-two (92) fresh ENC assemblies in Region 7, seventy-two (72) once-burnt ENC assemblies in Region 6, and twenty-nine (29) twice-burnt Westinghouse assemblies in Region 5. The Cycle 5 design also utilizes 1,040 fresh Al_2O_3-B_4C burnable absorber rods, each containing 0.026 gm/in of B-10. The burnable absorber rods are distributed among seventy-two (72) of the fresh assemblies.

The characteristics of the fuel and the reloaded core are in conformance with existing Technical Specification limits regarding shutdown margin provisions and thermal limits. The ENC fuel design is presented in Reference 1. The Plant Transient Analysis, the thermal-hydraulic analysis, and the LOCA-ECCS analysis will be presented under separate cover. The results of the Control Rod Ejection Analysis are provided herein and are derived from a combination of the generic parameters and results described in Reference 2 and specific analyses performed for Cycle 5.

The neutronics characteristics of Cycle 5 are similar to those of Cycle 4. The minimum excess shutdown margin above that required for safe operation is calculated to be 721 pcm at EOC. A postulated control rod ejection event is conservatively calculated to result in an energy deposition of less than 170 cal/gm.

At hot full power equilibrium xenon conditions, the peak F^N_Q is calculated to be 1.64 and occurs at BOC in an assembly supplied by ENC. The peak F^N_Q for Westinghouse (W) supplied fuel is calculated to be 1.40 at hot full power equilibrium xenon conditions, and also occurs at BOC5. Including a 3% engineering factor, a 5% measurement uncertainty, K(Z) considerations, and an 11% PDC-II allowance (for a ±5% target band on axial flux difference), the total peaking factor, F^T_Q, during Cycle 5 is calculated to be 1.97 in ENC supplied fuel and 1.68 in Westinghouse supplied fuel. The maximum relative pin power, $F^N_{\Delta H}$, during the cycle is calculated to be 1.38 in ENC supplied fuel and 1.16 in Westinghouse supplied fuel and occurs at 15,000 MWD/MT, and 500 MWD/MT, respectively. Throughout the cycle, both F^T_Q and $F^N_{\Delta H}$ are expected to remain within the allowable limits which will be defined by transient and accident analyses and presented under separate cover.

3.0 OPERATING HISTORY OF THE REFERENCE CYCLE

D. C. Cook Unit 2 Cycle 4 has been chosen as the reference cycle with respect to Cycle 5 due to the close resemblance of the neutronic characteristics between these two cycles. The Cycle 4 operations began in January, 1983, and as of the end of September, 1983, the core has accrued about 9,000 MWD/MT exposure. The Cycle 4 core loading consisted of one hundred twenty one (121) Westinghouse assemblies and seventy-two (72) ENC assemblies.

The measured power peaking factors at hot-full-power, equilibrium xenon conditions, have remained below the Technical Specification limits throughout Cycle 4. The total peaking factor, F^T_Q, and the radial pin peaking factors, $F^N_{\Delta H}$, have remained below 2.04 and 1.49, respectively. The Cycle 4 operation has typically been rod free with the D control rod bank positioned in the range of 218 to 225 steps, 228 steps being fully withdrawn. It is anticipated that similar control rod bank insertions will be used in Cycle 5 operations.

The critical boron concentration as calculated by ENC for Cycle 4 has agreed to within about 30 ppm with the measured values (see Figure 3.1). Also the power distribution calculated by ENC has generally agreed to within ±5 percent of the measured values (see Figure 3.2 for a comparison at 7,752 MWD/MT).

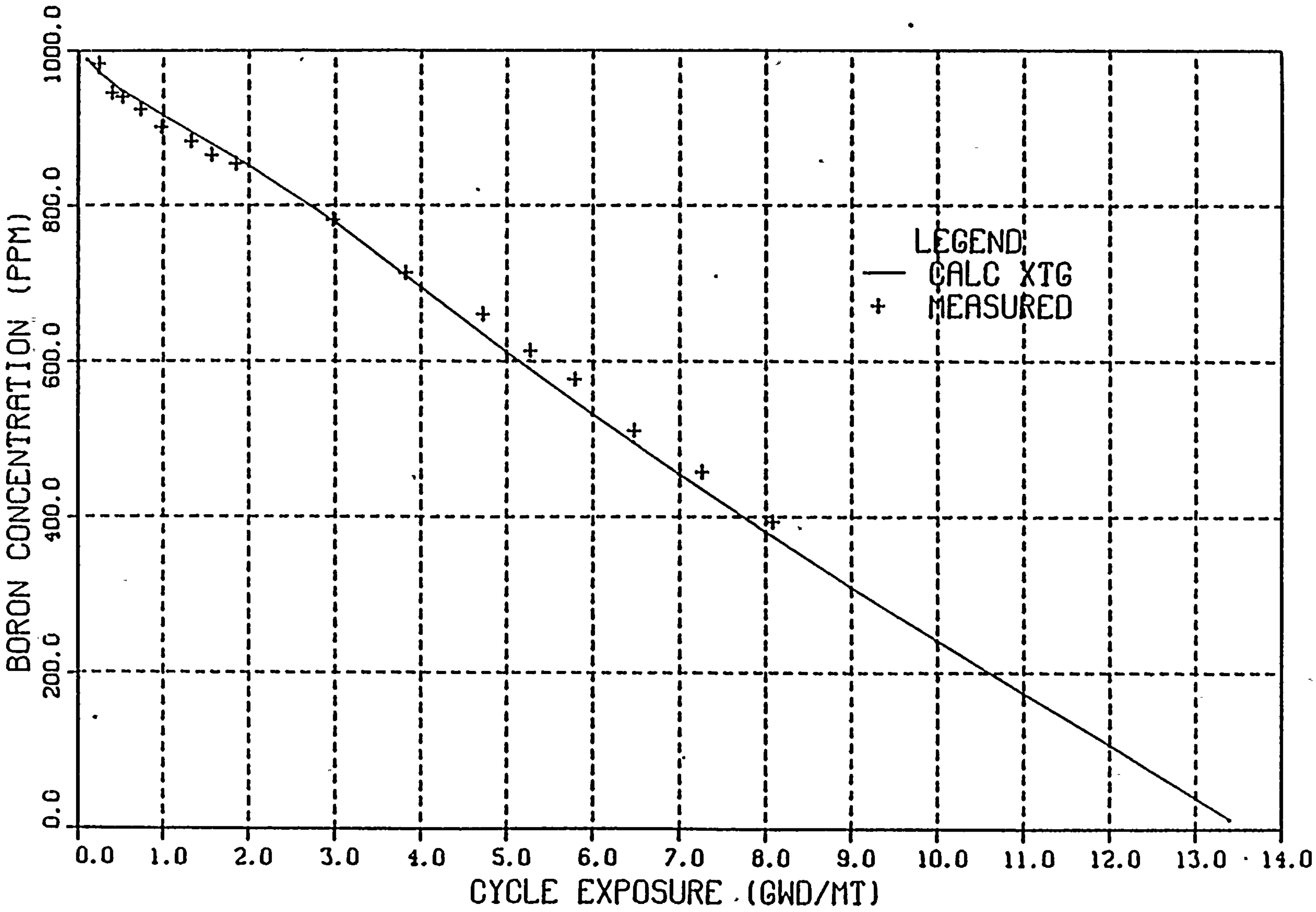

Figure 3.1 D.C. Cook Unit 2, Cycle 4 Boron Letdown Curve

	H	G	F	E	D	C	B	A
8	.856 .848 +0.9	.985 .966 +2.0	.975 .964 +1.1	1.046 1.042 +0.4	.971 .983 -1.2	1.069 1.086 -1.6	1.008 1.019 -1.1	.901 .859 +4.9
9	.982 .968 +1.4	1.079 1.064 +1.4	1.218 1.186 +2.7	1.071 1.069 +0.2	1.218 1.206 +1.0	.997 1.002 -0.5	1.128 1.125 +0.3	.742 .737 +0.7
10	.974 .972 +0.2	1.220 1.187 +2.8	1.081 1.079 +0.2	1.073 1.080 -0.6	1.104 1.123 -1.7	1.234 1.243 -0.7	1.020 1.039 -1.8	.862 .835 +3.2
11	1.049 1.041 +0.8	1.076 1.065 +1.0	1.095 1.072 +2.1	1.093 1.099 -0.5	1.246 1.249 -0.2	1.024 1.058 -3.2	1.107 1.126 -1.7	.554 .564 -1.8
12	.970 .983 -1.3	1.219 1.196 +1.9	1.105 1.118 -1.2	1.246 1.240 +0.5	.990 1.030 -3.9	1.175 1.195 -1.7	.758 .766 -1.0	
13	1.068 1.059 +0.9	.980 .986 -0.6	1.227 1.221 +0.5	1.023 1.051 -2.7	1.173 1.190 -1.4	1.019 1.031 -1.2	.396 .401 -1.2	
14	1.007 1.010 -0.3	1.124 1.109 +1.4	.999 1.030 -3.0	1.102 1.105 -0.3	.755 .757 -0.3	.395 .395 0.0		
15	.903 .852 +6.0	.748 .735 +1.8	.857 .822 +4.3	.551 .558 -1.3				

Calculated (XTGPWR)
Measured Assembly Power
$\frac{C-M}{M} \times 100$

	Calculated	Measured	% Diff.
$F^N_{\Delta H}$	1.354	1.343	+0.8
F^N_Q	1.565	1.557	+0.5

Figure 3.2 D.C. Cook Unit 2 Cycle 4, Power Distribution Comparison to Map 204-46, 100% Power, Bank D @220 Steps, 7,752 MWD/MT

4.0 GENERAL DESCRIPTION

The D. C. Cook Unit 2 reactor consists of one hundred ninety three (193) assemblies, each having a 17x17 fuel rod array. Each assembly contains two hundred sixty four (264) fuel rods, twenty-four (24) RCC guide tubes, and one (1) instrumentation tube. The fuel rods consist of slightly enriched UO_2 pellets inserted into zircaloy tubes. The RCC guide tubes and the instrumentation tube are also made of zircaloy. Each ENC assembly contains eight zircaloy spacers with Inconel springs; seven of the spacers are located within the active fuel region.

The Cycle 5 loading pattern is shown in Figure 4.1 with assemblies identified by their Cycle 4 location and Fabrication ID. The fresh fuel is not assigned a Fabrication ID but the burnable absorber configuration is noted. The initial enrichment of the various regions are listed in Table 4.1. The calculated BOC5 exposures, based on an EOC4 exposure of 13,400 MWD/MT, are shown in a quarter core representation in Figure 4.2 along with the quarter core fuel shuffle simulation. The core consists of ninety-two (92) fresh ENC assemblies at an average enrichment of 3.64 w/o U-235, seventy-two (72) once-burnt ENC assemblies, and twenty-nine (29) twice-burnt Westinghouse assemblies. A low radial leakage fuel management plan has been developed and results in the scatter-loading of the fresh fuel throughout the core with the fresh assemblies in the core interior containing Al_2O_3-B_4C burnable absorber rods. The exposed fuel is also scatter-loaded in the center in a manner to control the power peaking. The

Al_2O_3-B_4C burnable absorber rods contain 0.026 gm/in of B-10 and 1,040 of these rods are distributed among seventy-two (72) fresh assemblies loaded in the core interior. Pertinent fuel assembly parameters for the Cycle 5 fuel are depicted in Table 4.1.

Table 4.1 D.C Cook Unit 2, Principal Characteristics for Nuclear Analysis of Cycle 5 Fuel

	Region 5	Region 6	Region 7
Nominal Enrichment (w/o)	3.40	3.65	3.64
Nominal Density (% TD)	95	94	94
Pellet OD (in)	.3225	.3030	.3030
Clad OD (in)	.374	.360	.360
Diametral Gap (in)	.0065	.0070	.0070
Clad Thickness (in)	.0225	.0250	.0250
Rod Pitch (in)	.496	.496	.496
Spacer Material	Inconel	Bi-Metallic	Bi-Metallic
Fuel Supplier	W	ENC	ENC
Fuel Stack Height Nominal (in)	144	144	144
Number of Assemblies	29	72	92
Regionwise Loading (MTU)	13.286	29.077	37.154
Exposure (MWD/MT)			
BOC5	24,069	16,368	0
EOC5	34,866	35,410	19,546
Incremental	10,797	19,042	19,546

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
				M2 R47	+	+	+	+	+	D2 R8					1
		J7 R92	F15 S03	a	D13 S27	c	J1 R73	c	M13 S13	a	K15 S01	H3 R46			2
	N8 R19	a	b	L2 S21	c	L4 S51	H1 S06	E4 S46	c	E2 S57	b	a	G7 R70		3
	A10 S10	b	P7 S45	d	K3 S66	c	J12 S37	c	F3 S32	d	B7 S23	b	R10 S08		4
P4 R78	a	P5 S63	d	J6 S48	c	E15 R6	c	L15 R65	c	G6 S41	d	B5 S61	a	B4 R23	5
+	C12 S19	c	N6 S30	c	K7 S31	d	G4 S52	d	F7 S35	c	C6 S53	c	N12 S17	+	6
+	c	M5 S28	c	A11 R37	d	J2 S39	N13 S54	G2 S42	d	R11 R89	c	D5 S43	c	+	7
+	R7 R4	R8 S07	D7 S72	c	M9 S34	C13 S58	J15 R54	N3 S20	D9 S15	c	M7 S49	A8 S05	A9 R9	+	8
+	c	M11 S65	c	A5 R2	d	J14 S68	C3 S56	G14 S69	d	R5 R57	c	D11 S70	c	+	9
+	C4 S12	c	N10 S25	c	K9 S64	d	G12 S22	d	F9 S38	c	C10 S33	c	N4 S50	+	1
P12 R60	a	P11 S60	d	J10 S47	c	E1 R33	c	L1 R81	c	G10 S26	d	B11 S62	a	B12 R62	1
	A6 S02	b	P9 S29	d	K13 S36	c	J4 S71	c	F13 S44	d	B9 S40	b	R6 S09		1
	J9 R1	a	b	L14 S59	c	L12 S67	H15 S24	E12 S14	c	E14 S55	b	a	C8 R52		1
		H13 R42	F1 S11	a	D3 S18	c	G15 R36	c	M3 S16	a	K1 S04	G9 R71			1
				M14 R49	+	+	+	+	+	D14 R3					1

Previous Core Location
Fabrication ID

+	Fresh Fuel Assembly, No BA Pins
a	Fresh Fuel Assembly, 4 BA Pins
b	Fresh Fuel Assembly, 12 BA Pins
c	Fresh Fuel Assembly, 16 BA Pins
d	Fresh Fuel Assembly, 20 BA Pins

Figure 4.1 D.C. Cook Unit 2, Cycle 5 Full Core Loading Pattern

	H	G	F	E	D	C	B	A
8	G15 90 24,353	C13 270 16,089	D9 17,611	c 0	D9 180 17,973	A8 12,945	A9 23,843	+ 0
9	C13 90 13,487	G14 16,177	d 0	A11 180 19,856	c 0	D11 18,183	c 0	+ 0
10	G12 17,973	d 0	F9 17,865	c 0	C10 17,906	c 0	C12 180 17,142	+ 0
11	c 0	E15 180 19,790	c 0	G10 17,883	d 0	B11 16,105	a 0	B12 23,028
12	G12 180 17,611	c 0	F13 17,776	d 0	B9 16,265	b 0	A10 180 12,404	
13	H15 12,972	E12 18,190	c 0	E14 15,989	b 0	a 0	C8 28,483	
14	G15 24,023	c 0	D13 180 17,109	a 0	F15 180 12,295	G9 30,235		
15	+ 0	+ 0	+ 0	D14 23,083	Core Location in Previous Cycle Rotation (degrees) Assembly Average Exposure (MWD/MT)			

+	Fresh Fuel Assembly, No BA Pins
a	Fresh Fuel Assembly, 4 BA Pins
b	Fresh Fuel Assembly, 12 BA Pins
c	Fresh Fuel Assembly, 16 BA Pins
d	Fresh Fuel Assembly, 20 BA Pins

Figure 4.2 D. C. Cook Unit 2, Cycle 5, Loading Pattern and BOC Exposure Distribution

5.0 FUEL SYSTEM DESIGN

A description of the Exxon Nuclear supplied fuel design and design methods is contained in Reference 1. This fuel has been specifically designed to be compatible with the resident fuel supplied by Westinghouse.

6.0 NUCLEAR CORE DESIGN

The neutronic characteristics of the projected Cycle 5 core are similar to those of the Cycle 4 core (see Section 6.1).

The nuclear design bases for the Cycle 5 core are as follows:

1. The design shall permit operation within the Technical Specification for D. C. Cook Unit 2 nuclear plant.
2. The length of Cycle 5 shall be determined on the basis of a Cycle 4 energy of 1133.2 GWD (13,400 MWD/MT exposure).
3. The Cycle 5 loading pattern shall be designed to achieve power distributions and control rod reactivity worths according to the following constraints:
    a) The peak F^T_Q and the peak $F^N_{\Delta H}$ shall not exceed the Technical Specification limits in any single ENC fuel rod through the cycle under nominal full power operating conditions.
    b) The scram worth of all rods minus the most reactive rod shall exceed BOC and EOC shutdown requirements.

The neutronic design methods utilized to ensure the above requirements are consistent with those described in References 3, 4, and 5.

The Cycle 5 loading contains 1,040 Al_2O_3-B_4C burnable absorber rods distributed among seventy-two (72) of the ninety-two (92) fresh ENC supplied assemblies. In sixteen (16) of these assemblies there are twenty (20) burnable absorber rods per assembly. Another thirty-six (36) assemblies will each contain sixteen (16) Al_2O_3-B_4C rods, eight (8) assemblies will each contain twelve (12) Al_2O_3-B_4C rods, and twelve (12) assemblies will each contain four (4) Al_2O_3-B_4C rods. The Al_2O_3-B_4C burnable absorber rods each contain 0.026 gm/in of B-10. The core loading pattern has been designed to achieve a desirable power distribution while maximizing the benefit of assemblies with burnable absorbers to reduce the beginning of cycle (BOC) boron concentration. The BOC worth of the 1,040 Al_2O_3-B_4C absorber rods is calculated to be equivalent to the worth of 717 ppm soluble boron.

6.1 PHYSICS CHARACTERISTICS

The neutronics characteristics of the Cycle 5 core are compared with those of Cycle 4 and are presented in Table 6.1. The data presented in the table indicates the neutronic similarity between Cycles 4 and 5. The reactivity coefficients of the Cycle 5 core are bounded by the coefficients used in the safety analysis. The safety analysis for Cycle 5 is applicable for Cycle 4 burnup of +1,000 MWD/MT and -1,000 MWD/MT about the nominal burnup of 13,400 MWD/MT.

The boron letdown curve for Cycle 5 is shown in Figure 6.1. The BOC5 xenon free critical boron concentration is calculated to be 1,491 ppm. At 100 MWD/MT, equilibrium xenon, the critical boron concentration is 1,149 ppm. The Cycle 5 length is projected to be 17,900 MWD/MT at a core power of 3411 MWt with 10 ppm soluble boron remaining.

6.1.1 Power Distribution Considerations

Representative calculated power maps for Cycle 5 are shown in Figures 6.2 and 6.3 for BOC, (equilbrium xenon), and EOC conditions, respectively. The power distributions were obtained from a three-dimensional quarter core XTG(6) model with moderator density and Doppler feedback effects incorporated. As shown in Figure 6.2, for the design Cycle 5 loading pattern, the calculated BOC, hot-full-power, equilibrium xenon nuclear power peaking factors, F^N_Q, and $F^N_{\Delta H}$ are 1.64, and 1.32, respectively. At EOC conditions the corresponding values of F^N_Q and $F^N_{\Delta H}$ are 1.54 and 1.37, respectively for the limiting first cycle fuel. The BOC, HFP, equilibrium xenon F^N_Q value of 1.64 is compared to the measured Cycle 4 value of 1.59 in Table 6.1.

At hot full power, equilibrium conditions, the peak F^N_Q during the cycle is calculated to be 1.64. Including a 3% engineering factor, a 5% measurement uncertainty, K(Z) considerations, and an 11% allowance for PDC-II, (for a ±5% target band on axial flux difference) the expected total peak, F^T_Q, is 1.97. The maximum relative pin power, $F^N_{\Delta H}$, is calculated to be 1.38 at 15,000 MWD/MT. Both F^T_Q and $F^N_{\Delta H}$ are expected to remain within the allowable limits throughout the cycle.

The control of the core power distribution is accomplished by following the procedures for "Exxon Nuclear Power Distribution Control for Pressurized Water Reactors Phase II"(7,8,9). The results reported in those documents provide the means for projecting the maximum

$F^T_Q(Z)$ distribution anticipated during operation under the PDC-II procedure taking into account the incore measured equilibrium power distribution data. A comparison of this distribution with the Technical Specification limit curve assures that the Technical Specification limit will not be exceeded while operating with the PDC-II procedures. The PDC-II documents describe the maximum possible variation in $F^T_Q(Z)$ which can occur during operation when following the outlined procedures. The bounding variation in $F^T_Q(Z)$ represents the maximum variation when the axial offset is maintained within the allowable range.

6.1.2 Control Rod Reactivity Requirements

Detailed calculations of shutdown margins for Cycle 5 are compared with Cycle 4 data in Table 6.2. The D. C. Cook Unit 2 nuclear plant Technical Specifications require a minimum required shutdown margin of 1600 pcm at BOC and EOC. The Cycle 5 analysis indicates excess shutdown margin of 1,008 pcm at BOC and 721 at the EOC. The Cycle 4 analysis indicated an excess shutdown margin of 722 pcm at BOC and 734 pcm at EOC.

The reactivity allowance for control rod insertion and power defect at BOC and EOC conservatively bound the most adverse combination of power level and rod insertion to the power dependent insertion limit.

The control rod groups and insertion limits for Cycle 5 will remain unchanged from Cycle 4. With these limits the nominal worth of the control bank, D-Bank, inserted to the insertion limits at HFP is 149 pcm at BOC and 272 pcm at EOC. The control rod shutdown requirements allow for a HFP D-Bank insertion equivalent to 400 pcm and 500 pcm at BOC and EOC, respectively.

6.1.3 Moderator Temperature Coefficient Considerations

The Technical Specifications require that the moderator temperature coefficient be less than or equal to +5 pcm/°F below 70% of rated power and less than or equal to 0 pcm/°F at or above 70% power. The HZP, ARO moderator temperature coefficient is calculated to be $+3.0\pm2.$ pcm/°F and meets the Technical Specification limit below 70% power. The moderator temperature coefficient at or above 70% rated power is calculated to be less than 0 pcm/°F and also meets the Technical Specifications.

6.2 ANALYTICAL METHODOLOGY

The methods used in the Cycle 5 core analysis are described in References 3, 4, and 5. In summary, the reference neutronic design analysis of the reload core was performed using the XTG(6) reactor simulator code. The input isotopics data were based on quarter core depletion calculations performed for Cycle 4 using the XTG code. The fuel shuffling between cycles was accounted for in the calculations.

Calculated values of F_Q and $F_{\Delta H}^N$ were determined with the XTG reactor model. The calculational thermal-hydraulic feedback and axial exposure distribution effects on power shapes, rod worths, and cycle lifetime are explicitly included in the analysis.

Table 6.1 D.C. Cook Unit 2, Neutronics Characteristics of Cycle 5 Compared With Cycle 4 Data

	Cycle 4		Cycle 5	
	BOC	EOC	BOC	EOC
Critical Boron				
HFP, ARO, Eq. Xenon (ppm)	989[(b)]	10[(b)]	1,149	10
HZP, ARO, No Xenon (ppm)	1,465[(a)]	--------	1,569	--------
Moderator Temperature Coefficient				
HFP, (pcm/°F)	-4.0 [(b)]	-27.5[(b)]	-2.1	-26.3
HZP, (pcm/°F)	-0.97[(a)]	-21.9[(b)]	+3.0	-21.1
Isothermal Temperature Coefficient				
HFP, (pcm/°F)	-5.4 [(b)]	-29.2[(b)]	-3.4	-27.8
HZP, (pcm/°F)	-2.86[(a)]	-23.6[(b)]	+1.3	-23.0
Doppler Coefficient (pcm/°F)	-1.4	-1.6	-1.3	-1.5
Boron Worth, (pcm/ppm)				
HFP	-7.7 [(b)]	-8.7 [(b)]	-8.0	-9.6
HZP	-8.95[(a)]	-10.9[(b)]	-9.4	-11.7
Total Nuclear Peaking Factor				
F^N_Q, HFP, Equilibrium Xenon	1.59 [(a)]	1.55 [(b)]	1.64	1.54
Delayed Neutron Fraction	.0057	.0051	.0062	.0051
Control Rod Worth of All Rods In Minus Most Reactive Rod, HZP, (pcm)	5,525	6,093	6,301	6,172
Excess Shutdown Margin, (pcm)[(c)]	722	734	1,008	721

(a) Measured data

(b) ENC calculated

(c) Shutdown margin evaluation based on the most adverse combination of power level and rod insertion

Table 6.2 D.C. Cook Unit 2, Control Rod Shutdown Margins and Requirements of Cycle 5 Compared to Cycle 4

	Cycle 4		Cycle 5	
	BOC	EOC	BOC	EOC
Control Rod Worth (HZP), pcm				
All Rods Inserted (ARI)	6,348	6,888	7,065	7,279
ARI Less Most Reactive (N-1)	5,525	6,093	6,065	6,079
N-1 Less 10% Allowance [(N-1)*.9)]	4,972	5,484	5,458	5,471
Reactivity Insertion, pcm(a)				
Power Defect (Moderator+Doppler)	400	500	400	500
Flux Redistribution	600	600	600	600
Void	50	50	50	50
Sum of the Above Three	1,050	1,150	1,050	1,150
Rod Insertion Allowance	1,600	2,000	1,800	2,000
Total Requirements	2,650	3,150	2,850	3,150
Shutdown Margin (N-1)*.9 - Total Requirements	2,322	2,334	2,608	2,321
Required Shutdown Margin	1600(b)	1600(b)	1600(b)	1600(b)
Excess Shutdown Margin	722	734	1,008	721

(a) The reactivity insertion allowance assumes the most adverse combination of power level and rod insertion. The BOC shutdown margin is increased at HFP conditions and the EOC shutdowm margin remains unaffected at HFP conditions.

(b) Technical Specification limit.

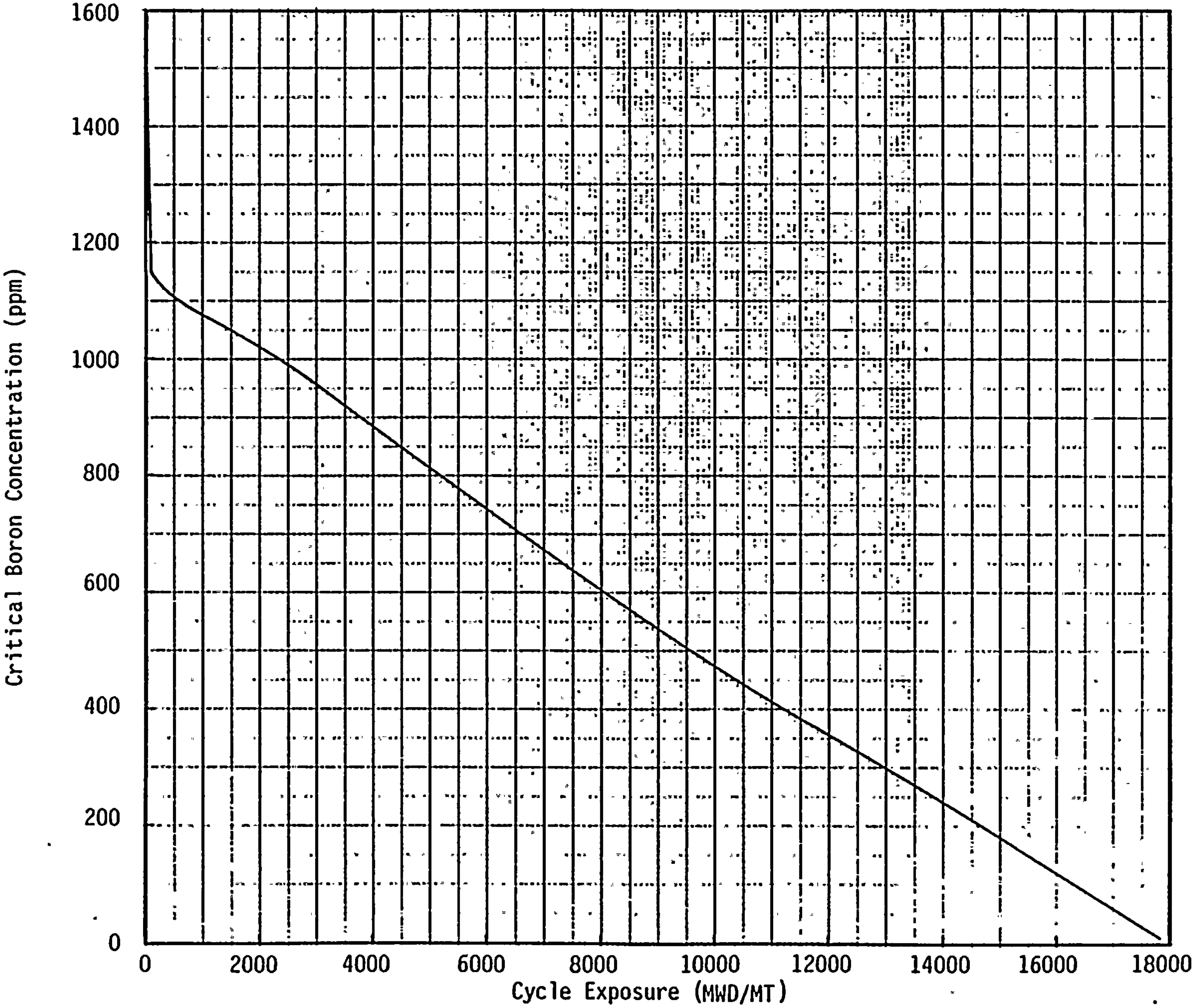

Figure 6.1 D. C. Cook Unit 2, Cycle 5, Boron Letdown Curve

	H	G	F	E	D	C	B	A
8	1.049	1.169	1.119	1.159	1.136	1.177	.955	.993
9	1.206	1.164	1.109	1.042	1.175	1.112	1.098	.982
10	1.116	1.110	1.099	1.154	1.102	1.148	1.021	.856
11	1.160	1.044	1.156	1.090	1.084	1.072	1.054	.409
12	1.141	1.177	1.106	1.085	1.071	1.050	.681	
13	1.177	1.113	1.151	1.075	1.050	.886	.316	
14	.954	1.099	1.023	1.056	.682	.309		
15	.993	.982	.857	.410				

Assembly Relative Power

Peak Assembly = 1.206 (H9)

Pin $F_{\Delta H}^{N}$ = 1.323 (H9)

Peak F_{Q}^{N} = 1.644 (G15)

Figure 6.2 D. C. Cook Unit 2, Cycle 5, Relative Power Distribution, 100 MWD/MT, 1149 ppm, 3411 MWt, ARO

	H	G	F	E	D	C	B	A
8	.904	1.002	1.075	1.233	1.072	1.035	.894	.841
9	1.025	1.054	1.216	1.094	1.221	1.036	1.077	.850
10	1.073	1.217	1.119	1.259	1.108	1.190	.954	.777
11	1.233	1.095	1.260	1.127	1.235	1.057	.997	.434
12	1.075	1.222	1.110	1.235	1.100	1.122	.732	
13	1.035	1.036	1.190	1.058	1.121	.955	.396	
14	.893	1.077	.954	.997	.732	.387		
15	.841	.850	.777	.434				

Assembly Relative Power

Peak Assembly = 1.260 (F11)

Pin $F_{\Delta H}^{N}$ = 1.369 (F11)

Peak F_{Q}^{N} = 1.536 (F11)

Figure 6.3 D. C. Cook Unit 2, Cycle 5, Relative Power Distribution, 17,900 MWD/MT, 10 ppm, 3411 MWD/MT, ARO,

7.0 THERMAL-HYDRAULIC DESIGN ANALYSIS

Thermal-hydraulic design analyses for ENC fuel that is being placed in D. C. Cook Unit 2 for this cycle will be provided under separate cover.

8.0 ACCIDENT AND TRANSIENT ANALYSES

8.1 PLANT TRANSIENT ANALYSIS

Plant transient analyses for the ENC fuel that is being placed in D. C. Cook Unit 2 this cycle will be provided under separate cover.

8.2 ECCS ANALYSIS

The LOCA-ECCS analysis for ENC fuel at D. C. Cook Unit 2 will be provided under separate cover.

8.3 ROD EJECTION ANALYSIS

A Control Rod Ejection Accident is defined as the mechanical failure of a control rod mechanism pressure housing, resulting in the ejection of a Rod Cluster Assembly (RCCA) and drive shaft. The consequence of this mechanical failure is a rapid reactivity insertion together with an adverse core power distribution, possibly leading to localized fuel rod damage.

The rod ejection accident has been evaluated with the procedures developed in the ENC Generic Rod Ejection Analysis(2). The ejected rod worths and hot pellet peaking factors were calculated using the XTG code. No credit was taken for the power flattening effects of Doppler or moderator feedback in the calculation of ejected rod worths or resultant peaking factors. The calculations made for Cycle 5 using a full core XTGPWR model were two-dimensional with appropriate axial buckling correction. The total peaking factor, F_Q^T, were determined as the product of radial peaking (as calculated using XTG) and a conservative axial peaking factor. The pellet energy deposition resulting from an ejected rod was conservatively evaluated explicitly for BOC and EOC conditions. The HFP pellet energy deposited was calculated to be 161.9 cal/gm at BOC and 159.2 cal/gm at EOC. The HZP pellet energy deposition was calculated to be less than 55 cal/gm for both BOC and EOC conditions. The rod ejection accident was found to result in an energy deposition of less than the 280 cal/gm limit as stated in Regulatory Guide 1.77. The significant parameters for the analyses, along with the results, are summarized in Tables 8.1 and 8.2.

Table 8.1 D. C. Cook Unit 2 Cycle 5, Ejected Rod Analysis, HFP

		BOC		EOC	
		Value	Contribution(a) to Energy Deposition, (cal/gm)	Value	Contribution(a) to Energy Deposition, (cal/gm)
A.	Initial Fuel Enthaply (cal/gm)	66.5	-----	68.2	-----
B.	Generic Initial Fuel Enthalpy (cal/gm)	40.8	-----	40.8	-----
C.	Delta Initial Fuel Enthalpy (cal/gm)	25.7	25.7	27.4	27.4
D.	Maximum Control Rod Worth (pcm)	179	130	194	143
E.	Doppler Coefficient (pcm/°F)	-1.0(e)	1.04(b)	-1.40(e)	0.89(b)
F.	Delayed Neutron Fraction, β	.0062	1.00(b)	.0051	1.05(b)
G.	Power Peaking Factor	2.6	-----	4.1	-----
H.	Power Peaking Factor Used(c)	6.0	-----	7.5	-----
			161.9(d)		159.2(d)

(a) The contribution to the total pellet energy deposition is a function of initial fuel enthalpy, maximum control rod worth, Doppler coefficient, and delayed neutron fraction. The energy deposition contribution values and factors are derived from data calculated in the "Generic Analysis of the Control Rod Ejection Transient...." document.

(b) These values are multiplication factors applied to (C+D).

(c) The energy deposition due to maximum control rod worth is a function of the power peaking factor.

(d) Total pellet energy deposition (cal/gm) calculated by the equation -

Total (cal/gm) = (C+D) (E) (F)

(e) For this Doppler coefficient conservative values of -1.0 and -1.40 were assumed at BOC and EOC, respectively.

Table 8.2 D. C. Cook Unit 2 Cycle 5, Ejected Rod Analysis, HZP

		BOC		EOC	
		Value	Contribution(a) to Energy Deposition, (cal/gm)	Value	Contribution(a) to Energy Deposition, (cal/gm)
A.	Initial Fuel Enthalpy (cal/gm)	16.7	-----	16.7	-----
B.	Generic Initial Fuel Enthalpy (cal/gm)	16.7	-----	16.7	-----
C.	Delta Initial Fuel Enthalpy (cal/gm)	0.0	0.0	0.0	0.0
D.	Maximum Control Rod Worth (pcm)	427	20	667	60
E.	Doppler Coefficient, (pcm/^{o}F)	-1.0(e)	1.03(b)	-1.5(e)	.73(b)
F.	Delayed Neutron Fraction, β	.0062	1.00(b)	.0051	1.20(b)
G.	Power Peaking Factor	5.8	-----	11.4	-----
H.	Power Peaking Factor Used(c)	13.0	-----	13.0	-----
		TOTAL	20.6(d)		52.6(d)

(a) The contribution to the total pellet energy deposition is a function of initial fuel enthalpy, maximum control rod worth, Doppler coefficient, and delayed neutron fraction.. The energy deposition contribution values and factors are derived from data calculated in the "Generic Analysis of the Control Rod Ejection Transient...." document.

(b) These values are multiplication factors applied to (C+D).

(c) The energy deposition due to maximum control rod worth is a function of the power peaking factor.

(d) Total pellet energy deposition (cal/gm) calculated by the equation -

$$\text{Total (cal/gm)} = (C+D)\ (E)\ (F)$$

(e) For this Doppler coefficient conservative values of -1.0 and -1.50 were assumed at BOC and EOC, respectively.

9.0 REFERENCES

1. XN-NF-82-25(A), "Generic Mechanical Design Report, Exxon 17x17 Fuel Assembly", Exxon Nuclear Company, April 1982.
2. XN-NF-78-44(A), "A Generic Analysis of The Control Rod Ejection Transient for Pressurized Water Reactors", Exxon Nuclear Company, January 1979.
3. XN-75-27(A), "Exxon Nuclear Neutronics Design Methods for Pressurized Water Reactors", Exxon Nuclear company, June 1975.
4. XN-75-27(A), Supplement 1, September 1976.
5. XN-75-27(A), Supplement 2, December 1977.
6. XN-CC-28, Revision 5, "XTG - A Two Group Three-Dimensional Reactor Simulator Utilizing Coarse Mesh Spacing", Exxon Nuclear Company, July 1979.
7. XN-NF-77-57(A), "Exxon Nuclear Power Distribution Control for Pressurized Water Reactors - Phase II", Exxon Nuclear Company, January 1978.
8. XN-NF-77-57(A), Supplement 1, June 1979.
9. XN-NF-77-57(A), Supplement 2, September 1981.

XN-NF-83-85
Issue Date: 10/24/83

D. C. COOK UNIT 2, CYCLE 5
SAFETY ANALYSIS REPORT

DISTRIBUTION

GJ BUSSELMAN
JC CHANDLER
RA COPELAND
MR KILLGORE
JN MORGAN
GF OWSLEY
RA PUGH
HG SHAW
FB SKOGEN
GA SOFER
RB STOUT
T TAHVILI
HE WILLIAMSON
PD WIMPY
DOCUMENT CONTROL (5)
AEP (5) / HG SHAW