RELOAD SAFETY EVALUATION

FOR

KEWAUNEE CYCLE 16

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KEWAUNEE NUCLEAR POWER PLANT

RELOAD SAFETY EVALUATION
KEWAUNEE CYCLE 16
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WISCONSIN PUBLIC SERVICE CORPORATION

WISCONSIN POWER & LIGHT COMPANY

MADISON GAS & ELECTRIC COMPANY

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1.0 Introduction

The Kewaunee Nuclear Power Plant is scheduled to shut down for the Cycle 15-16 refueling in March of 1990. Startup of Cycle 16 is forecast for April 1990.

This report presents an evaluation of the Cycle 16 reload and demonstrates that the reload will not adversely affect the safety of the plant. Those accidents which could potentially be affected by the reload core design are reviewed.

Details of the calculational model used to generate physics parameters for this Reload Safety Evaluation are described in Reference 1. Accident Evaluation methodologies applied in this report are detailed in Reference 2. These reports have been previously reviewed and approved by the NRC as shown in References 3 and 4. The current physics model reliability factors are discussed in Section 5 of this report.

An evaluation, by accident, of the pertinent reactor parameters is performed by comparing the reload analysis results with the current bounding safety analysis values. The evaluations performed in this document employ the current Technical Specification (Reference 5) limiting safety system setpoints and operating limits.

It is concluded that the Cycle 16 design is more conservative than results of previously docketed accident analyses and implementation of this design will not introduce an unreviewed safety question since:

1) the probability of occurrence or the consequences of an accident will not be increased,

2) the possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report will not be created and,

3) the margin of safety as defined in the basis for any technical specification will not be reduced.

This conclusion is based on these assumptions: Cycle 15 is shut down within a +300 MWD/MTU, -500 MWD/MTU window of the nominal design End of Cycle (EOC) burnup, and there is adherence to plant operating limitations and Technical Specifications (Reference 5).

2.0 CORE DESIGN

2.1 Core Description

The reactor core consists of 121 fuel assemblies of 14 x 14 design. The core loading pattern, assembly identification, control rod bank identification, instrument thimble I.D., thermocouple I.D., and burnable poison rod configurations for Cycle 16 are presented in Figure 2.1.1.

Twenty new Advanced Nuclear Fuel (ANF) assemblies enriched to 3.5 w/o U235 and eight new ANF assemblies enriched to 3.4 w/o U235 will reside with 93 partially depleted ANF assemblies. Table 2.1.1 displays the core breakdown by region, enrichment, and number of previous duty cycles. Reference 6 describes the ANF 14 x 14 design.

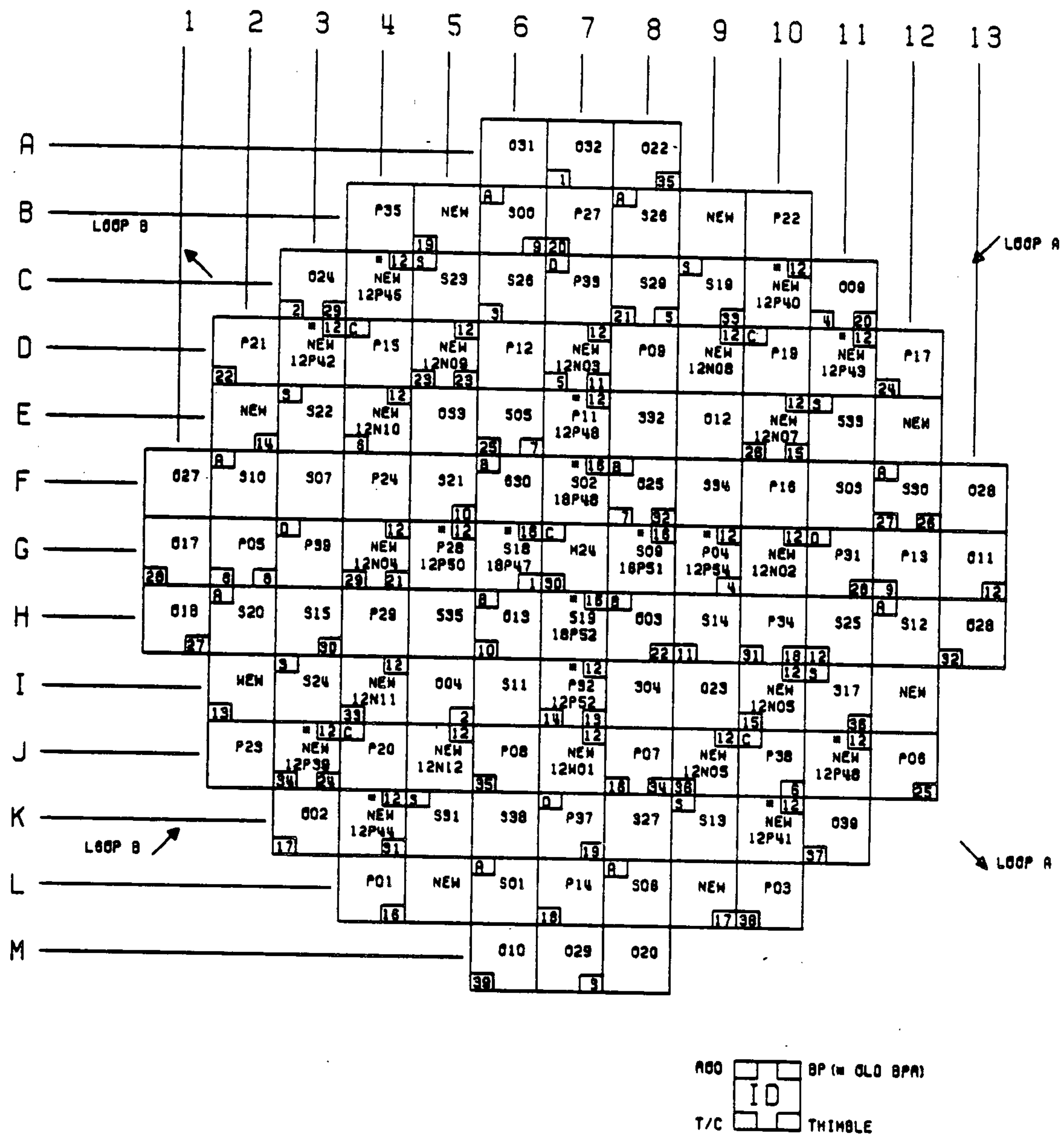
The Cycle 16 reload core will employ 28 burnable poison rod assemblies (BPRAs) containing 144 fresh and 208 partially depleted burnable poison rods. Twelve fresh BPRAs containing 12 burnable poison rods each are reconfigured in Cycle 16 such that the burnable poison rods are loaded into the 12 innermost BPRA positions. The burnable poison rods are repositioned to reduce peak rod powers in the fresh BPRed assemblies. These assemblies are identified as "12N" in Figure 2.1.1. The "12P" symbol in Figure 2.1.1 represents the BPRA configuration used in previous cycles in which the BPRAs are loaded into the 12 outermost BPRA positions.

Table 2.1.1

Cycle 16 Fuel Characteristics

Region	Initial W/O U235	Number of Previous Duty Cycles	Assemblies
13	3.4	3	1
15	3.4	2	12
15	3.4	3	12
16	3.4	1	8
16	3.4	2	24
17	3.5	1	36
18	3.4	0	8 (FEED)
18	3.5	0	20 (FEED)

FIGURE 2.1.1



CYCLE 16
LOADING PATTERN

2.2 Design Objectives and Operating Limits

- Power Rating 1650 MWTH
- System Pressure 2250 PSIA
- Core Average Moderator Temperature (HZP) 547 °F
- Core Average Moderator Temperature (HFP) 562 °F

Cycle 16 core design is based on the following design objectives and operating limits.

A. Nuclear peaking factor limits are as follows:

(i) FQ(Z) limits

$FQ(Z) \leq (2.28/P) * K(Z)$ for $P > 0.5$
$FQ(Z) \leq 4.56 * K(Z)$ for $P \leq 0.5$

(ii) FΔH limits

$F\Delta HN < 1.55(1 + 0.2(1-P))$

Where P is the fraction of full power at which the core is operating:

K(Z) is the function given in Figure 2.2.1
Z is the core height

B. The moderator temperature coefficient at operating conditions shall be negative.

C. With the most reactive rod stuck out of the core, the remaining control rods shall be able to shut down the reactor by a sufficient reactivity margin:

1.0% at Beginning of Cycle (BOC)

2.0% at End of Cycle (EOC)

D. The fuel loading pattern shall be capable of generating approximately 11,000 MWD/MTU based on a nominal end of Cycle 15 burnup of 11,000 MWD/MTU.

E. The power dependent rod insertion limits (PDIL) are presented in Figure 2.2.2. These limits are those currently specified in Reference 5.

F. The indicated axial flux difference shall be maintained within a $\pm$ 5% band about the target axial flux difference above 90% power. Figure 2.2.3 shows the axial flux difference limits as a function of core power. These limits are currently specified in Reference 5.

G. At refueling conditions a boron concentration of 2100 ppm will be sufficient to maintain the reactor subcritical by approximately 10% $\Delta k/k$ with all rods inserted and will maintain the core subcritical with all rods out.

H. Fuel duty during this fuel cycle will assure peak fuel rod burnups less than the maximum burnup recommended by the fuel vendor.

FIGURE 2.2.1

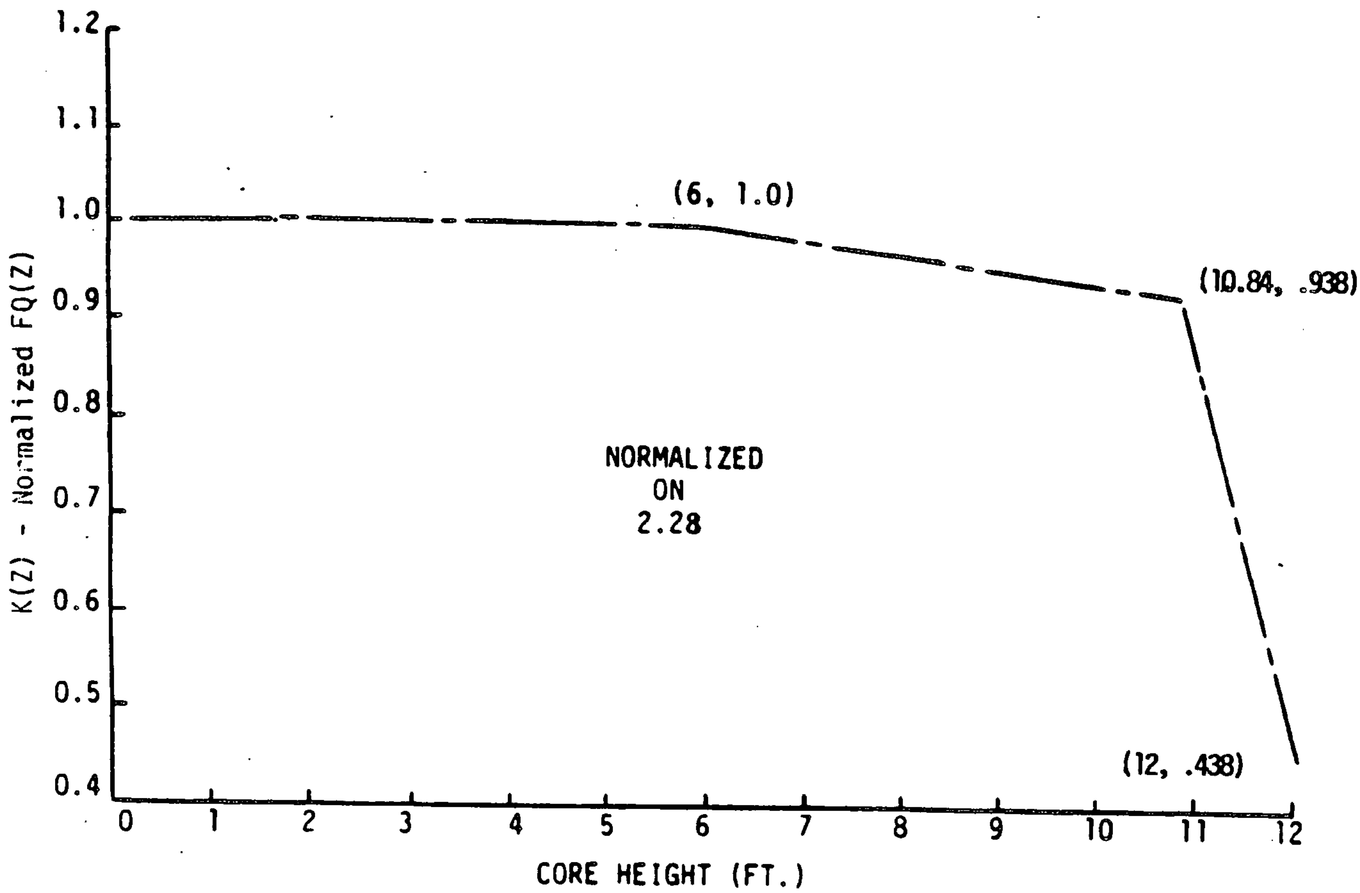


FIGURE 2.2.1 - HOT CHANNEL FACTOR NORMALIZED OPERATING ENVELOPE

FIGURE 2.2.2

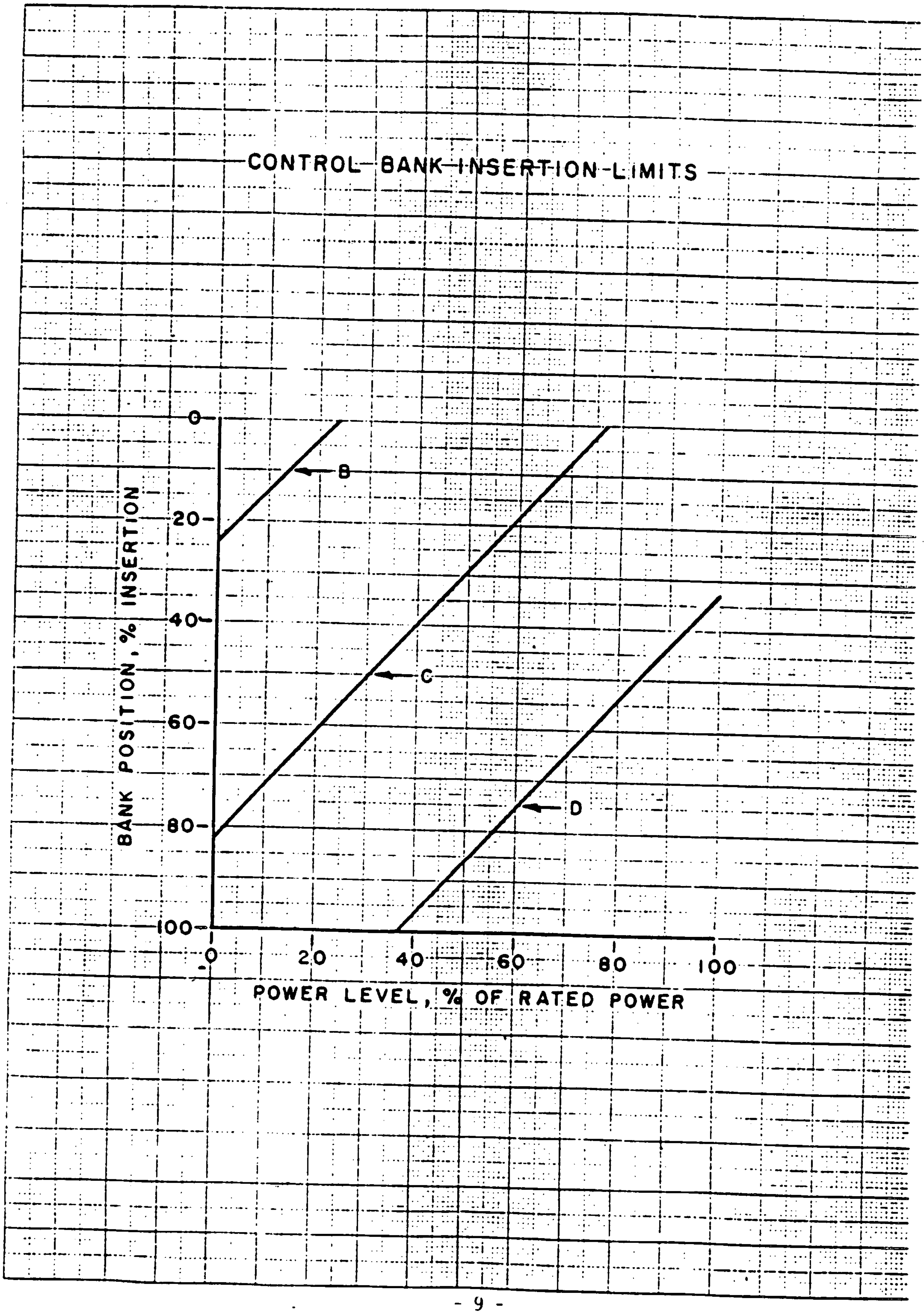
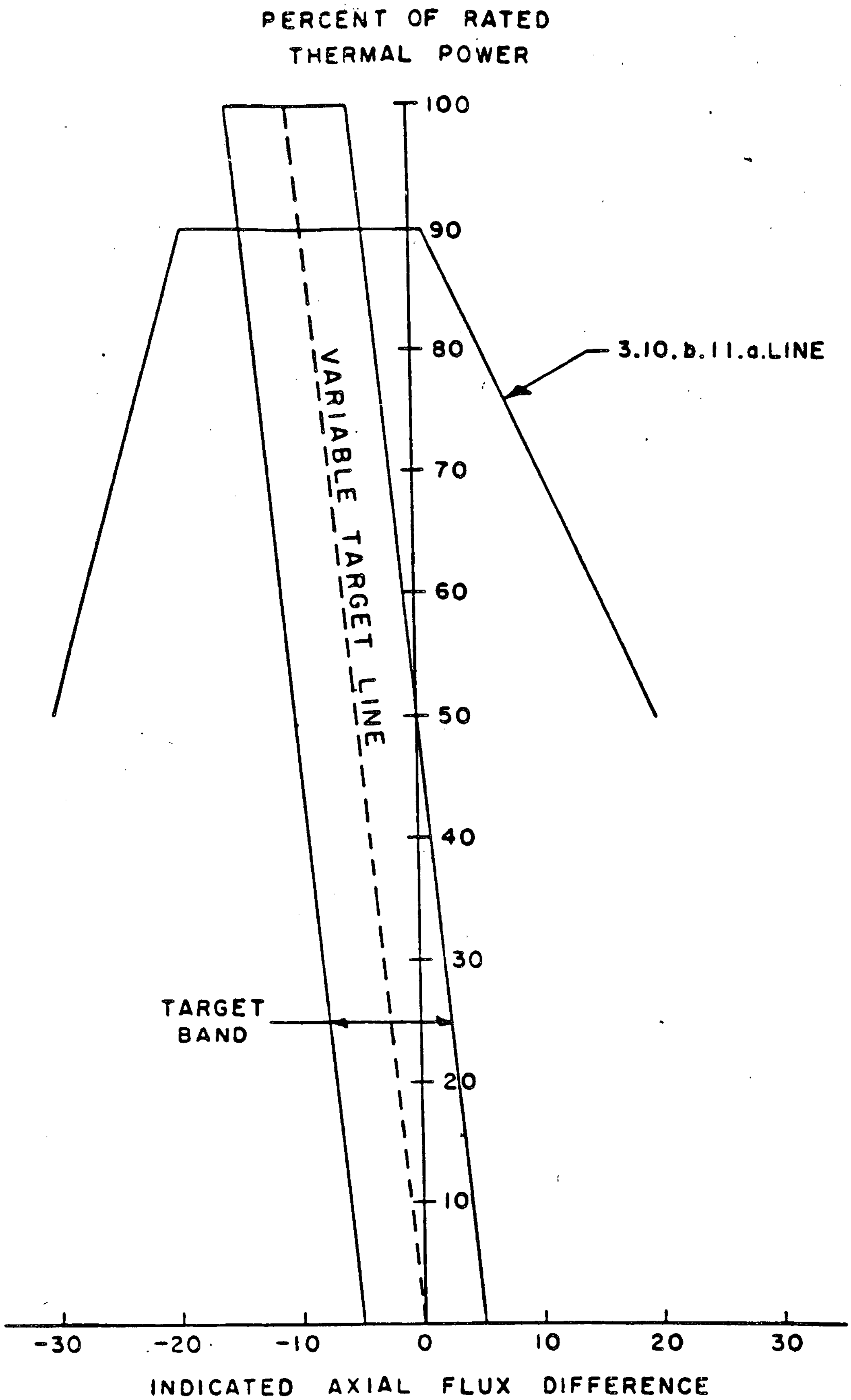

CONTROL BANK INSERTION LIMITS
BANK POSITION, % INSERTION
0
20
40
60
80
100
B
C
D
0
20
40
60
80
100
POWER LEVEL, % OF RATED POWER

FIGURE 2.2.3



Target Band on Indicated Flux Difference
As a Function of Operating Power Level (Typical)

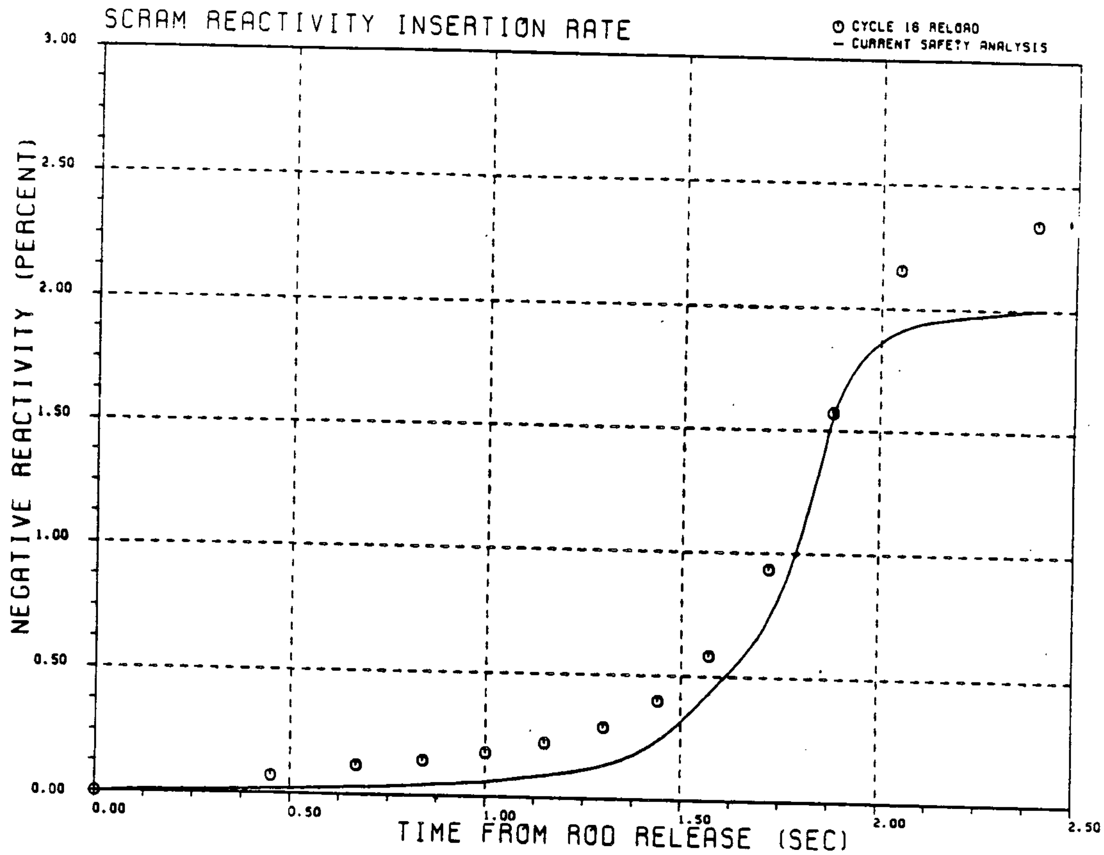
2.3 Scram Worth Insertion Rate

The most limiting scram curve is that curve which represents the slowest trip reactivity insertion rate normalized to the minimum shutdown margin. The Cycle 16 minimum shutdown margin is 2.34% at end of cycle hot full power conditions. Figure 2.3.1 compares the Cycle 16 minimum scram insertion curve to the current bounding safety analysis curve.

It is concluded that the minimum trip reactivity insertion rate for Cycle 16 is conservative with respect to the bounding value. Thus, for accidents in which credit is taken for a reactor trip, the proposed reload core will not adversely affect the results of the safety analysis due to trip reactivity assumptions.

FIGURE 2.3.1

Scram Worth vs. Time



2.4 Shutdown Window

An evaluation of the maximum full power equilibrium peaking factors versus EOC 15 burnup is presented in Table 2.4.1. The values shown have conservatisms applied in accordance with References 1 and 7.

It is concluded that if the refueling shutdown of Cycle 15 occurs within the burnup window, the Cycle 16 peaking factors will not be significantly affected and will not exceed their limiting values.

Table 2.4.1

Peaking Factor Versus Cycle 15 Shutdown Burnup

	FΔH		FQ	
	Cycle 15	Limit	Cycle 15	Limit
EOC 15 - 500 MWD/MTU	1.53	1.55	2.14	2.28
EOC 15 Nominal	1.52	1.55	2.13	2.28
EOC 15 + 300 MWD/MTU	1.52	1.55	2.12	2.28

3.0 ACCIDENT EVALUATIONS

Table 3.0.1 presents the latest safety analyses performed for the accidents which are evaluated in Sections 3.1 through 3.16 of this report. The bounding values derived from these analyses are shown in Table 3.0.2 and will be applied in the Cycle 16 accident evaluations.

Table 3.0.1

Kewaunee Nuclear Power Plant

List of Safety Analyses

Accident	Current Analysis	Ref. No.
Uncontrolled RCCA Withdrawal From a Subcritical Condition	2/78 (Cycle 4-RSE)	9
Uncontrolled RCCA Withdrawal at Power	2/78 (Cycle 4-RSE)	9
Control Rod Drop	1/27/71 (AM7-USAR)	8
RCC Assembly Misalignment	1/27/71 (AM7-USAR)	8
CVCS Malfunction	1/27/71 (AM7-USAR)	8
Startup of an Inactive RC Loop	1/27/71 (AM7-USAR)	8
Excessive Heat Removal Due to FW System Malfunctions	1/27/71 (AM7-USAR)	8
Excessive Load Increase Incident	1/27/71 (AM7-USAR)	8
Loss of Reactor Coolant Flow		
Due to Pump Trip	3/73 (WCAP-8092)	10
Due to Underfrequency	7/88 (Rev 6 - USAR)	8
Locked Rotor Accident	2/78 (Cycle 4-RSE)	9
Loss of External Electrical Load	1/27/71 (AM7-USAR)	8
Loss of Normal Feedwater	8/31/73 (AM33-USAR)	8
Fuel Handling Accidents	1/27/71 (AM7-USAR)	8
Rupture of a Steam Pipe	4/13/73 (AM28-USAR)	8
Rupture of CR Drive Mechanism Housing	2/78 (Cycle 4-RSE)	9
RC System Pipe Rupture (LOCA)	12/10/76 (AM40-USAR)	8
Westinghouse		
Zirc - Water Addendum	12/14/79	11
Clad Hoop Stress Addendum	1/8/80	12
Exxon	10/01/84 (XN-NF-84-31, Rev.1)	13

Table 3.0.2

Safety Analyses Bounding Values

Parameter	Lower Bound	Upper Bound	Units
Moderator Temp. Coefficient	-40.0	0.0	pcm/°F
Doppler Coefficient	-2.32	-1.0	pcm/°F
Differential Boron Worth	-11.2	-7.7	pcm/ppm
Delayed Neutron Fraction	.00485	.0071	
Prompt Neutron Lifetime	15	N/A	μsec
Shutdown Margin	1.0 (BOC)	N/A	% Δρ
	2.0 (EOC)	N/A	
Differential Rod Worth of 2 Banks Moving	N/A	82	pcm/sec
Ejected Rod Cases			
HFP, BOL			
βeff	.0055	N/A	
Rod Worth	N/A	.30	%Δρ
FQ	N/A	5.03	
HFP, EOL			
βeff	.0050	N/A	
Rod Worth	N/A	.42	%Δρ
FQ	N/A	5.1	
HZP, BOL			
βeff	.0055	N/A	
Rod Worth	N/A	.91	%Δρ
FQ	N/A	11.2	
HZP,EOL			
βeff	.0050	N/A	
Rod Worth	N/A	.92	%Δρ
FQ	N/A	13.0	

3.1 Evaluation of Uncontrolled Rod Withdrawal from Subcritical

An uncontrolled addition of reactivity due to uncontrolled withdrawal of a Rod Cluster Control Assembly (RCCA) results in a power excursion.

The most important parameters are the reactivity insertion rate and the doppler coefficient. A maximum reactivity insertion rate produces a more severe transient while a minimum (absolute value) doppler coefficient maximizes the nuclear power peak. Of lesser concern are the moderator coefficient and delayed neutron fraction which are chosen to maximize the peak heat flux.

Table 3.1.1 presents a comparison of Cycle 16 physics parameters to the current safety analysis values for the Uncontrolled Rod Withdrawal from a Subcritical Condition.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, an uncontrolled rod withdrawal from subcritical accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.1.1

Uncontrolled Rod Withdrawal From Subcritical

	Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A)	Moderator Temp. Coefficient	0.22	≤	10.0	pcm/°Fm
B)	Doppler Temp. Coefficient	-1.07	≤	-1.0	pcm/°Ff
C)	Differential Worth of Two Moving Banks	.042	≤	.115	$/sec
D)	Scram Worth vs. Time	See Section 2.3			
E)	Delayed Neutron Fraction	.00543	≥	.00485	
F)	Prompt Neutron Lifetime	28	≥	15	μsec

3.2 Evaluation of Uncontrolled Rod Withdrawal at Power

An uncontrolled control rod bank withdrawal at power results in a gradual increase in core power followed by an increase in core heat flux. The resulting mismatch between core power and steam generator heat load results in an increase in reactor coolant temperature and pressure.

The minimum absolute value of the doppler and moderator coefficients serves to maximize peak neutron power, while the delayed neutron fraction is chosen to maximize peak heat flux.

Table 3.2.1 presents a comparison of the Cycle 16 physics parameters to the current safety analysis values for the Uncontrolled Rod Withdrawal at Power Accident.

The application of the reliability factor to the moderator coefficient calculated at HZP, BOC, no xenon core conditions results in a slightly positive value. It is anticipated that BOC Startup Physics Test measurements will demonstrate that the moderator coefficient will be negative at operating conditions.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, an uncontrolled rod withdrawal at power accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.2.1

Uncontrolled Rod Withdrawal at Power

	Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A)	Moderator Temp. Coefficient	0.22*	$\leq$	0.0	pcm/°Fm
B)	Doppler Temp. Coefficient	-1.02	$\leq$	-1.0	pcm/°Ff
C)	Differential Rod Worth Of Two Moving Banks	.042	$\leq$	.115	$/sec
D)	FΔHN	1.54	$\leq$	1.55	
E)	Scram Worth vs. Time	See Section 2.3			
F)	Delayed Neutron Fraction	0.00543	$\geq$	0.00485	

*Moderator Temperature Coefficient will be verified negative at Startup Testing.

3.3 Evaluation of Control Rod Misalignment

The static misalignment of an RCCA from its bank position does not cause a system transient, however; it does cause an adverse power distribution which is analyzed to show that core Departure from Nuclear Boiling Ratio (DNBR) limits are not exceeded.

The limiting core parameter is the peak $F\Delta H$ in the worst case misalignment of Bank D fully inserted with one of its RCCAs fully withdrawn at full power.

Table 3.3.1 presents a comparison of the Cycle 16 $F\Delta HN$ versus the current safety analysis $F\Delta H$ limit for the Misaligned Rod Accident.

Since the pertinent parameter from the proposed Cycle 16 reload core is conservatively bounded by that used in the current safety analysis, a control rod misalignment accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.3.1

Control Rod Misalignment Accident

Parameter	Reload Safety Evaluation Value		Current Safety Analysis
A) $F_{\Delta H}^{N}$	1.87	$\leq$	1.92

3.4 Evaluation of Dropped Rod

The release of a full length control rod, or control rod bank by the gripper coils while the reactor is at power, causes the reactor to become subcritical and produces a mismatch between core power and turbine demand. The dropping of any control rod bank will produce a negative neutron flux rate trip with no resulting decrease in thermal margins. Dropping of a single RCCA may or may not result in a negative rate trip, and therefore the radial power distribution must be considered.

A comparison of the Cycle 16 $F\Delta HN$ to the current safety analysis $F\Delta HN$ limit for the Dropped Rod Accident is presented in Table 3.4.1.

Since the pertinent parameter from the proposed Cycle 16 reload core is conservatively bounded by that used in the current safety analysis, a dropped rod accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.4.1

Dropped Rod Accident

Parameter	Reload Safety Evaluation Value		Current Safety Analysis
A) FΔHN	1.71	$\leq$	1.92

3.5 Evaluation of Uncontrolled Boron Dilution

The malfunction of the Chemical and Volume Control System (CVCS) is assumed to deliver unborated water to the Reactor Coolant System (RCS).

Although the boron dilution rate and shutdown margin are the key parameters in this event, additional parameters are evaluated for the manual reactor control case. In this case core thermal limits are approached and the transient is terminated by a reactor trip on over-temperature ΔT.

Table 3.5.1 presents a comparison of Cycle 16 physics analysis results to the current safety analysis values for the Uncontrolled Boron Dilution Accident for refueling and full power core conditions.

The application of the reliability factor to the moderator coefficient calculated at HZP, BOC, no xenon core conditions results in a slightly positive value. It is anticipated that BOC Startup Physics Test measurements will demonstrate that the moderator coefficient will be negative at operating conditions.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, an uncontrolled boron dilution accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.5.1

Uncontrolled Boron Dilution Accident

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
i) Refueling Conditions				
A) Shutdown Margin	10.1	≥	10.0	%
ii) At-Power Conditions				
A) Moderator Temp. Coefficient	0.22*	≤	0.0	pcm/°Fm
B) Doppler Temp. Coefficient	-1.07	≤	-1.0	pcm/°Ff
C) Reactivity Insertion Rate by Boron	.0020	≤	.0023	$/sec
D) Shutdown Margin	2.34	≥	1.00	%
E) FΔHN	1.54	≤	1.55	
F) Delayed Neutron Fraction	0.00543	≥	0.00485	

*Moderator Temperature Coefficient will be verified negative at Startup Testing.

3.6 Evaluation of Startup of an Inactive Loop

The startup of an idle reactor coolant pump in an operating plant would result in the injection of cold water (from the idle loop hot leg) into the core which causes a rapid reactivity insertion and subsequent core power increase.

The moderator temperature coefficient is chosen to maximize the reactivity effect of the cold water injection. Doppler temperature coefficient is chosen conservatively low (absolute value) to maximize the nuclear power rise. The power distribution ($F_{\Delta H}$) is used to evaluate the core thermal limit acceptability.

Table 3.6.1 presents a comparison of the Cycle 16 physics calculation results to the current safety analysis values for the Startup of an Inactive Loop Accident.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, the startup of an inactive loop accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.6.1

Startup of an Inactive Loop Accident

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Unit
A) Moderator Temp. Coefficient	-33.59	$\geq$	-40.0	pcm/°Fm
B) Doppler Coefficient	-1.51	$\leq$	-1.0	pcm/°Ff
C) FΔHN	1.54	$\leq$	1.55	

3.7 Evaluation of Feedwater System Malfunction

The malfunction of the feedwater system such that the feedwater temperature is decreased or the flow is increased causes a decrease in the RCS temperature and an attendant increase in core power level due to negative reactivity coefficients and/or control system action.

Minimum and maximum moderator coefficients are evaluated to simulate both BOC and EOC conditions. The doppler reactivity coefficient is chosen to maximize the nuclear power peak.

A comparison of Cycle 16 physics calculation results to the current safety analysis values for the Feedwater System Malfunction Accident is presented in Table 3.7.1.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, a feedwater system malfunction will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.7.1

Feedwater System Malfunction Accident

	Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
i)	Beginning of Cycle				
	A) Moderator Temp. Coefficient	-5.38	≤	0.0	pcm/°Fm
	B) Doppler Temp. Coefficient	-1.07	≤	-1.0	pcm/°Ff
ii)	End of Cycle				
	A) Moderator Temp. Coefficient	-29.80	≥	-40.0	pcm/°Fm
	B) Doppler Temp. Coefficient	-1.17	≤	-1.0	pcm/°Ff
iii)	Beginning and End of Cycle				
	C) FΔHN	1.54	≤	1.55	

3.8 Evaluation of Excessive Load Increase

An excessive load increase causes a rapid increase in steam generator steam flow. The resulting mismatch between core heat generation and secondary side load demand results in a decrease in reactor coolant temperature which causes a core power increase due to negative moderator feedback and/or control system action.

This event results in a similar transient as that described for the feedwater system malfunction and is therefore sensitive to the same parameters.

Table 3.8.1 presents a comparison of Cycle 16 physics results to the current safety analysis values for the Excessive Load Increase Accident.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, an excessive load increase accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.8.1

Excessive Load Increase Accident

	Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
i)	Beginning of Cycle				
	A) Moderator Temp. Coefficient	-5.38	$\leq$	0.0	pcm/°Fm
	B) Doppler Temp. Coefficient	-1.07	$\leq$	-1.0	pcm/°Ff
ii)	End of Cycle				
	A) Moderator Temp. Coefficient	-29.80	$\geq$	-40.0	pcm/°Fm
	B) Doppler Temp. Coefficient	-1.17	$\leq$	-1.0	pcm/°Ff
iii)	Beginning and End of Cycle				
	C) FΔHN	1.54	$\leq$	1.55	

3.9 Evaluation of Loss of Load

A loss of load is encountered through a turbine trip or complete loss of external electric load. To provide a conservative assessment of this event, no credit is taken for direct turbine/reactor trip, steam bypass, or pressurizer pressure control, and the result is a rapid rise in steam generator shell side pressure and reactor coolant system temperature.

Minimum and maximum moderator coefficients are evaluated to simulate both BOC and EOC conditions. The doppler reactivity coefficient is chosen to maximize the nuclear power and heat flux transient. The power distribution ($F_{\Delta H}$) and scram reactivity are evaluated to ensure thermal margins are maintained by the reactor protection system.

A comparison of Cycle 16 physics parameters to the current safety analysis values for the Loss of Load Accident is presented in Table 3.9.1.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, a loss of load accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.9.1

Loss of Load Accident

	Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
i)	Beginning of Cycle				
	A) Moderator Temp. Coefficient	-5.38	≤	0.0	pcm/°Fm
	B) Doppler Temp. Coefficient	-1.31	≥	-2.32	pcm/°Ff
ii)	End of Cycle				
	A) Moderator Temp. Coefficient	-29.80	≥	-40.0	pcm/°Fm
	B) Doppler Temp. Coefficient	-1.43	≥	-2.32	pcm/°Ff
iii)	Beginning and End of Cycle				
	C) $F_{\Delta H}^{N}$	1.54	≤	1.55	
	D) Scram Worth Versus Time	See Section 2.3			

3.10 Evaluation of Loss of Normal Feedwater

A complete loss of normal feedwater is assumed to occur due to pump failures or valve malfunctions. An additional conservatism is applied by assuming the reactor coolant pumps are tripped, further degrading the heat transfer capability of the steam generators. When analyzed in this manner, the accident corresponds to a loss of offsite power.

The short term effects of the transient are covered by the Loss of Flow Evaluation (Sec. 3.11), while the long term effects, driven by decay heat, and assuming auxiliary feedwater additions and natural circulation RCS flow, have been shown not to produce any adverse core conditions.

The Loss of Feedwater Transient is not sensitive to core physics parameters and therefore no comparisons will be made for the Reload Safety Evaluation.

3.11 Evaluation of Loss of Reactor Coolant Flow Due to Pump Trip

The simultaneous loss of power or frequency decay in the electrical buses feeding the reactor coolant pumps results in a loss of driving head and a flow coast down. The effect of reduced coolant flow is a rapid increase in core coolant temperature. The reactor is tripped by one of several diverse and redundant signals before thermal hydraulic conditions approach those which could result in fuel damage.

The doppler temperature coefficient is compared to the most negative value since this results in the slowest neutron power decay after trip. The moderator temperature coefficient is least negative to cause a larger power rise prior to the trip. Trip reactivity and $F_{\Delta H}$ are evaluated to ensure core thermal margin.

Table 3.11.1 presents a comparison of Cycle 16 calculated physics parameters to the current safety analysis values for the Loss of Reactor Coolant Flow Due to Pump Trip Accident.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, a loss of reactor coolant flow due to pump trip accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.11.1

Loss of Reactor Coolant Flow Due to Pump Trip

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A) Moderator Temp. Coefficient	-5.38	$\leq$	D.0	pcm/°Fm
B) Doppler Temp. Coefficient	-1.43	$\geq$	-2.32	pcm/°Ff
C) FΔHN	1.54	$\leq$	1.55	
D) Scram Worth Versus Time	See Section 2.3			
E) Fuel Temperature	2025	$\leq$	2100	°F

3.12 Evaluation of Loss of Reactor Coolant Flow Due to Locked Rotor

This accident is an instantaneous seizure of the rotor of a single reactor coolant pump resulting in a rapid flow reduction in the affected loop. The sudden decrease in flow results in DNB in some fuel rods.

The minimum (absolute value) moderator temperature coefficient results in the least reduction of core power during the initial transient. The large negative doppler temperature coefficient causes a slower neutron flux decay following the trip as does the large delayed neutron fraction.

Table 3.12.1 presents a comparison of Cycle 16 physics parameters to the current safety analysis values for the Locked Rotor Accident.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, a locked rotor accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.12.1

Loss of Reactor Coolant Flow Due to Locked Rotor

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A) Moderator Temp. Coefficient	-5.38	≤	0.0	pcm/°Fm
B) Doppler Temp. Coefficient	-1.43	≥	-2.32	pcm/°Ff
C) Delayed Neutron Fraction	0.D0543	≥	0.00485	
D) Percent Pins > Limiting FΔHN (DNBR=1.3)	27.18	≤	4D.0	%
E) Scram Worth Versus Time	See Section 2.3			
F) FQ	2.14	≤	2.28	
G) Fuel Temperature	2025	≤	2100	°F

3.13 Evaluation of Main Steam Line Break

The break of a main steam line inside containment at the exit of the steam generator causes an uncontrolled steam release and a reduction in primary system temperature and pressure. The negative moderator coefficient produces a positive reactivity insertion and a potential return to criticality after the trip. The doppler coefficient is chosen to maximize the power increase.

Shutdown margin at the initiation of the cooldown and reactivity insertion and peak rod power ($F\Delta H$) during the cooldown are evaluated for this event. The ability of the safety injection system to insert negative reactivity and reduce power is minimized by using the least negative boron worth coefficient.

Table 3.13.1 presents a comparison of Cycle 16 calculated physics parameters to the current safety analysis values for the main steam line break accident. Figure 3.13.1 compares core Keff during the cooldown to the current bounding safety analysis curve.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, a main steam line break accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

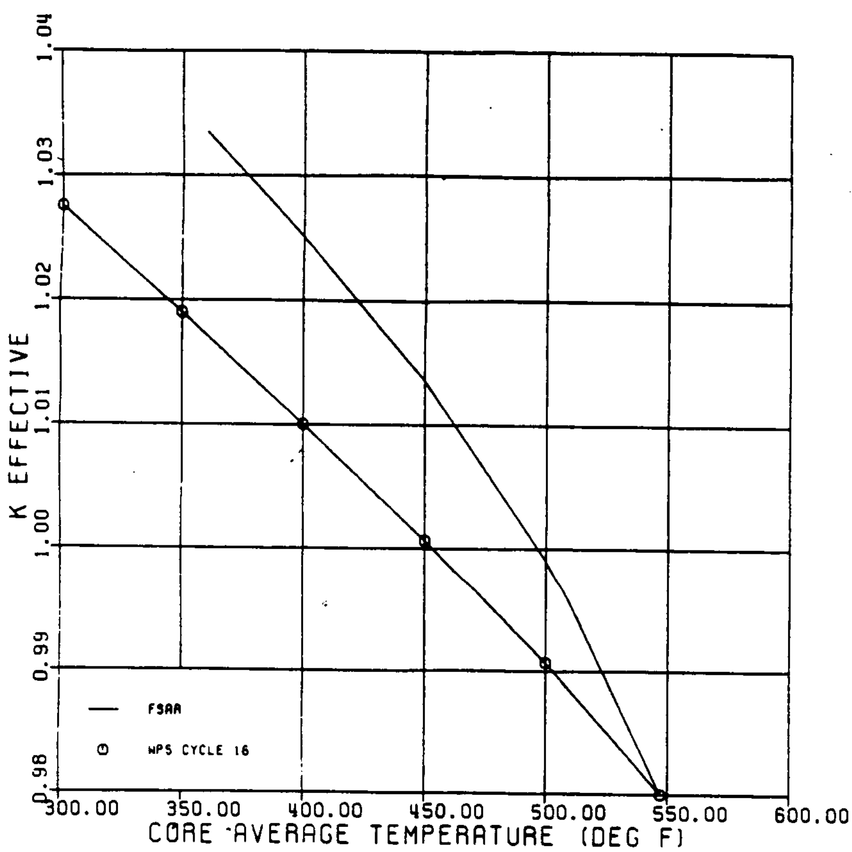
Table 3.13.1

Main Steam Line Break Accident

Parameter	Reload Safety Evaluation Value		Current Safety Analysis	Unit
A) Shutdown Margin	2.34	≥	2.00	%Δρ
B) FΔH	3.86	≤	8.8	
C) Doppler Temp. Coefficient	-1.D7	≤	-1.0	pcm/°Ff
D) Boron Worth Coefficient	-8.5D	≤	-7.7	pcm/ppm

FIGURE 3.13.1

VARIATION OF REACTIVITY, WITH CORE TEMPERATURE
AT 1000 PSIA FOR THE END OF LIFE RODDED
CORE WITH ONE ROD STUCK (ZERO POWER)



3.14 Evaluation of Rod Ejection Accidents

The ejected rod accident is defined as a failure of a control rod drive pressure housing followed by the ejection of a RCCA by the reactor coolant system pressure.

Tables 3.14.1 through 3.14.4 present the comparison of Cycle 16 calculated physics parameters to the current safety analysis values for the Rod Ejection Accident at zero and full power, BOC and EOC core conditions.

The application of the reliability factor to the moderator coefficient calculated at HZP, BOC, no xenon core conditions results in a slightly positive value. It is anticipated that BOC Startup Physics Test measurements will demonstrate that the moderator coefficient will be negative at operating conditions.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, a rod ejection accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.14.1

Rod Ejection Accidents

HFP, BOC

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A) Moderator Temp. Coefficient	-5.38	≤	0.0	pcm/°Fm
B) Delayed Neutron Coefficient	0.D0612	≥	D.00550	
C) Ejected Rod Worth	D.08	≤	D.30	%Δρ
D) Doppler Temp. Coefficient	-1.08	≤	-1.0	pcm/°Ff
E) Prompt Neutron Lifetime	28.4	≥	15.0	μsec
F) FQN	2.45	≤	5.03	
G) Scram Worth Versus Time	See Section 2.3			

Table 3.14.2

Rod Ejection Accidents

HZP, BOC

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A) Moderator Temp. Coefficient	0.22*	≤	0.0	pcm/°Fm
B) Delayed Neutron Fraction	0.0D612	≥	0.00550	
C) Ejected Rod Worth	0.51	≤	0.91	%Δρ
D) Doppler Temp. Coefficient	-1.77	≤	-1.0	pcm/°Ff
E) Prompt Neutron Lifetime	28.4	≥	15.0	μsec
F) FQN	4.86	≤	11.2	
G) Scram Worth Versus Time	See Section 2.3			

*Moderator Temperature Coefficient will be verified negative at Startup Testing.

Table 3.14.3

Rod Ejection Accidents

HFP, EOC

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A) Moderator Temp. Coefficient	-18.4	≤	0.0	pcm/°Fm
B) Delayed Neutron Fraction	0.00543	≥	0.00500	
C) Ejected Rod Worth	0.13	≤	0.42	%Δρ
D) Doppler Temp. Coefficient	-1.18	≤	-1.0	pcm/°Ff
E) Prompt Neutron Lifetime	31.5	≥	15.0	μsec
F) FQN	2.96	≤	5.1	
G) Scram Worth Versus Time	See Section 2.3			

Table 3.14.4

Rod Ejection Accidents

HZP, EOC

Parameter	Reload Safety Evaluation Values		Current Safety Analysis	Units
A) Moderator Temp. Coefficient	-11.60	$\leq$	0.0	pcm/°Fm
B) Delayed Neutron Fraction	0.00543	$\geq$	0.0D500	
C) Ejected Rod Worth	0.63	$\leq$	0.92	%Δρ
D) Doppler Temp. Coefficient	-2.22	$\leq$	-1.0	pcm/°Ff
E) Prompt Neutron Lifetime	31.5	$\geq$	15.0	µsec
F) FQN	7.47	$\leq$	13.0	
E) Scram Worth Versus Time	See Section 2.3			

3.15 Evaluation of Fuel Handling Accident

This accident is the sudden release of the gaseous fission products held within the fuel cladding of one fuel assembly. The fraction of fission gas released is based on a conservative assumption of high power in the fuel rods during their last six weeks of operation.

The maximum FQ expected during this period is evaluated within the restrictions of the power distribution control procedures.

Table 3.15.1 presents a comparison of the Cycle 16 FQN, calculated at end of Cycle 16 less 2.0 GWD/MTU, to the current safety analysis FQN limit for the Fuel Handling Accident.

Since the pertinent parameter from the proposed Cycle 16 reload core is conservatively bounded by that used in the current safety analysis, a fuel handling accident will be less severe than the accident in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.15.1

Fuel Handling Accident

Parameter	Reload Safety Evaluation Values		Current Safety Analysis
A) FQN	1.98	$\leq$	2.53

3.16 Evaluation of Loss of Coolant Accident

The Loss of Coolant Accident (LOCA) is defined as the rupture of the reactor coolant system piping or any line connected to the system, up to and including a double-ended guillotine rupture of the largest pipe.

The principal parameters which affect the results of LOCA analysis are the fuel stored energy, fuel rod internal pressures, and decay heat. These parameters are affected by the reload design dependent parameters shown in Table 3.16.1.

The initial conditions for the LOCA analyses are assured through limits on fuel design, fuel rod burnup, and power distribution control strategies.

Table 3.16.1 presents the comparison of Cycle 16 physics calculation results to the current safety analysis values for the Loss of Coolant Accident.

Since the pertinent parameters from the proposed Cycle 16 reload core are conservatively bounded by those used in the current safety analysis, a loss of coolant accident will be less severe than the transient in the current analysis. The implementation of the Cycle 16 reload core design, therefore, will not adversely affect the safe operation of the Kewaunee Plant.

Table 3.16.1

Loss of Coolant Accident

Parameter	Reload Safety Evaluation Values		Current Safety Analysis
A) Scram Worth Versus Time	See Section 2.3		
B) FQ	See Section 3.17		
C) FΔH	1.54	≤	1.55

3.17 Power Distribution Control Verification

The total peaking factor FQT relates the maximum local power density to the core average power density. The FQT is determined by both the radial and axial power distributions. The radial power distribution is relatively fixed by the core loading pattern design. The axial power distribution is controlled by the procedures (Reference 7) described in Section 2.2 of this report.

Following these procedures, FQT(Z) are determined by calculations performed at full power, equilibrium core conditions, at exposures ranging from BOC to EOC. Conservative factors which account for potential power distribution variations allowed by the power distribution control procedures, manufacturing tolerances, and measurement uncertainties are applied to the calculated FQT(Z).

Figure 3.17.1 compares the calculated FQT(Z), including uncertainty factors, to the FQT(Z) limits. These results demonstrate that the power distributions expected during Cycle 16 operation will not preclude full power operation under the power distribution control specifications currently applied (Reference 5).

MAX (FQ * P REL) VS AXIAL
CORE HEIGHT CYCLE 16
S3D 89320.1029

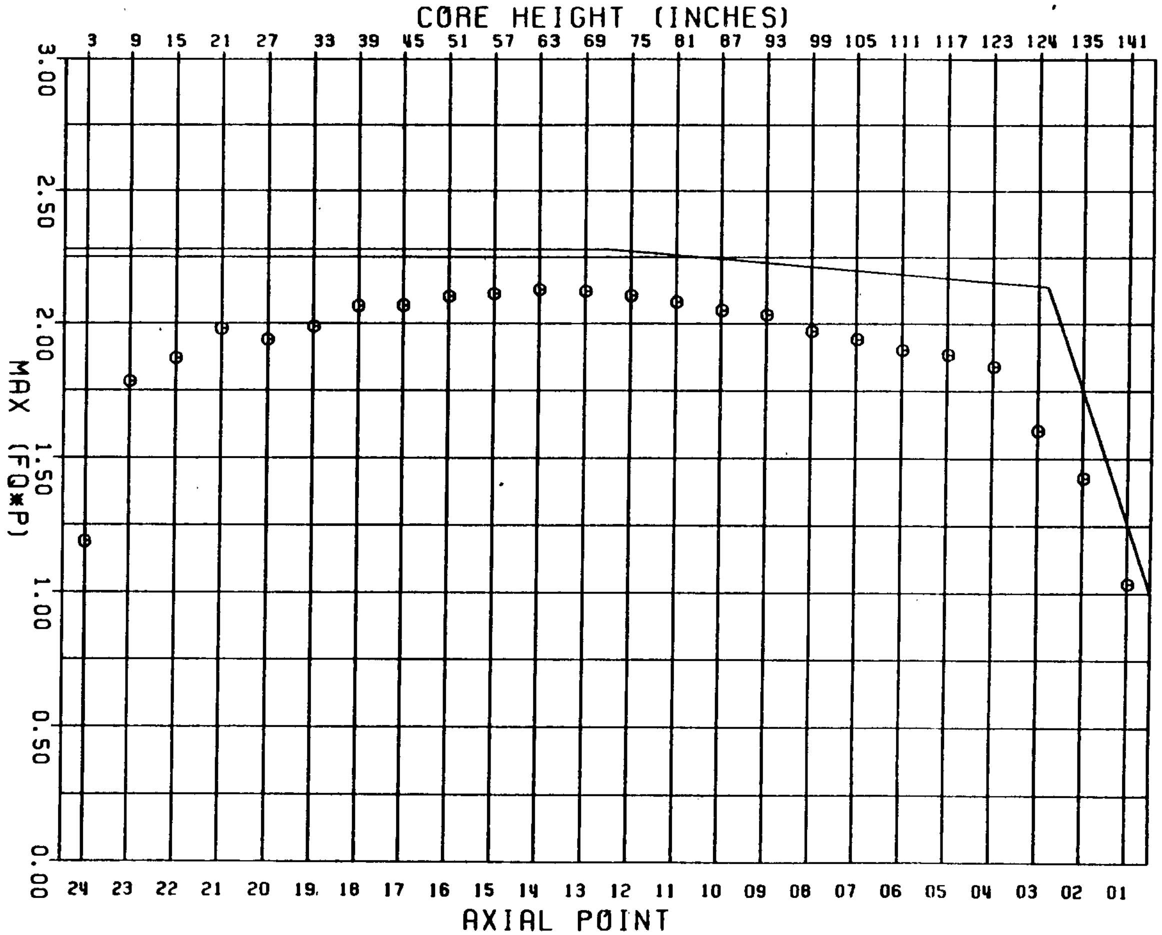


FIGURE 3.17.1

4.0 TECHNICAL SPECIFICATIONS

No Technical Specification changes are required as a result of this reload.

5.0 STATISTICS UPDATE

In an effort to provide continuing assurance of the model applicability, Cycle 14 measurements and calculations were added to the statistics data base prior to model applications to the Cycle 16 Reload Analysis. The reliability and bias factors applicable to Cycle 16 analyses are presented in Tables 5.0.1 and 5.0.2.

Table 5.0.1

Reliability Factors

Parameter	Reliability Factor	Bias
FQN	See Table 5.0.2	
FΔH	3.2%	0
Rod Worth	10.0%	0
Moderator Temperature Coefficient	3.89 PCM/°F	1.32 PCM/°F
Doppler Coefficient	10.0%	0
Boron Worth	5.0%	0
Delayed Neutron Parameters	3.0%	0

Table 5.0.2

FQN Reliability Factors

Core Level	σNode	RF (%)
1 (Bottom)	.062	10.79
2	.053	9.26
3	.027	5.34
4	.030	5.74
5	.030	5.79
6	.031	5.85
7	.031	5.82
8	.030	5.75
9	.030	5.72
10	.031	5.86
11	.028	5.41
12	.028	5.38
13	.025	5.06
14	.025	5.09
15	.022	4.63
16	.023	4.69
17	.021	4.54
18	.021	4.52
19	.025	5.09
20	.024	4.92
21	.043	7.64
22	.034	6.30
23	.078	13.39
24 (Top)	.072	12.42

6.0 REFERENCES

1. Wisconsin Public Service Corporation, Kewaunee Nuclear Power Plant, topical report entitled, "Qualification of Reactor Physics Methods for Application to Kewaunee."

2. Wisconsin Public Service Corporation, Kewaunee Nuclear Power Plant, topical report WPSRSEM-NP-A entitled, "Reload Safety Evaluation Methods for Application to Kewaunee", Revision 2.

3. Safety Evaluation Report by the Office of Nuclear Reactor Regulation: "Qualifications of Reactor Physics Methods for Application to Kewaunee," October 22, 1979.

4. Safety Evaluation Report by the Office of Nuclear Reactor Regulation: "Reload Safety Evaluation Methods for Application to Kewaunee," April, 1988.

5. Wisconsin Public Service Corporation Technical Specifications for the Kewaunee Nuclear Power Plant. Docket number 50-305

6. Exxon Nuclear Company, "Generic Mechanical and Thermal Hydraulic Design for Exxon Nuclear 14 X 14 Reload Fuel Assemblies with Zircaloy Guide Tubes for Westinghouse 2-Loop Pressurized Water Reactors," November 1978.

7. R.J. Burnside and J.S. Holm, "Exxon Nuclear Power Distribution Control For Pressurized Water Reactors, Phase II" XN-NF-77-57, Exxon Nuclear Company, Inc., January 1978.

8. Wisconsin Public Service Corporation, Kewaunee Nuclear Power Plant, Updated Safety Analysis Report.

9. "Reload Safety Evaluation," for Kewaunee Nuclear Power Plant Cycles 2, 3 and 4.

10. WCAP 8092, "Fuel Densification Kewaunee Nuclear Power Plant," March 1973.

11. ECCS Reanalysis - ZIRC/Water Reaction Calculation. Letter from E. R. Mathews to A. Schwencer, December 14, 1979.

12. Clad Swelling and Fuel Blockage Models. Letter from E. R. Mathews to D.G. Eisenhut, January 8, 1980.

13. "Kewaunee High Burnup Safety Analysis: Limiting Break Loca & Radiological Consequences", XN-NF-84-31, Revision 1, Exxon Nuclear Company, Inc., October 1, 1984.