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EXTENDED BURNUP DEMONSTRATION REACTOR FUEL PROGRAM

SEMI-ANNUAL PROGRESS REPORT JANUARY 1979 – SEPTEMBER 1979

**WORK PERFORMED UNDER CONTRACT
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RICHLAND, WA 99352

EXXON NUCLEAR COMPANY, Inc.

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EXTENDED BURNUP DEMONSTRATION
REACTOR FUEL PROGRAM

SEMI-ANNUAL PROGRESS REPORT
JANUARY 1979 - SEPTEMBER 1979

K. N. WOODS

L. F. VAN SWAM

Approved:

G. A. Sofen, Manager
Nuclear Fuels Engineering

Consumers Power Company
212 West Michigan Ave.
Jackson, MI 49201

Exxon Nuclear Company
2101 Horn Rapids Road
Richland, WA 99352

✓ GPU Service Corporation
260 Cherry Hill Road
Parsippany, NJ 07054

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EXXON NUCLEAR COMPANY
2101 Horn Rapids Road
Richland, Washington 99352

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OCTOBER 1980

EXTENDED BURNUP DEMONSTRATION
REACTOR FUEL PROGRAM
SEMI-ANNUAL PROGRESS REPORT JAN. 1979 - SEPT. 1979

ABSTRACT

This is the first semi-annual progress report for the DOE-sponsored Extended Burnup Demonstration program. The program objectives, description, and organization are detailed. Characteristics are given for the 64 Big Rock Point fuel rods and the four 8x8 Oyster Creek fuel assemblies which will be driven to extended burnup. The transfer of 64 Big Rock Point fuel rods from their original assemblies into host assemblies and the results of the fuel examination of these rods are described.

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TABLE OF CONTENTS

Page

1.0	INTRODUCTION.	
1.1	PROGRAM OBJECTIVES	
1.2	BACKGROUND	
1.3	PROGRAM DESCRIPTION.	
1.4	PROGRAM ORGANIZATION	
2.0	PROGRESS ON TASK A - FUEL ROD SELECTION AND CHARACTERIZATION.	
2.1	BIG ROCK POINT 64-ROD PROGRAM.	
2.2	OYSTER CREEK 4-ASSEMBLY PROGRAM.	
3.0	PROGRESS ON TASK B - FUEL ROD EXAMINATIONS.	
3.1	SUBTASK B1 - POOLSIDE EXAMINATIONS	
3.2	SUBTASK B2 - HOT CELL EXAMINATION.	
4.0	PROGRESS ON TASK C - FUEL MANAGEMENT AND LICENSING.	
4.1	BIG ROCK POINT.	
4.2	OYSTER CREEK.	
5.0	PROGRESS ON TASK D - EVALUATION OF MECHANICAL DESIGN PARAMETERS.	
5.1	BIG ROCK POINT	
5.2	OYSTER CREEK	
6.0	PROGRESS ON TASK E - DEVELOPMENT OF POOLSIDE FUEL EXAMINATION TECHNIQUES.	

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page</u>
2.1	Design Parameters for Big Rock Point Reload G-1.	
2.2	Summary of Design Variables for 64 Big Rock Point Extended Burnup Rods.	
2.3	Mechanical Design Parameters for Oyster Creek 8x8 Fuel Assembly.	

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>	<u>Page</u>
1.1	Schedule of Events at Reactor Sites.	
2.1	Big Rock Point G-01 Fuel Rod Types & Locations at EOC15.	
2.2	Big Rock Point G-02 Fuel Rod Types & Locations at EOC15.	
2.3	Big Rock Point G-13 and G-14 Fuel Types and Locations at EOC15.	
2.4	Big Rock Point G-13 Fuel Types & Locations at BOC16	
2.5	Big Rock Point G-14 Fuel Types & Locations at BOC16	
2.6	Oyster Creek 8x8 Lead Assembly Layout UD3-109.	
3.1	Big Rock Point Average Fuel Rod Diameter Versus Axial Position.	
3.2	Big Rock Point Elongation of Fuel Rod Cladding Versus Burnup.	
4.1	Big Rock Point Local Exposure and Power Distribution of G-01 at EOC15	
4.2	Big Rock Point Local Exposure and Power Distribution of G-02 at EOC15	
4.3	Big Rock Point Local Exposure and Power Distribution of G-12 after Reconstitution at BOC16.	
4.4	Big Rock Point Local Exposure and Power Distribution of G-14 after Reconstitution at BOC16.	
4.5	Big Rock Point, Cycle 16 Loading Pattern	

SUMMARY

The Extended Burnup Demonstration (EBD) Reactor Fuel program has been established as a prime contract between the Department of Energy (DOE) and Consumers Power Company (CPCo), with subcontracts to Exxon Nuclear Company (ENC) and General Public Utilities Service Corporation (GPU). Under this program, ENC nuclear fuel of standard design will be irradiated to rod average burnup in excess of 35,000 MWD/MTU in two boiling water reactors, the Big Rock Point reactor in Michigan and the Oyster Creek reactor in New Jersey.

This first semi-annual report describes the basic organization of the program and the progress achieved during the period from January 1, 1979, to September 30, 1979.

At the beginning of the program, two standard ENC 11x11 fuel assemblies had achieved an average assembly burnup of ~ 30,000 MWD/MTU in the Big Rock Point reactor. Under normal circumstances, these two assemblies would have been discharged at that burnup. Under this program, 32 fuel rods from each of these two assemblies were transferred at poolside to equivalent positions in two lower burnup fuel assemblies for irradiation in the Big Rock Point core for two additional cycles. The 64 rods will be driven to rod average burnup levels exceeding 38,000 MWD/MTU in late 1981.

The fuel assembly reconstitution program at Big Rock Point was conducted in January/February of 1979. As each rod was transferred to a new assembly, detailed poolside nondestructive examination measurements were carried out. The purpose of these measurements was to characterize the condition of the 64

rods accurately prior to the extended burnup demonstration. As part of the program, extensive poolside measurements will also be taken after each of the next two irradiation cycles. Highlights of the first fuel examination are included in this semi-annual report. In general, the fuel rods appeared to be in excellent condition after being irradiated to $\sim 30,000$ MWD/MTU.

Four 8x8 ENC fuel assemblies at Oyster Creek will be irradiated to an assembly average burnup exceeding $\sim 35,000$ MWD/MTU. These four assemblies, which represent the lead ENC 8x8 assemblies at Oyster Creek, represent an opportunity to verify the Big Rock Point results with a larger number of fuel rods in a larger commercial BWR. Whereas in Big Rock Point only individual rods will be irradiated to extended burnup, complete assemblies will be driven to higher burnup in this part of the program. The four assemblies were located in symmetrical, high power locations in the Oyster Creek core and achieved an assembly average burnup of approximately 25,000 MWD/MTU in early 1980. At that time, one of the assemblies, which had been examined in previous years, was disassembled and individual fuel rods were subjected to a detailed poolside examination, the results of which are discussed in the second EBD Semi-Annual program report. The four assemblies were then returned to the core for two additional irradiation cycles, and are ultimately expected to achieve a discharge burnup of over 35,000 MWD/MTU in 1982. Detailed poolside examination will be carried out after the first and second extended burnup irradiation cycles.

In addition to the major poolside fuel examination activities on this program, a limited amount of hot cell destructive examination will be performed on four of the 64 fuel rods undergoing extended burnup at Big Rock

Point. The program will also develop a germanium scanning system for application at poolside. This technique will allow measurement at poolside of relative axial burnup profiles and fission product isotope distributions of individual fuel rods.

Additional tasks under the EBD program cover documentation of preirradiation fuel characteristics, fuel management and licensing support for the extended burnup irradiation cycles, and (mechanical analysis of fuel performance) analysis of the impact on the mechanical aspects of fuel design on fuel performance during the extended burnup irradiation. Detailed information covering all aspects of the program will be documented in separate topical reports.

EXTENDED BURNUP DEMONSTRATION REACTOR FUEL PROGRAM

1.0 INTRODUCTION

1.1 PROGRAM OBJECTIVES

The objective of the Extended Burnup Demonstration (EBD) Reactor Fuel Program is to demonstrate that current boiling water reactor (BWR) nuclear fuel of standard design can achieve significantly higher burnup levels than that for which the fuel was originally designed (average assembly burnup $\sim 27,000$ MWD/MTU) without serious fuel performance degradation. Fuel performance in the EBD program will be monitored by nondestructive poolside examinations during reactor outages and by a limited amount of destructive hot cell examination. In accomplishing the objective of the program, two requirements are to be met: 1) the experimental data should be achieved rapidly by extending the burnup of existing fuel that has already achieved relatively high burnup levels, and 2) the program should obtain such data without posing a significant risk of fuel failure to the selected BWRs.

1.2 BACKGROUND

Standard BWR nuclear fuel has generally been designed to remain in the reactor for four to five annual operating cycles and eventually be discharged at a typical burnup of 27,000 MWD/MTU. At the time such fuel was designed, the price of uranium oxide and the price of enrichment services were significantly lower than they are today. It was also expected that the discharged fuel would be ultimately reprocessed to recover the residual fissile material. Due to significant increases in uranium and enrichment costs and to the

indefinite ban on reprocessing, the economically optimum discharge burnup level for BWR fuel is now estimated to be significantly higher than 27,000 MWD/MTU, in the range of 35,000 - 40,000 MWD/MTU.

Several advanced fuel design concepts, such as (1) annular pellets, (2) graphite and metallic coatings on the cladding inside surface, (3) particle fuel, and (4) large grain size fuel are under investigation in both domestic and international programs. In many cases these programs have been initiated in an attempt to develop fuel forms which can accommodate more rapid changes in reactor power. Because of the improved performance characteristics expected from these advanced fuel designs, it has been assumed that such advanced fuel designs would also be ideally suited for higher burnup application. In general, however, these advanced fuel forms will represent a higher fabrication cost than standard fuel. Although the added expense of such fuel would normally be justified for load-following nuclear reactors, there is still the possibility that such an expense might not be required for those nuclear reactors which will continue to operate in a base loaded mode. For these base-loaded applications, there is an obvious incentive to determine the discharge burnup limits which might be achieved with a relatively less expensive fuel of standard design.

Exxon Nuclear is currently providing BWR fuel of standard design to the Big Rock Point and Oyster Creek reactors. A brief summary of the key features of each reactor is listed below:

Name: Big Rock Point
Owner: Consumers Power Company
Net Electrical Power: 65 MWe
Standard Fuel Form: 11x11
No. Of Assemblies/Core: 84
No. Of Fuel Rods/Core: ~ 10,000

Name: Oyster Creek
Owner: Jersey Central & Light Company
Net Electrical Power: 650 MWe
Standard Fuel Form: 8x8
No. Of Fuel Assemblies/Core: 560
No. Of Fuel Rods/Core: ~ 34,000

Under previous programs, two lead 11x11 fuel assemblies had been left in the Big Rock Point core after they had reached the design discharge burnup of 27,000 MWD/MTU. In late 1978 these two assemblies were approaching an assembly average burnup of 30,000 MWD/MTU. The two assemblies were scheduled for discharge from the core in January 1979. As part of the planning for the EBD program, it was recognized that the fuel rods in these two assemblies represented an opportunity to achieve even higher discharge burnup in a relatively short period of time.

In October 1978, four Oyster Creek 8x8 lead assemblies had achieved a burnup of 19,500 MWD/MTU in this larger commercial reactor. The four

assemblies, which had been located in symmetrical positions in the center of the core, would normally have been relocated to lower power positions during their last two operating cycles at Oyster Creek. The ultimate discharge burnup of these assemblies could be increased by modifying the fuel management scheme so that the four assemblies stayed in relatively high power locations in the core during all subsequent cycles.

As a result of this pre-program evaluation, a two-pronged program was conceived by which 64 of the Big Rock Point 11 x11 fuel rods would remain in the reactor for an additional two cycles to achieve a final average rod discharge burnup exceeding 38,000 MWD/MTU. On a larger scale, incorporating the testing of complete assemblies, a total of 240 fuel rods in the four 8x8 lead assemblies at Oyster Creek would be designated for additional irradiation to achieve an average assembly discharge burnup of about 35,000 MWD/MTU. Based on the operating schedules for the two reactors, the Big Rock Point program would precede the more extensive demonstration at Oyster Creek.

1.3 PROGRAM DESCRIPTION

The overall EBD program consists of two separate programs: 1) a 64-rod program at Big Rock Point, and 2) a 4-assembly program at Oyster Creek. Under the Big Rock Point 64-rod program, a total of 64 fuel rods were removed from two discharged 11x11 fuel assemblies and reinserted into two lower burnup 11x11 assemblies for continued irradiation. After two additional cycles of irradiation, the rod average burnup of the 64 fuel rods is projected to increase from approximately 30,000 MWD/MTU to approximately 38,000 MWD/MTU. Poolside examination of the 64 fuel rods will be conducted before and after each additional irradiation cycle.

To verify the Big Rock Point results in a large commercial BWR, the four lead 8x8 fuel assemblies in the Oyster Creek reactor are scheduled to be irradiated for two additional cycles beyond their normal point of discharge. This Oyster Creek 4-assembly program is projected to achieve an assembly average discharge burnup of approximately 35,000 MWD/MTU, with individual rods approaching exposures of 37,000 MWD/MTU rod average. As with the Big Rock Point program, the major emphasis of the Oyster Creek program will be extensive poolside examination before and after each of the two additional burnup cycles.

In contrast to the Big Rock Point program, where individual rods are driven to extended burnup, complete assemblies will be irradiated in Oyster Creek for six consecutive cycles. The extended burnup capability of assembly components such as tie plates, spacers, holdown springs, etc. will thus be demonstrated.

The schedule of events at the two different reactor sites is shown in Figure 1.1.

The EBD program will also include several supporting activities. Data on the pre-irradiation properties of the fuel together with results of pre-program irradiated fuel examinations at poolside will be compiled into reference reports. Fuel management, licensing, and mechanical design considerations associated with extended burnup of standard BWR fuel will also be addressed. A limited amount of fuel rod destructive examination in a hot cell will be done and an advanced method for measuring the burnup profile and fission product distribution in high burnup fuel rods at poolside will be developed.

1.4 PROGRAM ORGANIZATION

The work to be performed under the EBD program is structured around specific tasks, as described below. Each of these tasks will be applied to the 64-rod program at Big Rock Point and the 4-assembly program at Oyster Creek.

TASK A - FUEL ROD CHARACTERIZATION

This task will compile into two separate topical reports all applicable background information on the fuel rods and fuel assemblies which will be irradiated to extended burnup in Big Rock Point and Oyster Creek, respectively. This background information will include the as-fabricated fuel rod characteristics and the irradiated fuel rod properties measured at previous poolside non-destructive examinations.

TASK B - FUEL ROD EXAMINATIONS

This task is divided into two subtasks: B-1 (poolside measurements) and B-2 (hot cell examination).

Subtask B-1 - Poolside Measurements

The scope of this subtask includes three major poolside examinations at each of the Big Rock Point and Oyster Creek reactors. The poolside examination program will include both nondestructive measurements on individual fuel rods and destructive measurements to determine fission gas release in a smaller number of individual fuel rods. This subtask also includes the repositioning of the 64 Big Rock Point fuel rods into two host assemblies at the beginning of the

program. The lower burnup host assemblies will allow the 64 rods to be driven to a higher discharge burnup after two additional irradiation cycles than would have been possible with the original two assemblies.

The poolside measurement techniques available during a fuel examination are listed below:

- ° Bundle sipping to detect cladding breach (conducted by utility personnel).
- ° Visual examinations with photography or video recording as required to document any unusual surface conditions.
- ° Profilometry measurements to detect diameter changes, clad ovality, and other clad distortions such as ridging.
- ° Eddy current and ultrasonic measurements for the detection of failures and changes in clad wall thickness.
- ° Gamma scan measurements to determine relative axial end-of-cycle power profiles, fuel column stack height (shrinkage or swelling), and the potential presence of axial gaps between pellets.
- ° Fuel rod withdrawal force to determine spacer spring relaxation.

- ° Rod length measurements to determine irradiation-induced growth in the fuel cladding.
 - ° Fission gas pressure and void volume measurements.
- The fuel rods are punctured at poolside for the determination of gas pressure and volume. A sample of the gas is sent to a hot cell to determine the elemental and isotopic compositions of the released fission gases. The punctured fuel rods are mechanically resealed and returned to storage in the spent fuel pool.

The results of the Big Rock Point and Oyster Creek poolside fuel examination under Subtask B-1 will be documented in six separate topical reports.

Subtask B-2 Hot Cell Examinations

To supplement the detailed nondestructive information obtained at poolside, a minimum of four Big Rock Point fuel rods will be destructively examined after the first extended burnup cycle. These fuel rods will be shipped to a hot cell, such as Argonne National Laboratory. Data from the hot cell examination will be obtained during the second extended burnup cycle of the remaining 60 rods at Big Rock Point. In this manner, both non-destructive and destructive data on extended burnup fuel rods will be available shortly after the second extended burnup cycle in Big Rock Point.

The hot cell examinations may include any or all of the following activities and measurements:

- ° Sectioning of fuel rods at specified axial locations and preparation of samples suitable for the tests below.
- ° Released fission gas and fuel rod void volume.
- ° Retained fission gas.
- ° Burnup measurements
- ° Isotopic compositions and mass analyses.
- ° Fuel density.
- ° Ceramographic determination of porosity and grain size distribution.
- ° Waterside cladding corrosion.
- ° Metallographic examination of fuel restructuring, cracking, gap size, and fuel-clad bonding.
- ° Fission product distributions.
- ° Stress corrosion cracking susceptibility.
- ° Clad mechanical tests including tensile and burst tests.
- ° Waste disposal.

The results of the Subtask B-2 measurements will be documented in a separate topical report.

TASK C - FUEL MANAGEMENT AND LICENSING

The scope of this task includes the specific neutronic and fuel management analyses necessary to 1) support licensing the

fuel rods and assemblies used in the extended burnup program, 2) compute the irradiation histories of the program rods, 3) predict the isotopic compositions for the destructively analyzed rods, and 4) compare the fuel examination gamma scan data of Task E below to neutronic predictions at burnup levels achieved during the program.

A key responsibility of this task is to provide all the neutronic information necessary to support licensing the Big Rock Point and Oyster Creek fuel for extended burnup. The reconstitution effort at Big Rock Point will require establishing the rod locations in the new host assemblies and analyzing the neutronics reactions of the reconstituted host assembly with other assemblies in the core to assure that all peaking margins are adequate.

TASK D - EVALUATION OF MECHANICAL DESIGN PARAMETERS

The purpose of this task is to identify and evaluate the mechanical design parameters of current fuel which might be affected during continued irradiation to higher burnup. It is known that fuel design variations such as density, gap size, pellet length, clad thickness, plenum volume, and clad texture influence high burnup fuel performance. Variations in several of these parameters can be found among the Big Rock Point rods available to this program. This task will support Task A in identifying those Big Rock Point fuel rods selected for extended burnup so that the impact of design features on the mechanical performance of the fuel can be evaluated. This task will also support Subtask B-1 by comparing the measured poolside data to the theoretically predicted irradiation performance of the fuel.

TASK E- DEVELOPMENT OF POOLSIDE FUEL EXAMINATION TECHNIQUES

Under Task E of the program, poolside gamma scanning technology based on the use of a cryogenically cooled intrinsic germanium detector will be developed. The expected high energy resolution of the intrinsic germanium detector will allow the measurement of a large number of individual isotopes and specifically of isotopes with long half-life. Fission product migration, fuel burnup and possibly the presence in the fuel rod plenum of Kr-85 resulting from fission gas release can be determined. An immediate goal of this task will be to develop this measurement capability in time for use on the four Big Rock Point fuel rods being discharged for hot cell examination after the first extended burnup cycle. By using the germanium gamma scanning technique at poolside on those four rods, a subsequent verification of the results can be attained when the four rods are shipped to a hot cell for destructive examination.

SCHEDULE OF EVENTS AT REACTOR SITES

FIGURE 1.1 SCHEDULE OF FUEL EXAMINATIONS AND EXTENDED BURNUP CYCLES AT THE BIG ROCK POINT AND OYSTER CREEK REACTOR SITES.

2.0 PROGRESS ON TASK A - FUEL CHARACTERIZATION

2.1 BIG ROCK POINT 64-ROD PROGRAM

In April 1973, the first two ENC 11x11 fuel assemblies, designated G-01 and G-02, were inserted into the Big Rock Point core. In January 1979, at the end of reactor cycle 15 (EOC15), these two assemblies had achieved an average burnup of approximately 30,000 MWD/MTU.

As is discussed in Section 3.0 below, a total of 64 fuel rods were removed from the assemblies during the January 1979 fuel examination at Big Rock Point. After nondestructive examination of each fuel rod, the 64 rods were used to replace 64 corresponding rods from two lower burnup 11x11 assemblies, designated G-13 and G-14. These two so called host assemblies had originally been inserted into the Big Rock Point core in 1974. At the time of the fuel rod transfer, the average burnup of the host assemblies was ~ 20,000 MWD/MTU.

The enrichment and location of individual fuel rods in assemblies G-01 and G-02 are shown in Figure 2.1 and 2.2, respectively. The fuel rod enrichment and locations in the original configuration of assemblies G-13 and G-14 are shown in Figure 2.3. The distribution of individual fuel rods in the newly reconstituted assemblies G-13 and G-14 are shown in Figure 2.4 and 2.5, respectively.

The nominal design characteristics of the Big Rock Point pellets, cladding, and fuel rods are summarized in Table 2.1. Several of the 64 transferred rods represented small modifications of the standard fuel design. The number of rods of each enrichment and design characteristic is summarized in Table 2.2.

During the reporting period archive data on the pre-irradiation characteristics of the fuel (powder, pellets, cladding and fuel rod) were compiled. A summary of previous poolside examination data for the 64 fuel rods was also compiled. This data will be included in a topical report and in the computerized EPRI fuel performance data base.

2.2 OYSTER CREEK 4-ASSEMBLY PROGRAM

The first four ENC 8x8 lead assemblies in the Oyster Creek core were inserted in April 1975. These four assemblies were identical in design and have been symmetrically located in the center of the Oyster Creek core since their beginning of life (BOL).

One of these four assemblies, designated UD3-109, had been disassembled for individual fuel rod examinations at three previous Oyster Creek refueling outages. At the time of the last examination, November 1978, the average burnup of the 4 lead assemblies was approximately 19,500 MWD/MTU.

The individual fuel rod enrichments and locations within assembly UD3-109 are shown in Figure 2.6. The nominal characteristics of the fuel (power, pellets, cladding, and fuel rods) are summarized in Table 2.3.

Table 2.1MECHANICAL DESIGN PARAMETERS FOR BIG ROCK POINT11X11 Fuel AssemblyFuel Pellet (Sintered UO_2 , UO_2 - PuO_2)

Diameter (in.)	0.3715
Length (in.)	0.300
Dish Volume, One End Dished, (% of Pellet Vol.)	2
Density (% Theoretical)	93.5
Density (gm/cm ³)	10.26
Enrichment (wt% ²³⁵ U in U)	
Low	2.30
Medium	3.20
High	4.60
Mixed Oxide (wt% Pu)	5.45
Mixed Oxide (wt% fissile)	5.00
Average for Assembly (wt% fissile)	3.98

Poison Pellet (Sintered UO_2 - Gd_2O_3)

Poison (wt% Gd_2O_3)	1.20
Enrichment (wt% ²³⁵ U)	4.60
Diameter (in.)	0.3715
Length (in.)	0.300
Density (% of Theoretical)	91.5
Density (g/cm ³)	10.03
Dish Volume, One End Dished (% of Pellet Vol.)	2

Table 2.1 (Cont'd)

<u>11x11 Fuel Assembly</u>	
<u>Insulator Disc</u> (Sintered Al_2O_3)	
Aluminum Oxide Content on Dry Weight Basis (wt%)	99.0
<u>Plenum Spring</u> (Inconel X-750)	
Spring Volume (in. ³)	0.04
Nominal Spring Force (lb)	11
<u>Cladding</u> (Zircaloy-2 Cold Worked, Stress Relieved)	
Outside Diameter (in.)	0.449
Inside Diameter (in.)	0.381
Nominal Wall Thickness (in.)	0.034
<u>Fuel Rod</u>	
Overall Fuel Rod Length (in.)	78.501
Active Fuel Length (in.)	70.00
Diametral Pellet-to-Clad Gap (in.)	0.0095
Plenum Length (in.)	3.901
Weight of Oxide (g/rod)	
Standard UO_2	1249
UO_2 - PuO_2	1252
Poison	1215
<u>Fuel Assembly</u>	
Rod Array	11x11
Rod Pitch (in.)	0.577
Water-to-Fuel Volume Ratio of Lattice	2.68
Heat Transfer Area (ft ²)	79.48

Table 2.1 (Cont'd)

11x11 Fuel Assembly

Fuel Assembly (Cont'd)

Spacer Grids (Number)	3
Rod Types (Number)	
Cobalt Target	4
Low Enrichment	16
Medium Enrichment	32 (includes 4 Tie Rods)
High Enrichment	40 (includes 8 Tie Rods)
UO ₂ -Gd ₂ O ₃ Poison	4
PuO ₂ -UO ₂ Mixed Oxide	24
Inert (Solid Zircaloy)	1
Fuel Weight (kg UO ₂)	144.7

Table 2.2

SUMMARY OF DESIGN VARIABLES FOR
64 BIG ROCK POINT EXTENDED BURNUP RODS

<u>Standard Rod</u>	<u>Number of Rods</u>
High Enrichment	41
Medium Enrichment	11
Poison	<u>4</u>
	SUBTOTAL 56
 <u>Special Rods</u>	
Low Density (90.0% TD, 9.86 g/cm ³)	1
Short Pellets (L/D = 0.54)	<u>7</u>
	SUBTOTAL 8
	TOTAL <u>64</u>

Table 2.3

MECHANICAL DESIGN PARAMETERS FOR OYSTER CREEK 8x8 FUEL ASSEMBLY

Fuel Pellet (Sintered UO_2)

Diameter (in.)	0.4195
Length (in.)	0.320
Density (% TD)	95.0

Poison Pellet (Sintered UO_2 - Gd_2O_3)

Poison (wt% Gd_2O_3)	1.15
Enrichment (wt% ^{235}U)	3.15
Length (in.)	0.320
Density (% TD)	94.5
Dish Volume, Two Ends Dished (% of Pellet Volume)	1.0

Insulator Disc (Sintered Al_2O_3)

Aluminum Oxide Content on a Dry Weight Basis	99.0 min.
Disc Length (in.)	0.200
Number of Discs Per Rod	2

Plenum Spring (Inconel X-750)

Spring Volume (in. ³)	0.18
Nominal Spring Force (lb)	31.7

Cladding (Zircaloy-2, Cold Worked, Stress Relieved)

Outside Diameter (in.)	0.5015
Inside Diameter (in.)	0.4295
Nominal Wall Thickness (in.)	0.036

Table 2.3 (Cont'd)

11x11 Fuel AssemblyFuel Rod

Overall Fuel Rod Length (in.):	
All Rods Except Tie Rods	158.153
Tie Rods	160.003
Active Fuel Length (in.)	144
Diametral Gap (in.)	0.010
Plenum Length (in.)	10.623
Weight of Oxide (gms/rd)	
Standard and Tie Rods (UO_2)	3343
Poison Rods (UO_2 /Total Oxide)	3268/3306

Fuel Assembly

Rod Array	8x8
Rod Pitch (in.)	0.642
Water-to-Fuel Volume Ratio of Lattice (Cold)	2.45
Spacer Grids (Number)	7
Rod Types (Number)	
Low Enrichment	5
Medium Enrichment	22
High Enrichment	29
UO_2 - Gd_2O_3 Poison	4
Inert (Solid Zircaloy)	4
Fuel Weight (UO_2)	200.3
Overall Length (in.)	< 171.13

BIG ROCK POINT

	A	B	C	D	E	F	G	H	I	J	K
1	Co	L	L	M	MS	M	MS	M	L	L	Co
2	LS	M	MS	H	H	H	H	H	MS	M	L
3	L	M	H	H	H	G	H	H	H	M	L
4	M	H	H	MO	MO	MO	MO	MO	H	H	M
5	M	H	H	MO	MO	MO	MO	MO	Z	H	M
6	MS	H	G	MO	MO	Z	MO	MO	G	HL	M
7	M	H	Z	MO	MO	MO	MO	MO	Z	H	M
8	M	HL	H	MO	MO	MO	MO	MO	H	H	MS
9	L	M	H	H	H	G	H	H	H	M	L
10	LS	M	M	H	H	H	H	H	M	M	L
11	Co	L	LS	M	M	M	M	M	LS	L	Co

Figure 2.1 G-01 Fuel Rod Types and Locations at EOC15
The 32 highlighted rods were transferred
to assembly G-13

Legend:

L - 2.30 w/o U-235	
M - 3.20 w/o U-235	(4 rods)
MO - Mixed Oxide PuO_2-UO_2 , 5.00 total fissile	
MS - 3.20 w/o U-235 extra short pellets	(5 rods)
H - 4.60 w/o U-235	(20 rods)
HL - 4.60 w/o U-235 low density pellets	(1 rods)
G - 4.60 w/o U-235 with 1.2 w/o Gd_2O_3	(2 rods)
Z - Solid inert rod	
Co - Cobalt rod 23 gm/ft	
LS - 2.30 w/o U-235 extra short pellets	
	32 rods total

	BIG ROCK POINT										
	A	B	C	D	E	F	G	H	I	J	K
1	Co	L	L	M	MS	M	MS	M	L	L	Co
2	LS	M	MS	H	H	H	H	H	MS	M	L
3	L	M	H	H	H	G	H	H	H	M	L
4	M	H	H	MO	MO	MO	MO	MO	H	H	MS
5	M	H	H	MO	MO	MO	MO	MO	H	H	M
6	MS	H	G	MO	MO	Z	MO	MO	G	Z	M
7	M	H	H	MO	MO	MO	MO	MO	H	H	M
8	M	Z	H	MO	MO	MO	MO	MO	H	H	MS
9	L	M	H	H	H	G	H	H	H	M	L
10	LS	M	M	H	H	H	H	H	M	M	L
11	Co	L	LS	M	M	M	M	M	LS	L	Co

Figure 2.2 G-02 Fuel Rod Types and Location at EOC15
The 32 highlighted rods were transferred to
Assembly G-14

Legend:

L - 2.30 w/o U-235	
M - 3.20 w/o U-235	(5 rods)
MO - Mixed Oxide, PuO ₂ -UO ₂ , 5.00 total fissile	
MS - 3.20 w/o U-235 extra short pellets	(4 rods)
H - 4.60 w/o U-235	(21 rods)
G - 4.60 w/o U-235 with 1.2 w/o Gd ₂ O ₃	(2 rods)
Z - solid inert rod	32 rods total
Co - Cobalt rod 23 gm/ft	
LS - 2.30 w/o U-235 extra short pellets	

BIG ROCK POINT

	A	B	C	D	E	F	G	H	I	J	K
1	Co	L	L	M	M	M	M	M	L	L	Co
2	L	M	M	H	H	H	H	H	M	M	L
3	L	M	H	H	H	G	H	H	H	M	L
4	M	H	H	MO	MO	MO	MO	MO	H	H	M
5	M	H	H	MO	MO	MO	MO	MO	H	H	M
6	M	H	G	MO	MO	Z	MO	MO	G	H	M
7	M	H	H	MO	MO	MO	MO	MO	H	H	M
8	M	H	H	MO	MO	MO	MO	MO	H	H	M
9	L	M	H	H	H	G	H	H	H	M	L
10	L	M	M	H	H	H	H	H	M	M	L
11	Co	L	L	M	M	M	M	M	L	L	Co

Figure 2.3 G-13 and G-14 Fuel Types and Locations at EOC15

Legend:

L - 2.30 w/o U-235
 M - 3.20 w/o U-235
 H - 4.60 w/o U-235
 G - 4.60 w/o U-235 with 1.2 w/o Gd₂O₃
 MO - Mixed Oxide, PuO₂-UO₂, 5.00 total fissile
 Z - solid inert rod
 Co - Cobalt rod 23 gm/ft

BIG ROCK POINT

	A	B	C	D	E	F	G	H	I	J	K
1	Co	L	L	M	M	M	M	MS	L	L	Co
2	L	M	M	H	H	H	H	MS	M	M	L
3	L	M	H	H	H	G	H	H	H	M	L
4	MS	H	H	MO	MO	MO	MO	MO	H	H	MS
5	M	H	H	MO	MO	MO	MO	MO	H	H	M
6	M	H	G	MO	MO	Z	MO	MO	G	HL	M
7	M	H	H	MO	MO	MO	MO	MO	H	H	M
8	M	M	H	MO	MO	MO	MO	MO	H	H	MS
9	L	M	H	H	H	G	H	H	H	M	L
10	L	M	M	H	H	H	H	H	M	M	L
11	Co	L	L	M	M	M	M	M	L	L	Co

Figure 2.4 G-13 Fuel Types and Locations at BOC16

Legend:

- L - 2.3 w/o U-235
- M - 3.20 w/o U-235
- MS - 3.20 w/o U-235 extra short pellets
- H - 4.60 w/o U-235
- HL - 4.60 w/o U-235 Low density pellets
- G - 4.60 w/o U-235 with 1.2 w/o Gd_2O_3
- MO - Mixed Oxide, PuO_2 - UO_2 , 5.00 total fissile
- Z - solid inert rod
- Co - Cobalt rod 23 gm/ft

BIG ROCK POINT

	A	B	C	D	E	F	G	H	I	J	K
1	Co	L	L	M	M	M	M	M	L	L	Co
2	L	M	M	H	H	H	H	H	M	M	L
3	L	M	H	H	H	G	H	H	H	M	L
4	MS	H	H	MO	MO	MO	MO	MO	H	H	MS
5	M	H	H	MO	MO	MO	MO	MO	H	H	M
6	M	H	G	MO	MO	Z	MO	MO	G	H	M
7	M	H	H	MO	MO	MO	MO	MO	H	H	M
8	M	M	H	MO	MO	MO	MO	MO	H	H	MS
9	L	M	H	H	H	G	H	H	H	M	L
10	L	M	M	H	H	H	H	H	M	M	L
11	Co	L	L	M	M	M	M	M	L	L	Co

Figure 2.5 G-14 Fuel Types and Locations at BOC16

Legend:

- L - 2.30 w/o U-235
- M - 3.20 w/o U-235
- MS - 3.20 w/o U-235 extra short pellets
- H - 4.60 w/o U-235
- G - 4.60 w/o U-235 with 1.2 w/o Gd₂O₃
- MO - Mixed Oxide PuO₂-UO₂, 5.00 total fissile
- Z - solid inert rod
- Co - Cobalt rod 23 gm/ft

OYSTER CREEK

	a	b	c	d	e	f	g	h
1	M	M	H	H	H	M	M	L
2	M	H	H	G	H	H	M	M
3	H	H	H	H	H	H	H	M
4	H	G	H	I	I	H	G	M
5	H	H	H	I	I	H	H	M
6	M	H	H	H	H	H	M	M
7	M	M	H	G	H	M	M	L
8	L	M	M	M	M	M	L	L

Wide-Wide Corner

Control Blade

Figure 2.6 Oyster Creek 8x8 Lead Assembly Fuel Types and Rod Locations

Legend:

- L - 1.42 w/o U-235
- M - 2.18 w/o U-235
- H - 3.15 w/o U-235
- G - 3.15 w/o U-235 with 1.15 w/o Gd_2O_3
- I - Inert zircaloy rod

3.0 PROGRESS ON TASK B - FUEL ROD EXAMINATIONS

3.1 SUBTASK B-1 POOLSIDE MEASUREMENTS

3.1.1 Big Rock Point

The first Big Rock Point fuel examination occurred between February 9, 1979 and March 18, 1979. The major emphasis during the examination was the reconstitution of two assemblies (G-13 and G-14) with fuel rods from two discharged assemblies (G-01 and G-02). Thirty-two (32) rods were transferred from assembly G-01 to assembly G-13. Another thirty-two (32) rods were transferred from assembly G-02 to assembly G-14.

Profilometry traces were obtained on each of the 64 fuel rods. A helical profilometry trace was obtained on a given rod by axially traversing the rod while the rod was rotating. The fuel rod rotation was then stopped and a non-rotating scan was taken as the profilometer traversed the full length of the rod in the opposite direction.

During the profilometry measurements, eddy current measurements were made on the fuel rod cladding to detect the potential presence of defects.

The overall length of about half of the fuel rods was individually measured. The force required to withdraw a fuel rod from a fuel bundle was measured for four rods. Ultrasonic tests, intended to detect potential pellet to clad bonding, were planned but were not performed due to equipment problems.

All the profilometry and eddy current data were recorded on strip charts for later data reduction and analysis. A computerized data

acquisition system was setup at poolside for digitizing and recording the data. Although the data for some of the rods was successfully captured in the computer system, hardware problems prevented most of the data from being collected in that form.

Rod Diameter

Analysis of the helical (rotating) profilometry traces yields information on the average cladding diameter change and the ovality of the cladding. Figure 3.1 summarizes the average diameter of the 32 rods in each assembly as a function of axial position. The diameter of the cladding at the very bottom of the fuel rod is representative of the as-fabricated cladding diameter. Along the fueled section of the rods the cladding diameter has typically decreased by about two mils. This degree of creepdown is consistent with other ENC experience on cladding diameter of irradiated fuel rods.

The cross section of a typical fuel rod after irradiation will not be a perfect circle but will actually have a slightly elliptical shape. The ovality of a fuel rod is defined here as the difference between the major axis and the minor axis of such an ellipse. The average ovality of the Big Rock Point fuel rods varied from 0.4 to 1.6 mils. The maximum ovality on any given rod ranged between 1.6 and 4.8 mils. This degree of ovality is typical for ENC fuel at a burnup exceeding 20,000 MWD/MTU.

The non-rotating fuel rod profilometry traces yield information on "ridging". "Ridging" may occur when the cladding comes in contact with the fuel pellets.

In general, the 64 Big Rock Point fuel rods exhibited very little ridging. Only fifteen (15) of the 64 fuel rods examined exhibited ridging, and in all but one case the amplitude of the ridging was ≤ 0.3 mils on a diametral basis. One rod exhibited ridging with an amplitude of approximately 0.6 mils.

Eddy Current

During the profilometry measurements, each fuel rod was passed through an encircling eddy current coil to detect the presence of defects in the cladding. The sensitivity of the eddy current system was set so that pin holes greater than 10 mils could easily be detected. No defects were observed, which is consistent with the very low radioactivity in the Big Rock Point offgas during the preceding cycle.

The eddy current system was able to detect slight indentations in the cladding where the cladding had been in direct contact with spacer grids. Such data verify the sensitivity of the eddy current system and are consistent with previous ENC experience during poolside examinations.

Fuel Rod Length

Fuel rod length in the G-01 and G-02 assemblies had been measured during previous fuel examinations. These measurements, along with data from the 1979 fuel examination, are summarized in Figure 3.2. It is evident that irradiation-induced cladding growth is linear with burnup to at least 30,000 MWD/MTU.

3.1.2 Oyster Creek

No Oyster Creek fuel examination was conducted during this reporting period.

3.2 SUBTASK B-2 - HOT CELL EXAMINATION

There was no activity on this Subtask during the reporting period.

BIG ROCK POINT

Figure 3.1

The average fuel rod diameter as a function of axial location on the rods from assembly G-01 and G-02 at an average assembly burnup of 31,000 MWD/MTU. The error bars denote the standard direction of the measurements at each axial location.

BIG ROCK POINT

Figure 3.2

Fuel rod growth as a function of fast fluence for rods from assembly G-01 and G-02. The number underneath each data point indicates the number of rods measured. The error bars denote the standard deviation of the measurements at each fluence.

4.0 PROGRESS ON TASK C - FUEL MANAGEMENT AND LICENSING

4.1 BIG ROCK POINT

The major Task C effort during the reporting period was to support the licensing of the reconstituted assemblies G-13 and G-14 for the first two extended burnup irradiation cycles. Since power peaking factors and limits are burnup dependent, the licensing analysis for host assemblies G-13 and G-14 had to be re-evaluated taking into consideration the 64 replacement fuel rods of significantly higher burnup.

The local exposure and relative power distribution in the original assemblies G-01 and G-02 at the end of reactor cycle 15(E0C15) are shown in Figures 4.1 and 4.2. The local exposure and relative power distribution in the reconstituted fuel assemblies G-13 and G-14 are shown in Figures 4.3 and 4.4, respectively. As shown in Figures 4.3 and 4.4, the local peaking factors of the 64 rods are maintained at acceptable levels. Due to the core and the cruciform control blade configurations, an unique wide-wide gap cannot be ascribed to assemblies in the Big Rock Point reactor. In Figure 4.1 through 4.4 it is indicated which side of the assembly faced the core center and which side faced the core edge.

The core location of the reconstituted fuel assemblies G-13 and G-14 during the first extended burnup cycle (Cycle 16) is shown in Figure 4.5.

A review was completed on all mechanical design features of the 64 rods which might approach licensing limits during the first extended burnup cycle. All design features were projected to remain within design limits throughout the first extended burnup cycle, and it was concluded that there were no unreviewed safety issues associated with the first extended burnup cycle.

4.2 OYSTER CREEK

There was no significant activity during this reporting period.

Results of the 1980 fuel examination are covered in the second EBD Semi-Annual Progress Report.

BIG ROCK POINT

Core Center

	A	B	C	D	E	F	G	H	I	J	K
1	0.0			33.2 1.17			32.3 1.16				0.0
2				34.1 1.22				30.3 1.22			
3			32.2 1.18	29.0 1.12				29.1 1.13	32.3 1.19		
4	33.0 1.12	33.4 1.18	28.9 1.10						29.2 1.14	34.1 1.20	33.1 1.13
5											
6		31.7 1.09	25.8 1.03			0.0				32.3 1.11	
7											
8			28.3 0.94							33.7 1.00	32.5 0.95
9		29.1 0.84	31.1 0.89	27.8 0.83				27.9 0.83	31.4 0.89		
10				32.4 0.81		30.4 0.77		32.4 0.80			
11				31.2 0.69				31.2 0.69			0.0

Core Edge

Figure 4.1 Local Exposure and Power Distribution of Assembly G-01 at EOC15. Assembly Average Exposure = 3.0 GWD/MTU

Legend: - First Entry: Local Exposure, MWD/MTU
Second Entry: Power Distribution, Relative to Assembly Average Power.

BIG ROCK POINT

	A	B	C	D	E	F	G	H	I	J	K	
1	0.0			33.0 1.11				33.3 0.94			0.0	
2				34.1 1.20		31.9 1.10						
3			32.4 1.20	29.1 1.12				28.4 0.92	31.3 0.90			
4	33.3 1.17	34.4 1.25	29.2 1.15						28.3 0.85	33.0 0.83	31.5 0.69	
5												
6	33.3 1.17	32.9 1.24	26.4 1.10				0.0					
7	32.9 1.18											
8			30.7 1.21						28.3 0.85	33.0 0.83	31.5 0.69	
9			33.2 1.23	29.4 1.14		25.7 1.00		28.4 0.93	31.3 0.90			
10				34.4 1.21		31.9 1.10		33.4 1.01				
11	0.0			33.1 1.12				32.3 0.94			0.0	

Core
Center

Core
Edge

Figure 4.2 Local Exposure and Power Distribution of Assembly G-02 at EOC15. Assembly Average Exposure = 30.0 GWD/MTU

Legend: First Entry: Local Exposure, MWD/MTU
Second Entry: Power Distribution, Relative to Assembly Average Power.

BIG ROCK POINT											
Core Center											
	A	B	C	D	E	F	G	H	I	J	K
1				33.2 1.12				32.3 1.18			
2				34.1 1.16		32.1 1.13		30.3 0.97			
3			32.2 1.12	29.0 1.07		26.1 1.03		29.1 1.07	32.2 1.12		
4	33.0 1.07	33.9 1.12	28.9 1.04						29.2 1.04	34.1 1.12	33.1 1.07
5											
6		31.7 1.02	25.8 0.93							32.3 1.00	
7											
8		29.1 0.78	28.3 0.86							33.7 0.92	32.5 0.90
9			31.0 0.84	27.8 0.86				27.9 0.92	31.4 0.83		
10				32.4 0.77		30.1 0.79		32.4 0.76			
11				31.2 0.66				31.2 0.66			
	Core Edge										

Core Edge

Figure 4.3 Local Exposure and Power Distribution of Assembly G-13 at BOC16 after reconstitution. Assembly Average Exposure = 24.4 GWD/MTU

Legend: First Entry: Local Exposure, MWD/MTU
Second Entry: Power Distribution, Relative to Assembly Average Power.

BIG ROCK POINT

	A	B	C	D	E	F	G	H	I	J	K	
1				33.0 1.07				32.3 0.93				
2				34.1 1.15		31.9 1.14						
3			32.4 1.15	29.1 1.06			28.4 0.87	31.3 0.85				
4	33.3 1.12	34.4 1.19	29.2 1.09						28.3 0.80	33.0 0.78	31.5 0.66	
5												
Core Center		32.9 1.14	26.4 1.01									Core Edge
6												
7												
8	32.3 1.17	32.9 0.88	30.7 1.08						28.3 0.79	33.0 0.78	31.5 0.65	
9			33.2 1.13		29.0 1.05	25.7 0.97		28.4 0.87	31.3 0.85			
10				34.4 1.15		31.9 1.04		33.4 0.96				
11				33.1 1.07				32.2 0.90				

Figure 4.4

Local Exposure and Power Distribution of Assembly G-14 after reconstitution at BOC16. Assembly Average Exposure = 24.3 GWD/MTU

Legend: First Entry: Local Exposure, MWD/MTU
Second Entry: Power Distribution, Relative to Assembly Average Power.

Figure 4.5 Big Rock Point Reactor, Cycle 16 Loading Pattern

Note: During Cycle 15, assemblies G-01 and G-02 were in the same core locations as indicated above for the Cycle 16 location of G-13 and G-14, respectively.

5.0 PROGRESS ON TASK D - EVALUATION OF MECHANICAL DESIGN PARAMETERS

5.1 BIG ROCK POINT

To aid in the safety analysis that supported the licensing of the 64 rods, preliminary mechanical analysis was performed on the projected performance of the 64 rods. Previous ENC profilometry measurements coincide with fuel rod performance code calculations that predicted negative cladding strain for the individual fuel rods, indicating that cladding creepdown remained a more dominant factor than fuel pellet swelling. Mechanical interaction between the fuel and the cladding was projected to be low during the first extended burnup cycle and not to represent a severe risk of fuel failure due to PCI.

In reactor operating Cycle 15 the 64 extended burnup fuel rods were in assemblies G-01 and G-02. As indicated in Figure 4.5, these two assemblies were located on the periphery of the Big Rock Point core. Although a higher ultimate burnup could have been achieved for the 64 fuel rods by locating the reconstituted assemblies into higher power locations in the Cycle 16 core, the corresponding power shock to the 64 rods could have significantly increased the risk of fuel failure by PCI. By intentionally locating the reconstituted assemblies G-13 and G-14 on the core periphery during the first extended burnup cycle, no significant power escalation attributable to fuel shuffling occurred and, thus, no increased risk of PCI due to fuel shuffling was expected.

5.2 OYSTER CREEK

There was no significant activity during the reporting period.

6.0 PROGRESS ON TASK E - DEVELOPMENT OF POOLSIDE FUEL EXAMINATION TECHNIQUES

There was no significant activity during the reporting period.

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