PALO VERDE NUCLEAR GENERATING STATION - UNIT 2

END-OF-CYCLE 1

SURVEILLANCE FUEL EXAMINATION REPORT

CEN-375(V)-NP

MAY, 1988

A REPORT TO

ARIZONA NUCLEAR POWER PROJECT

FROM

COMBUSTION ENGINEERING, INC.

NUCLEAR POWER SYSTEMS

WINDSOR, CONNECTICUT

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Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

This report documents fuel examinations conducted during the End-of-Cycle 1 refueling outage at Palo Verde Nuclear Generating Station - Unit 2. The inspections were performed to fulfill examination requirements for EOC-1 that are specified by the PVNGS-2 operating license. The examinations conducted at EOC-1 include:

- Eddy Current Testing of Assembly Guide Tubes for Wear

- Dimensional Measurements to Characterize Fuel Rod and Assembly Growth

A total of 1/ assemblies were inspected. Table 1 lists the assemblies and identifies the specific examinations performed on each.

Table 1

PVNGS-2 Fuel Assemblies Selected for Examinations

Assembly S/N[2]	Discharged EOC-1	Core Location Cycle-1	Examinations: Guide Tube Wear	Examinations: Dimension Measures[1]	Examinations: CEA Type
A057	yes	R11		x	
A062	yes	H12	x		4 center fingers of a 12-finger CEA
A063	yes	F4	x		4 center fingers of a 12-finger CEA
A024	yes	L3	x		4 finger part-length CEA
A046	yes	G15	x		4 finger part-length CEA
A036	yes	H8		x	
A059	yes	N15		x	
B109	yes	C8		x	
B119	yes	L7		x	
B137	yes	K2	x		4 center fingers of a 12-finger CEA
B144	yes	F3	x		4 outer fingers of two 12-finger CEAs
P1B226[3]	no	H7	x	x	4 outer fingers of two 12-finger CEAs
B205	no	B11		x	
C005	no	J17	x	x	4 finger CEA
C025	no	C15	x	x	4 finger CEA
C112	no	B13	x		2 fingers of a 12-finger CEA
P1C114[3]	no	R4	_	x	
17			10	10	

(1) Shoulder gap and guide tube length.
(2) Assembly serial numbers are prefixed with "P2" unless otherwise specified.
(3) P1xxx denotes fuel assemblies initially scheduled for PVNGS-1.

2.0 GUIDE TUBE WEAR EVALUATION

This section describes the evaluation of the guide tube wear measurements taken on ten PVNGS-2 fuel assemblies following Cycle 1. The selection of the measured fuel assemblies, establishment of a wear criterion, and extrapolation of the measured wear were all based on knowledge gained by C-E over nearly ten years of experience. Detailed information regarding this experience base is included in Section 2.0 of Reference 1. Also included in this reference are the evaluation results of the twenty PVNGS-1 fuel assemblies inspected after Cycle 1. Based on those favorable results (a maximum projected wear volume of only 25% of the allowable wear volume), the number of PVNGS-2 fuel assemblies inspected was reduced from twenty to ten.

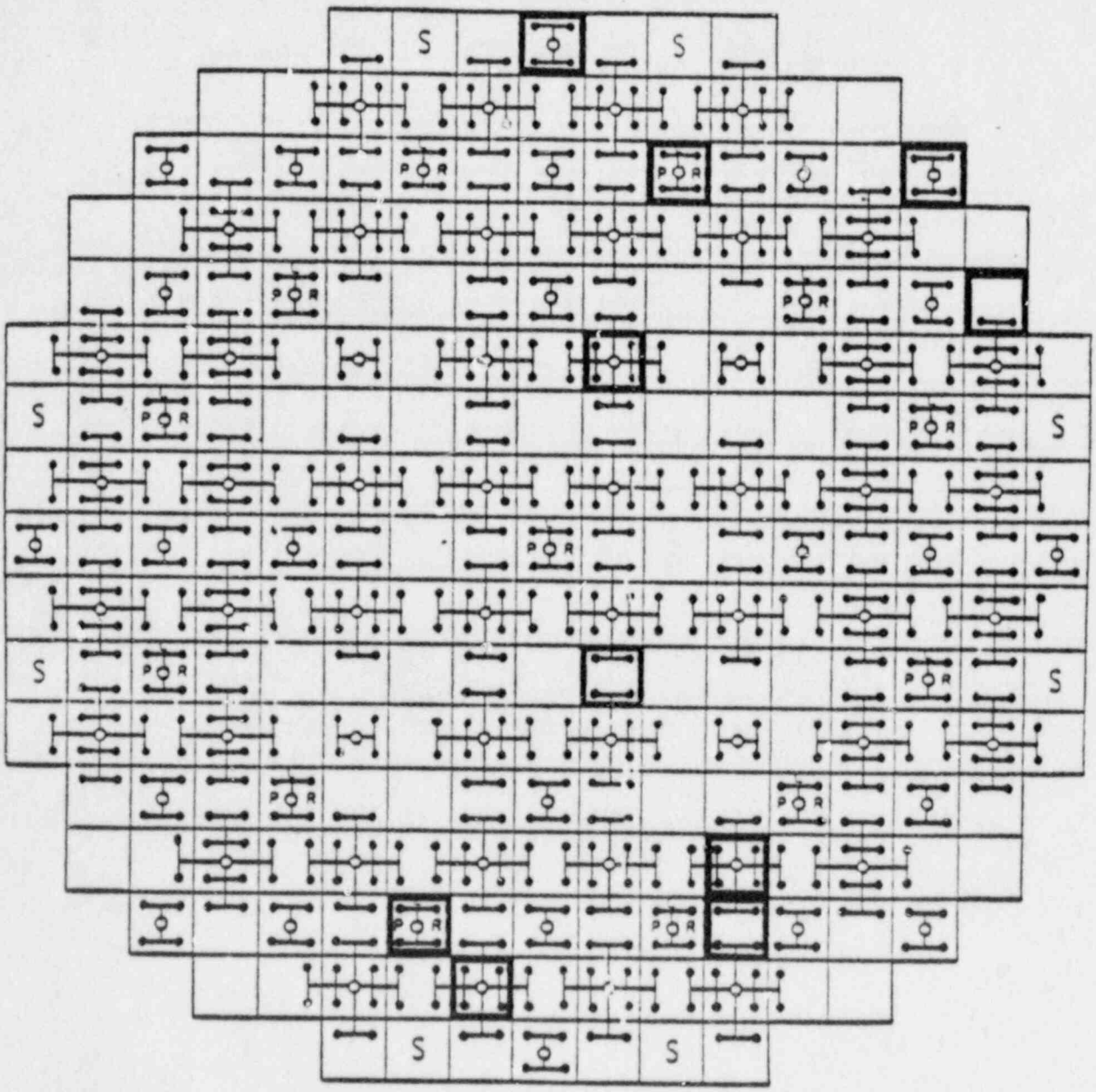
Details on the ten fuel assemblies selected for examination following Cycle 1 are provided in Table 1, and their locations in the core are shown in Figure 1. It can be seen that all of the various CEA geometries are represented in the sample, and that in general the assemblies were located close to the reactor outlets. Each of the four outer guide tubes of the ten fuel assemblies were inspected with an eddy current testing (ECT) probe.

2.1 Evaluation of Guide Tube Wear Data

The inspection of the ten PVNGS-2 fuel assemblies for guide tube wear employed an improved ECT probe design compared to the ECT probe design used for the PVNGS-1 inspections. The new probe design resulted in a slightly different relationship between ECT voltage and guide tube wear volume. This relationship, shown in Figure 2, was again derived by using the ECT probe to inspect calibration standards (actual Zircaloy guide tube stock with known geometries of mechanical flaws on the inner diameter).

Figure 1

Cycle 1 Core Locations of PVNGS-2
Fuel Assemblies Inspected for Guide Tube Wear

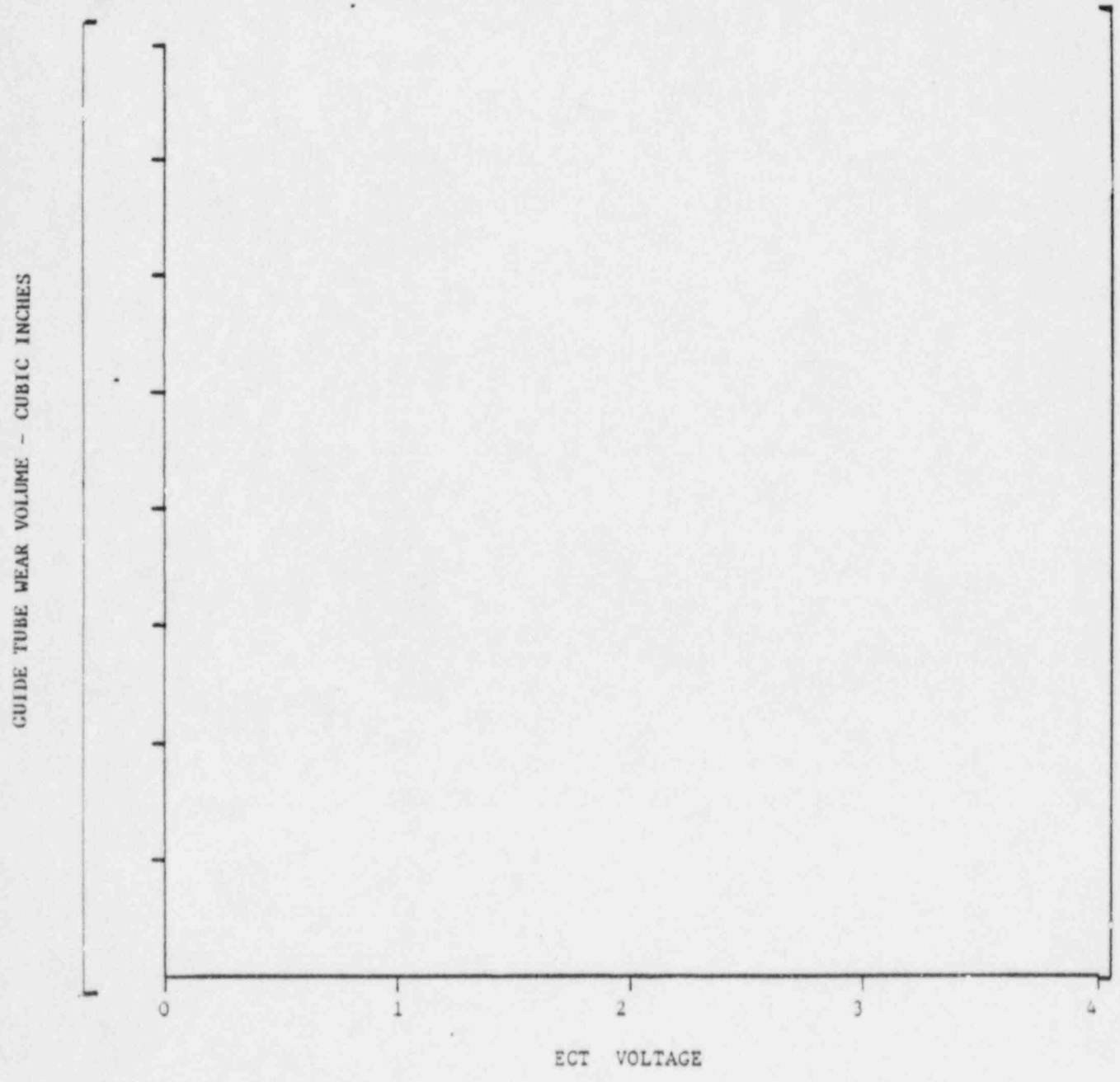


LEGEND:
S=SPARE 4-FINGERED CEA

Note: Reactor outlets are on the core centerline at the top and bottom of the diagram.

Figure 2

ECT VOLTAGE VS. GUIDE TUBE WEAR VOLUME
FOR PVNGS-2



The ECT measurements are summarized in Appendix A. The reported data include the serial number of the fuel assembly inspected, the ECT voltage, location, and axial extent of any wear indication for each of the guide tubes within the fuel assembly. Figure A-1 shows the C-E convention used when identifying individual guide tubes.

2.2 Evaluation Results

The evaluation of guide tube wear is based on wear volumes. The analytical technique, including the development of a volume loss of [ ] as a limiting wear criterion, are discussed in Reference 1. The results of the PVNGS-1 inspection showed a maximum projected wear volume after three cycles of operation under a CEA to be [ ]. Since this maximum projected value was well below the criterion of [ ], it was concluded that the guide tube wear data verified that PVNGS-1 fuel assemblies were acceptable for operation without guide tube modification (wear sleeves). Similarly, it could be concluded the PVNGS-2 fuel assemblies are acceptable without wear sleeves provided their wear data were bounded by the PVNGS-1 wear data.

A direct comparison of the ECT voltages from PVNGS-1 and PVNGS-2 is not appropriate because of the differences in the ECT probe designs and differences in the operating times of the two plants. The proper parameters to compare are the maximum projected wear volumes for three cycles of operation. As stated above, this value is [ ] for the PVNGS-1 data. Based on a conservatively large wear volume associated with the PVNGS-2 data and its extrapolation to three cycles, the PVNGS-2 value is less than half the PVNGS-1 value. Therefore, since the PVNGS-2 wear extrapolation is less than the PVNGS-1 wear extrapolation, and since the PVNGS-1 wear evaluation confirmed that sleeves were not required, it is concluded that the PVNGS-2 fuel assemblies do not require wear sleeves.

3.0 FUEL ASSEMBLY DIMENSIONAL CHANGE EVALUATION

This section describes the evaluation of the shoulder gap (distance between the top of the fuel rods and the bottom of the upper end fitting) and guide tube length measurements taken at PVNGS-2 during the EOC-1 outage. A total of ten fuel assemblies were inspected; three Batch A, four Batch B, and three Batch C. The specific fuel assemblies inspected are identified in Table 1. The shoulder gap of peripheral fuel rods on the four faces of the length of each fuel assembly were measured optically using a periscope, while each of the four guide tubes was measured using the guide-tube length-measurement tool.

3.1 Pre-Shutdown Evaluation

The shoulder gap evaluation for PVNGS-2 fuel parallels the method used for PVNGS-1, i.e., predictions of the remaining shoulder gap were based on the minimum available shoulder gap at the beginning of life (BOL), a conservatively high fuel rod growth prediction, and a conservatively low guide tube growth prediction. Both the PVNGS-1 and PVNGS-2 evaluations adjust the available shoulder gap at BOL to account for component dimensional tolerances, elastic compression of the guide tubes, and differential thermal expansion between the fuel rods and the guide tubes. Both evaluations also employ a fuel rod growth rate that represents more growth than the 95/95 upper limit for the distribution of data from the batch whose high fluence rods had the highest observed growth rates of any fuel examined by C-E, (Arkansas Nuclear One Unit 2 Batch C). The difference in the Cycle 2 evaluations of the PVNGS-1 fuel and the PVNGS-2 fuel is the treatment of the guide tube growths.

As discussed in Reference 1, the shoulder gap evaluation for the PVNGS-1 fuel used a conservatively low guide tube growth prediction calculated using the methods described in Reference 2. In order to accomodate the higher EOC-2 fluences at PVNGS-2, the PVNGS-2

evaluation uses the PVNGS-1 measurement data to reduce the excessive amount of conservatism in the guide tube growth predictions associated with the method of Reference 2. The minimum guide tube growth required to prevent shoulder gap closure for the limiting fuel rod in PVNGS-2 Cycle 2 is calculated. The growth rate associated with this required growth and the PVNGS-1 data are shown in Figure 3. The margin between the actual data and the calculated growth rate indicates that the guide tube growths of the PVNGS-1 fuel assemblies, extrapolated to the appropriate fluence, will all be in excess of the minimum guide tube growth required at EOC-2 for the PVNGS-2 fuel. Therefore, as long as the PVNGS-2 guide tube growth data show similar margin, the use of the minimum required guide tube growth can be concluded to be conservative for the PVNGS-2 Cycle 2 shoulder gap evaluation.

3.2 Dimensional Change Data

The individual shoulder gap measurements are tabulated in Appendix B, Tables B-1 through B-10. For each shoulder gap measured, the tabulation also contains the initial shoulder gap (the nominal value from the design drawings), the resulting shoulder gap change (initial gap - EOC-1 gap), the inferred fuel rod growth (shoulder gap change plus guide tube growth), fuel rod growth strain (fuel rod growth/active length), and the fuel rod's axial average fast fluence. Guide tube information (average growth and average fluence) is included at the bottom of each fuel assembly's shoulder gap tabulation. The shoulder gap change data, guide tube growth data, and fuel rod growth data are plotted relative to the appropriate fast fluence in Figure 4, 5, and 6, respectively.

3.3 Post-Shutdown Evaluation

Fuel rod growth data are shown in Figure 6 along with the design basis taken from the ANO-2 Batch C data [ ]. The figure shows that the high fluence data are all below the design

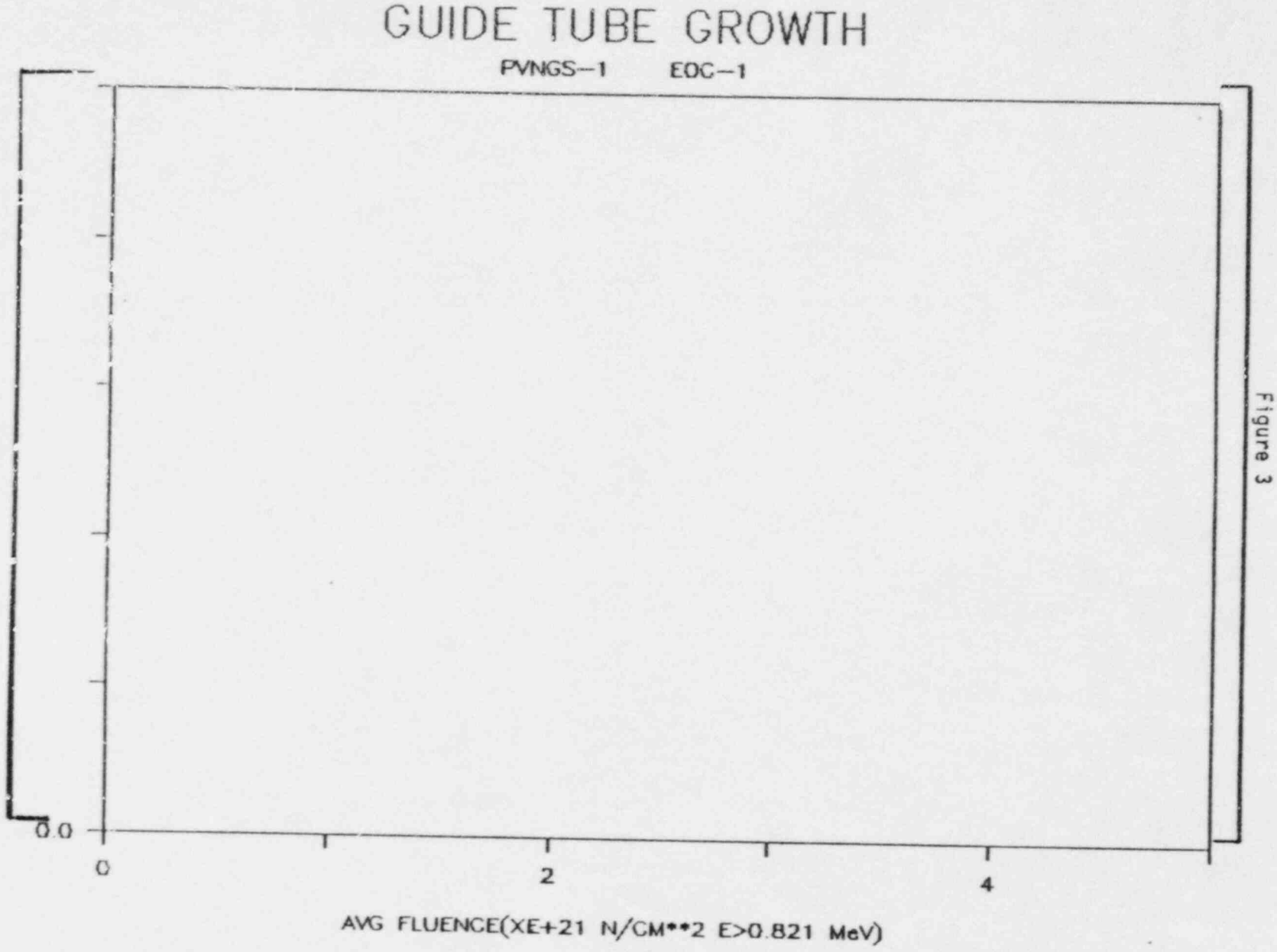

GUIDE TUBE GROWTH
PVNGS-1 EOC-1
AVG GUIDE TUBE GROWTH (IN.)
0.0
0
2
4
AVG FLUENCE(XE+21 N/CM**2 E>0.821 MeV)

Figure 3

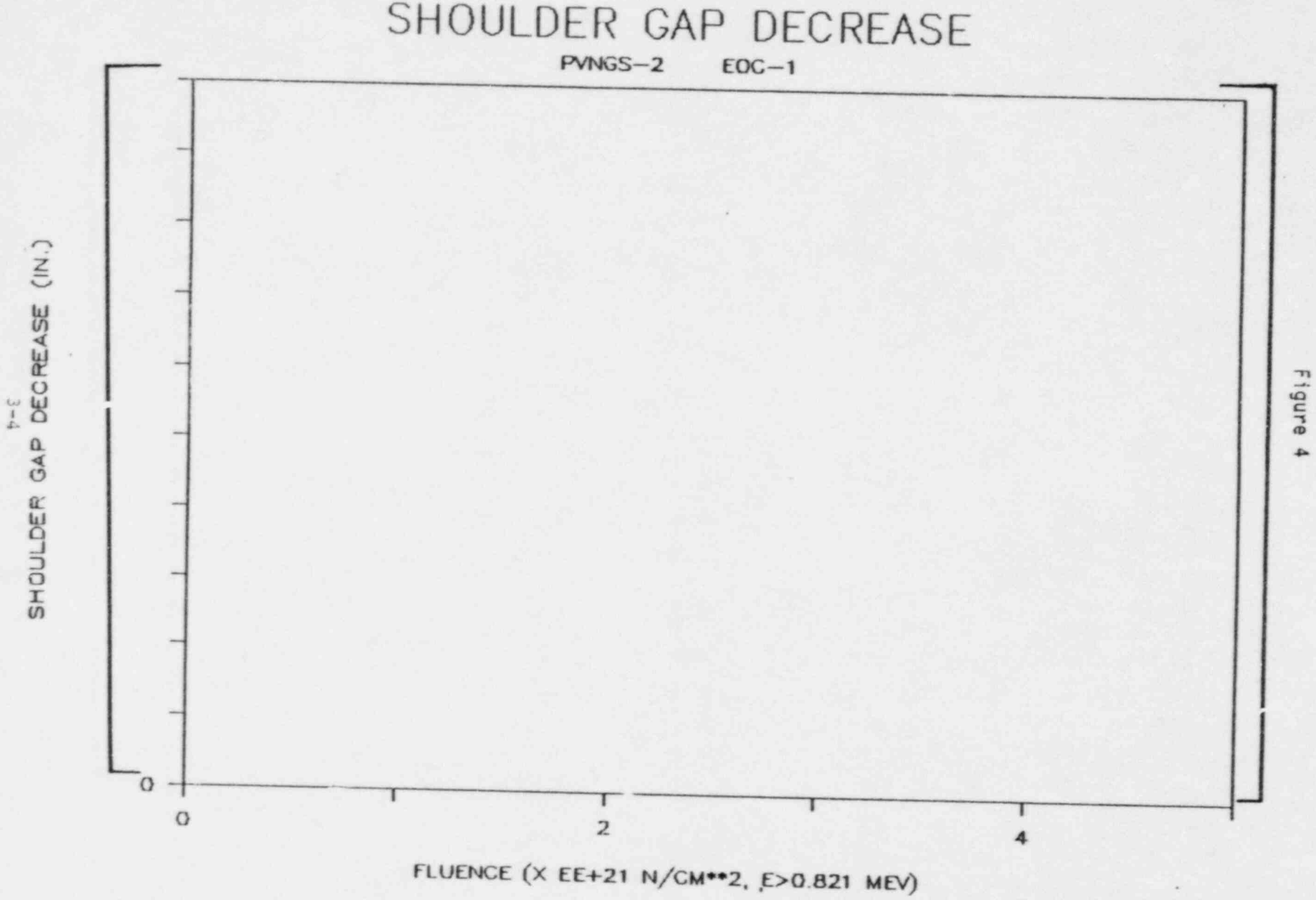

SHOULDER GAP DECREASE
PVNGS-2 EOC-1
SHOULDER GAP DECREASE (IN.)
0
0
2
4
FLUENCE (X EE+21 N/CM**2, E>0.821 MEV)

Figure 4

GUIDE TUBE GROWTH

PVNGS–2 EOC–1

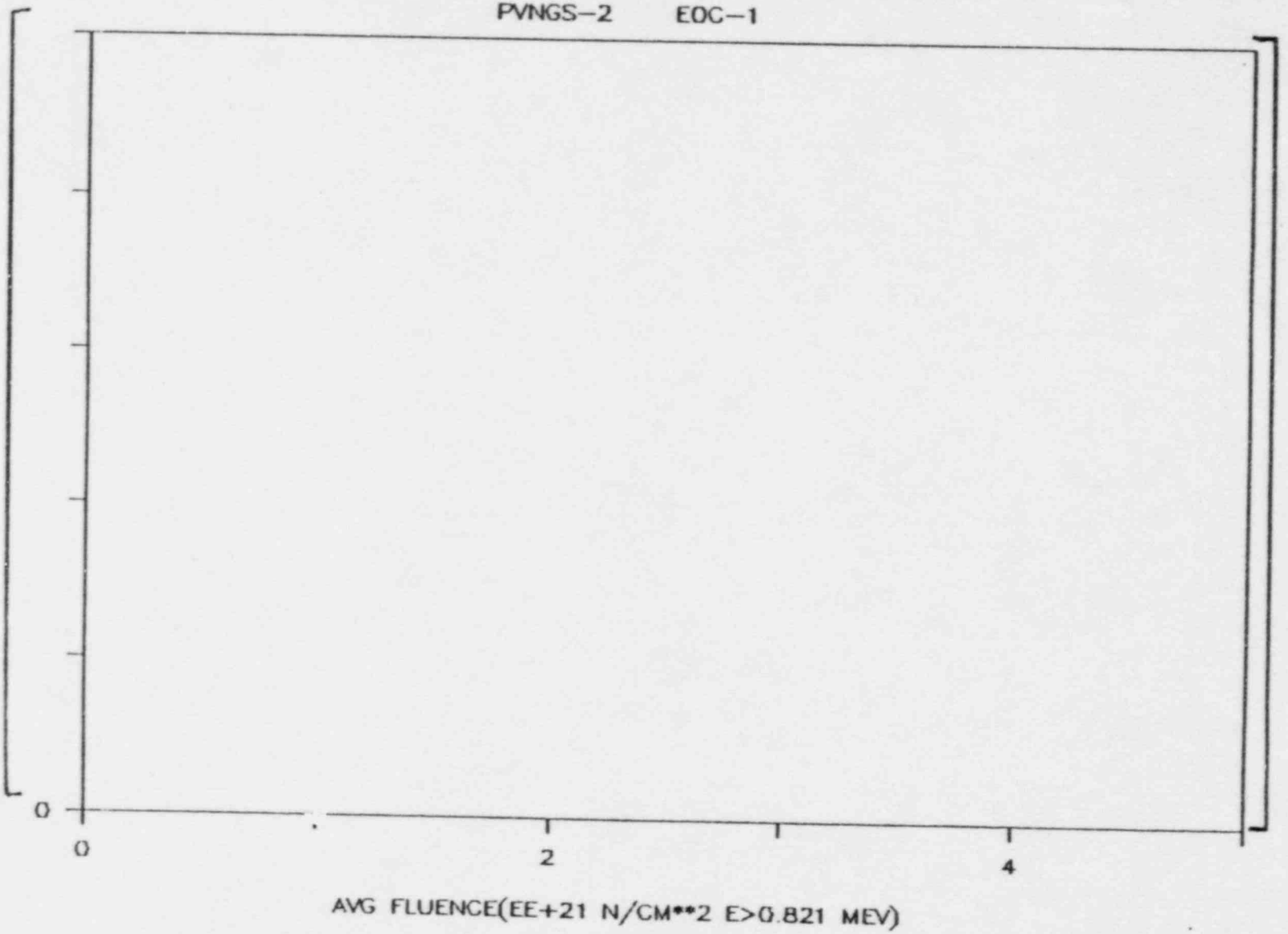


Figure 5

FUEL ROD GROWTH

PVNGS-2 EOC-1

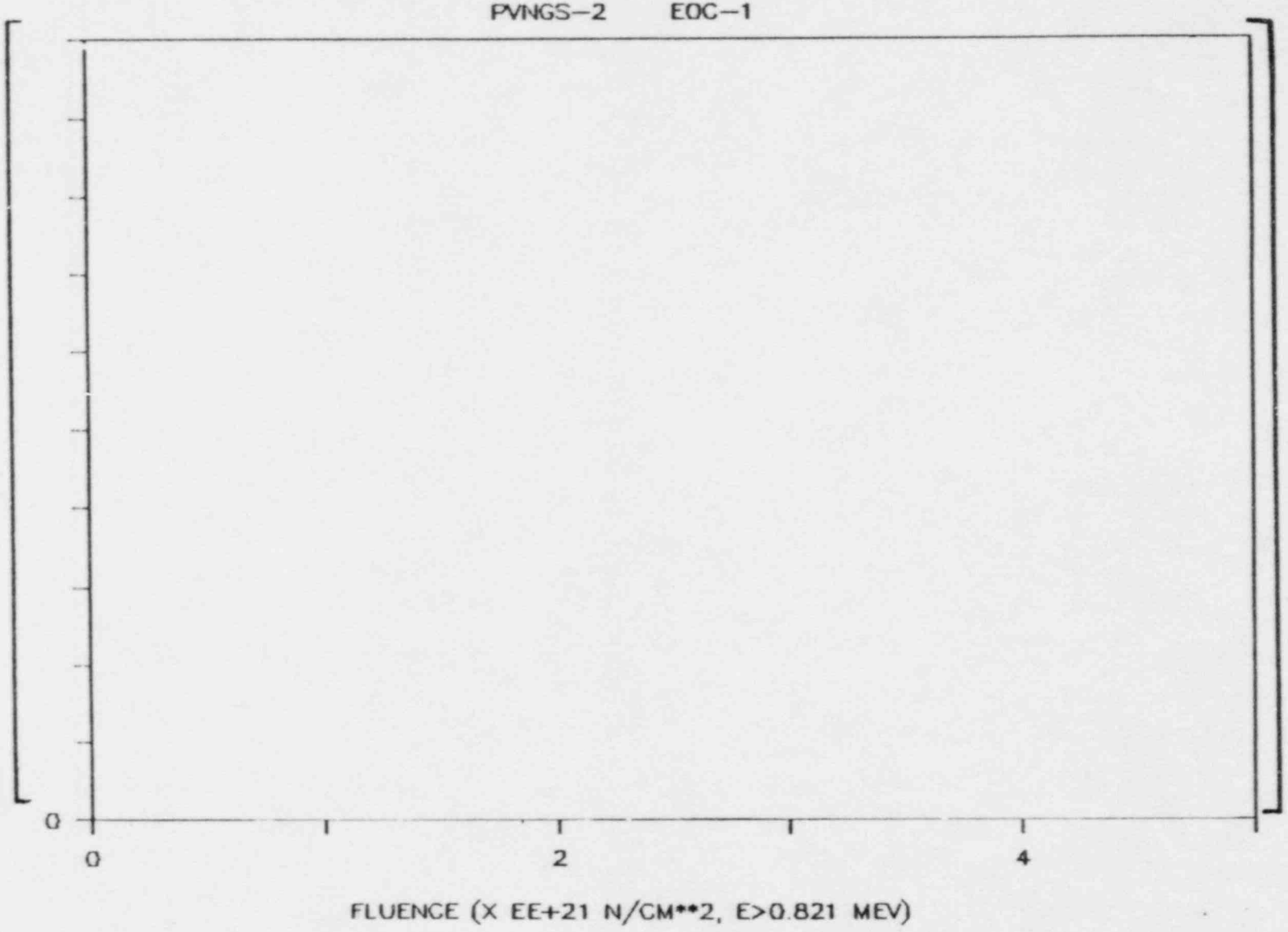


Figure 6

basis and the trend of the data is for increased margin at higher fluences. Therefore, it is conservative to use the fuel rod growth model when predicting limiting shoulder gap changes.

Guide tube length change data for the PVNGS-2 fuel are shown in Figure 5, along with the minimum required guide tube growth rate discussed in Section 4.1 The figure shows similar margin for the PVNGS-2 measurements as Figure 3 shows for the PVNGS-1 measurements. Therefore, the use of the minimum rquired guide tube growth can be concluded to be conservative for the PVNGS-2 Cycle 2 shoulder gap evaluation.

The fuel rod growth data and the guide tube growth data from PVNGS-1 and PVNGS-2 at EOC-1 have confirmed the conservations of the analytical modeling used in the shoulder gap evaluation of the PVNGS-2 Cycle 2 fuel. Therefore, since the shoulder gap evaluation verified that the limiting fuel rod in Cycle 2 had sufficient shoulder gap and since the analytical modeling used in the evaluation has been shown to be conservative, it is concluded that the fuel in PVNGS-2 Cycle 2 is acceptable with respect to shoulder gap.

4.0 SUMMARY AND CONCLUSIONS

Guide tube wear originating from the mechanical interaction between guide tubes and CEAs was first observed by C-E in 1978. Since that time, C-E has established several surveillance programs to ensure significant margin to the limiting wear criterion. A program of this type was implemented for the System 80 design.

Ten fuel assemblies from PVNGS-2 were selected for guide tube wear examination following Cycle 1. The assemblies examined represent all combinations of CEA types and geometries. The selections were biased towards regions of the core which have higher than average coolant flow rates; areas expected to generate more severe wear. A total of 40 guide tubes were examined bringing the total C-E experience with System 80 guide tubes to 120 (80 from PVNGS-1).

The criterion used to evaluate the results was based on deterministically conservative assumptions of wear geometry, loading severity, and material properties. This criterion was the same as that used in the original decision to operate the System 80 fuel type without protective wear sleeves.

The evaluation of all wear measurements showed that the most limiting of the 120 measured guide tubes (total System 80) had acceptable wear. Its wear rate was less than that determined in the original flow tests of the System 80 design. Extrapolation of the wear to three cycles of operation demonstrated significant margin to the guide tube wear limit criterion. The effects of core shuffling and of fuel exposure to the reactor environment lead C-E to conclude that no case of guide tube wear will be as severe as predicted by the extrapolation.

The inspection samples and the evaluation results from PVNGS-1 and PVNGS-2 support the continued operation of all System 80 fuel assemblies through the completion of their design life without guide tube modification (wear sleeves).

Dimensional measurements of peripheral fuel rod shoulder gap and of guide tube lengths were performed on ten PVNGS-2 fuel assemblies following Cycle 1. Fuel rod growth data, determined from the measurements, indicate that the growth of high fluence fuel rods is less than the growth predicted by the model used to determine design limits for shoulder gap. In addition, the trend of the data is for an increasing margin between rod growth and the design basis at higher fluences. The measured guide tube growths are greater than the growths predicted by the growth rate associated with the minimum guide tube growth required at EOC-2.

Based on the fuel assembly dimensional measurements performed at PVNGS-1 and PVNGS-2, the C-E models for predicting guide tube growth and fuel rod growth have been shown to be conservative. As a result, adequate margin for shoulder gap reduction exists in all fuel assemblies designated for operation in PVNGS-2 Cycle 2. In addition, it is concluded that the shoulder gap evaluation technique is acceptable for determining the fluence capabilities of PVNGS fuel. Therefore, comparisons of fluence capabilities and peak fuel rod fluence can be made for subsequent cycles to verify the acceptability of the shoulder gap of the operating fuel.

5.0 REFERENCES

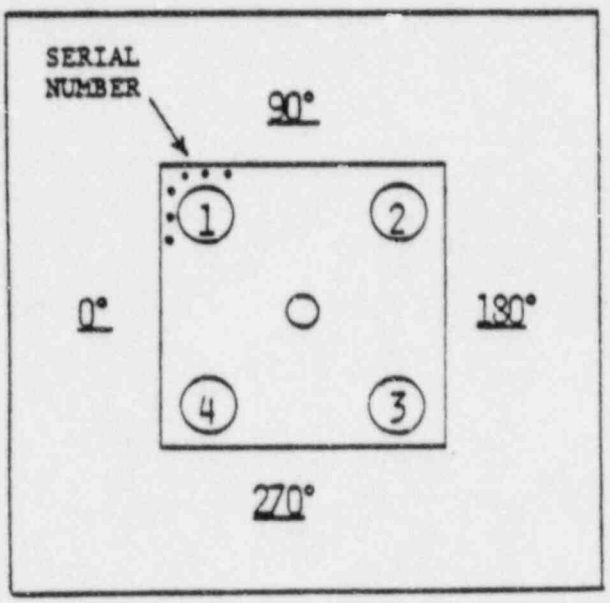
(1) CE NPSD-428-P, "Palo Verde Nuclear Generating Station - Unit 1 End-of-Cycle 1 Fuel Examination Report", December, 1987.

(2) CE NPD-269-P, Rev. 1-P. "Extended Burnup Operation of Combustion Engineering PWR Fuel", July, 1984.

Appendix A

Figure A-1

Guide Tube Identification Format



EDDY-CURRENT GUIDE TUBE WEAR DATA

Assembly Number	Guide Tube Number	Voltage	Axial Location From Top of Post (Inches)	Axial Extent of Indication (Inches)
2A024	1	[redacted]		
	2			
	3			
	4			
2B137	1			
	2			
	3			
	4			
2B144	1			
	2			
	3			
	4			
2C005	1			
	2			
	3			
	4			
2C112	1			
	2			
	3			
	4			

N.D. - Nothing Detectable

EDDY-CURRENT GUIDE TUBE WEAR DATA

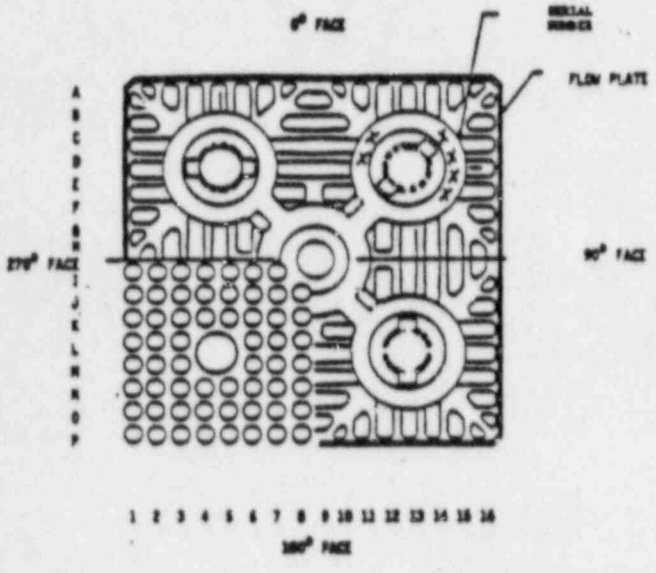
Assembly Number	Guide Tube Number	Voltage	Axial Location From Top of Post (Inches)	Axial Extent of Indication (Inches)
1B226	1	[redacted]	[redacted]	[redacted]
	2			
	3			
	4			
2A068	1			
	2			
	3			
	4			
2A062	1			
	2			
	3			
	4			
2A046	1			
	2			
	3			
	4			
2C025	1			
	2			
	3			
	4			

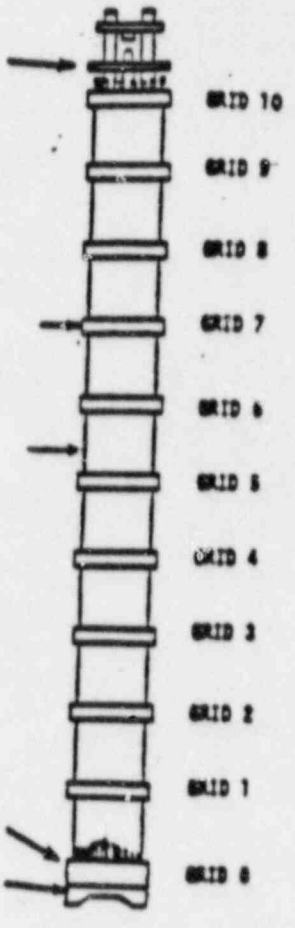
N.D. - Nothing Detectable

Appendix B

Figure B-1

Fuel Assembly and Fuel Rod
Identification Format





FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2A036

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.785	[			]
2	1.682	3.793				
3	1.682	3.800				
4	1.682	3.805				
5	1.682	3.809				
6	1.682	3.815				
7	1.682	3.822				
8	1.682	3.826				
9	1.682	3.825				
10	1.682	3.821				
11	1.682	3.813				
12	1.682	3.806				
13	1.682	3.802				
14	1.682	3.796				
15	1.682	3.789				
16	1.682	3.780				]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.810	[			]
2	1.682	3.816				
3	1.682	3.821				
4	1.682	3.824				
5	1.682	3.826				
6	1.682	3.831				
7	1.682	3.835				
8	1.682	3.838				
9	1.682	3.837				
10	1.682	3.831				
11	1.682	3.822				
12	1.682	3.815				
13	1.682	3.809				
14	1.682	3.803				
15	1.682	3.794				
16	1.682	3.785				]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.790	[			]
2	1.682	3.799				
3	1.682	3.807				
4	1.682	3.813				
5	1.682	3.820				
6	1.682	3.826				
7	1.682	3.835				
8	1.682	3.841				
9	1.682	3.843				
10	1.682	3.838				
11	1.682	3.833				
12	1.682	3.828				
13	1.682	3.825				
14	1.682	3.822				
15	1.682	3.816				
16	1.682	3.810				]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.780	[			]
2	1.682	3.789				
3	1.682	3.796				
4	1.682	3.803				
5	1.682	3.809				
6	1.682	3.815				
7	1.682	3.823				
8	1.682	3.828				
9	1.682	3.830				
10	1.682	3.825				
11	1.682	3.819				
12	1.682	3.813				
13	1.682	3.809				
14	1.682	3.804				
15	1.682	3.797				
16	1.682	3.790				]

1) NOMINAL BOL SHOULDER GAP= 1.682 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 3.164
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2A057

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.729	[			
2	1.682	3.733				
3	1.682	3.735				
4	1.682	3.735				
5	1.682	3.734				
6	1.682	3.732				
7	1.682	3.731				
8	1.682	3.727				
9	1.682	3.718				
10	1.682	3.702				
11	1.682	3.680				
12	1.682	3.667				
13	1.682	3.649				
14	1.682	3.631				
15	1.682	3.611				
16	1.682	3.589	]			

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.762	[			
2	1.682	3.764				
3	1.682	3.766				
4	1.682	3.766				
5	1.682	3.766				
6	1.682	3.769				
7	1.682	3.772				
8	1.682	3.774				
9	1.682	3.772				
10	1.682	3.765				
11	1.682	3.758				
12	1.682	3.751				
13	1.682	3.747				
14	1.682	3.742				
15	1.682	3.735				
16	1.682	3.729	]			

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.620	[			
2	1.682	3.646				
3	1.682	3.670				
4	1.682	3.690				
5	1.682	3.709				
6	1.682	3.729				
7	1.682	3.747				
8	1.682	3.762				
9	1.682	3.771				
10	1.682	3.775				
11	1.682	3.775				
12	1.682	3.775				
13	1.682	3.775				
14	1.682	3.773				
15	1.682	3.769				
16	1.682	3.762	]			

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.589	[			
2	1.682	3.590				
3	1.682	3.593				
4	1.682	3.595				
5	1.682	3.597				
6	1.682	3.603				
7	1.682	3.610				
8	1.682	3.617				
9	1.682	3.619				
10	1.682	3.618				
11	1.682	3.616				
12	1.682	3.615				
13	1.682	3.617				
14	1.682	3.619				
15	1.682	3.619				
16	1.682	3.620	]			

1) NOMINAL BOL SHOULDER GAP= 1.682 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 3.071
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2A059

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.409	[			]
2	1.682	3.391				
3	1.682	3.371				
4	1.682	3.350				
5	1.682	3.328				
6	1.682	3.309				
7	1.682	3.290				
8	1.682	3.272				
9	1.682	3.248				
10	1.682	3.223				
11	1.682	3.196				
12	1.682	3.171				
13	1.682	3.149				
14	1.682	3.127				
15	1.682	3.106				
16	1.682	3.084				]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.699	[			]
2	1.682	3.695				
3	1.682	3.687				
4	1.682	3.676				
5	1.682	3.664				
6	1.682	3.651				
7	1.682	3.640				
8	1.682	3.626				
9	1.682	3.606				
10	1.682	3.580				
11	1.682	3.552				
12	1.682	3.524				
13	1.682	3.496				
14	1.682	3.468				
15	1.682	3.439				
16	1.682	3.409				]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.647	[			]
2	1.682	3.652				
3	1.682	3.659				
4	1.682	3.666				
5	1.682	3.672				
6	1.682	3.681				
7	1.682	3.691				
8	1.682	3.700				
9	1.682	3.704				
10	1.682	3.706				
11	1.682	3.703				
12	1.682	3.703				
13	1.682	3.704				
14	1.682	3.704				
15	1.682	3.702				
16	1.682	3.699				]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.084	[			]
2	1.682	3.143				
3	1.682	3.200				
4	1.682	3.253				
5	1.682	3.305				
6	1.682	3.356				
7	1.682	3.404				
8	1.682	3.450				
9	1.682	3.489				
10	1.682	3.521				
11	1.682	3.548				
12	1.682	3.575				
13	1.682	3.599				
14	1.682	3.620				
15	1.682	3.636				
16	1.682	3.647				]

1) NOMINAL BOL SHOULDER GAP= 1.682 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 2.899
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMB[illegible]E I 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.8[illegible] ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2B109

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.594	[			]
2	2.382	3.623				
3	2.382	3.732				
4	2.382	3.764				
5	2.382	3.784				
6	2.382	3.803				
7	2.382	3.827				
8	2.382	3.848				
9	2.382	3.856				
10	2.382	3.853				
11	2.382	3.845				
12	2.382	3.843				
13	2.382	3.840				
14	2.382	3.825				
15	2.382	3.730				
16	2.382	3.716				]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.540	[			]
2	2.382	3.559				
3	2.382	3.659				
4	2.382	3.682				
5	2.382	3.695				
6	2.382	3.707				
7	2.382	3.724				
8	2.382	3.740				
9	2.382	3.744				
10	2.382	3.737				
11	2.382	3.726				
12	2.382	3.720				
13	2.382	3.716				
14	2.382	3.700				
15	2.382	3.607				
16	2.382	3.594				]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.673	[			]
2	2.382	3.681				
3	2.382	3.768				
4	2.382	3.774				
5	2.382	3.773				
6	2.382	3.772				
7	2.382	3.775				
8	2.382	3.776				
9	2.382	3.768				
10	2.382	3.749				
11	2.382	3.727				
12	2.382	3.710				
13	2.382	3.692				
14	2.382	3.667				
15	2.382	3.565				
16	2.382	3.540				]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.716	[			]
2	2.382	3.724				
3	2.382	3.814				
4	2.382	3.824				
5	2.382	3.825				
6	2.382	3.828				
7	2.382	3.836				
8	2.382	3.843				
9	2.382	3.841				
10	2.382	3.828				
11	2.382	3.814				
12	2.382	3.805				
13	2.382	3.797				
14	2.382	3.782				
15	2.382	3.688				
16	2.382	3.673				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 3.155
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2B119

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.721	[			]
2	2.382	3.735				
3	2.382	3.834				
4	2.382	3.853				
5	2.382	3.861				
6	2.382	3.868				
7	2.382	3.883				
8	2.382	3.895				
9	2.382	3.895				
10	2.382	3.884				
11	2.382	3.868				
12	2.382	3.862				
13	2.382	3.854				
14	2.382	3.835				
15	2.382	3.738				
16	2.382	3.722				]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.716	[			]
2	2.382	3.731				
3	2.382	3.830				
4	2.382	3.847				
5	2.382	3.855				
6	2.382	3.864				
7	2.382	3.878				
8	2.382	3.890				
9	2.382	3.890				
10	2.382	3.879				
11	2.382	3.865				
12	2.382	3.858				
13	2.382	3.851				
14	2.382	3.833				
15	2.382	3.735				
16	2.382	3.721				]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.716	[			]
2	2.382	3.731				
3	2.382	3.828				
4	2.382	3.846				
5	2.382	3.854				
6	2.382	3.862				
7	2.382	3.876				
8	2.382	3.887				
9	2.382	3.887				
10	2.382	3.876				
11	2.382	3.862				
12	2.382	3.854				
13	2.382	3.846				
14	2.382	3.828				
15	2.382	3.730				
16	2.382	3.716				]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.722	[			]
2	2.382	3.737				
3	2.382	3.835				
4	2.382	3.853				
5	2.382	3.859				
6	2.382	3.867				
7	2.382	3.881				
8	2.382	3.893				
9	2.382	3.892				
10	2.382	3.879				
11	2.382	3.865				
12	2.382	3.856				
13	2.382	3.848				
14	2.382	3.830				
15	2.382	3.731				
16	2.382	3.716				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 3.072
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2B205

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	2.985	[			]
2	1.682	3.035				
3	1.682	3.155				
4	1.682	3.212				
5	1.682	3.258				
6	1.682	3.305				
7	1.682	3.357				
8	1.682	3.406				
9	1.682	3.442				
10	1.682	3.466				
11	1.682	3.486				
12	1.682	3.511				
13	1.682	3.534				
14	1.682	3.544				
15	1.682	3.478				
16	1.682	3.484				]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.161	[			]
2	1.682	3.159				
3	1.682	3.225				
4	1.682	3.224				
5	1.682	3.215				
6	1.682	3.207				
7	1.682	3.205				
8	1.682	3.201				
9	1.682	3.189				
10	1.682	3.169				
11	1.682	3.146				
12	1.682	3.130				
13	1.682	3.114				
14	1.682	3.091				
15	1.682	3.005				
16	1.682	2.985				]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.504	[			]
2	1.682	3.496				
3	1.682	3.566				
4	1.682	3.559				
5	1.682	3.543				
6	1.682	3.525				
7	1.682	3.514				
8	1.682	3.501				
9	1.682	3.476				
10	1.682	3.440				
11	1.682	3.402				
12	1.682	3.370				
13	1.682	3.339				
14	1.682	3.299				
15	1.682	3.193				
16	1.682	3.161				]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.484	[			]
2	1.682	3.483				
3	1.682	3.561				
4	1.682	3.566				
5	1.682	3.566				
6	1.682	3.568				
7	1.682	3.578				
8	1.682	3.589				
9	1.682	3.592				
10	1.682	3.586				
11	1.682	3.579				
12	1.682	3.580				
13	1.682	3.585				
14	1.682	3.582				
15	1.682	3.504				
16	1.682	3.504				]

1) NOMINAL BOL SHOULDER GAP= 1.682 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 2.829
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P18226

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.717	[			]
2	1.682	3.722				
3	1.682	3.810				
4	1.682	3.819				
5	1.682	3.820				
6	1.682	3.822				
7	1.682	3.831				
8	1.682	3.838				
9	1.682	3.837				
10	1.682	3.826				
11	1.682	3.814				
12	1.682	3.809				
13	1.682	3.804				
14	1.682	3.793				
15	1.682	3.702				
16	1.682	3.692	[			]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.718	[			]
2	1.682	3.732				
3	1.682	3.830				
4	1.682	3.847				
5	1.682	3.855				
6	1.682	3.862				
7	1.682	3.877				
8	1.682	3.888				
9	1.682	3.888				
10	1.682	3.876				
11	1.682	3.862				
12	1.682	3.854				
13	1.682	3.847				
14	1.682	3.826				
15	1.682	3.730				
16	1.682	3.717	[			]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.692	[			]
2	1.682	3.702				
3	1.682	3.793				
4	1.682	3.805				
5	1.682	3.810				
6	1.682	3.815				
7	1.682	3.827				
8	1.682	3.838				
9	1.682	3.840				
10	1.682	3.832				
11	1.682	3.823				
12	1.682	3.821				
13	1.682	3.820				
14	1.682	3.811				
15	1.682	3.723				
16	1.682	3.718	[			]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	3.692	[			]
2	1.682	3.702				
3	1.682	3.792				
4	1.682	3.803				
5	1.682	3.806				
6	1.682	3.811				
7	1.682	3.822				
8	1.682	3.832				
9	1.682	3.832				
10	1.682	3.822				
11	1.682	3.811				
12	1.682	3.806				
13	1.682	3.803				
14	1.682	3.791				
15	1.682	3.701				
16	1.682	3.692	[			]

1) NOMINAL BOL SHOULDER GAP= 1.682 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 3.189
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2C005

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	1.436	[			]
2	2.382	1.437				
3	2.382	1.446				
4	2.382	1.445				
5	2.382	1.445				
6	2.382	1.447				
7	2.382	1.448				
8	2.382	1.448				
9	2.382	1.448				
10	2.382	1.448				
11	2.382	1.447				
12	2.382	1.445				
13	2.382	1.445				
14	2.382	1.446				
15	2.382	1.437				
16	2.382	1.436				]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.288	[			]
2	2.382	3.263				
3	2.382	3.237				
4	2.382	3.176				
5	2.382	3.100				
6	2.382	3.011				
7	2.382	2.911				
8	2.382	2.796				
9	2.382	2.666				
10	2.382	2.524				
11	2.382	2.369				
12	2.382	2.203				
13	2.382	2.027				
14	2.382	1.841				
15	2.382	1.637				
16	2.382	1.436				]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.288	[			]
2	2.382	3.298				
3	2.382	3.328				
4	2.382	3.335				
5	2.382	3.340				
6	2.382	3.346				
7	2.382	3.351				
8	2.382	3.356				
9	2.382	3.356				
10	2.382	3.351				
11	2.382	3.346				
12	2.382	3.340				
13	2.382	3.335				
14	2.382	3.328				
15	2.382	3.298				
16	2.382	3.288				]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	1.436	[			]
2	2.382	1.637				
3	2.382	1.841				
4	2.382	2.027				
5	2.382	2.203				
6	2.382	2.369				
7	2.382	2.524				
8	2.382	2.666				
9	2.382	2.796				
10	2.382	2.911				
11	2.382	3.011				
12	2.382	3.100				
13	2.382	3.176				
14	2.382	3.237				
15	2.382	3.263				
16	2.382	3.288				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 2.188
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P2C025

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	0.656	[			]
2	2.382	0.742				
3	2.382	0.831				
4	2.382	0.913				
5	2.382	0.994				
6	2.382	1.075				
7	2.382	1.156				
8	2.382	1.236				
9	2.382	1.316				
10	2.382	1.397				
11	2.382	1.481				
12	2.382	1.570				
13	2.382	1.664				
14	2.382	1.766				
15	2.382	1.861				
16	2.382	1.970				]

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	1.971	[			]
2	2.382	1.862				
3	2.382	1.766				
4	2.382	1.665				
5	2.382	1.570				
6	2.382	1.482				
7	2.382	1.398				
8	2.382	1.316				
9	2.382	1.236				
10	2.382	1.156				
11	2.382	1.075				
12	2.382	0.994				
13	2.382	0.913				
14	2.382	0.831				
15	2.382	0.742				
16	2.382	0.656				]

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.280	[			]
2	2.382	3.249				
3	2.382	3.228				
4	2.382	3.179				
5	2.382	3.120				
6	2.382	3.055				
7	2.382	2.984				
8	2.382	2.905				
9	2.382	2.817				
10	2.382	2.719				
11	2.382	2.613				
12	2.382	2.500				
13	2.382	2.381				
14	2.382	2.255				
15	2.382	2.108				
16	2.382	1.971				]

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	1.970	[			]
2	2.382	2.107				
3	2.382	2.254				
4	2.382	2.380				
5	2.382	2.499				
6	2.382	2.611				
7	2.382	2.717				
8	2.382	2.814				
9	2.382	2.903				
10	2.382	2.982				
11	2.382	3.052				
12	2.382	3.118				
13	2.382	3.177				
14	2.382	3.228				
15	2.382	3.249				
16	2.382	3.280				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) AVERAGE GUIDE TUBE GROWTH= [ ]
3) AVERAGE GUIDE TUBE FLUENCE= 1.781
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 44

NM = not measured

FUEL ASSEMBLY DIMENSIONAL MEASUREMENTS

ASSEMBLY SERIAL NO. P1C114

FACE: NORTH (0)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.698	[redacted]			
2	2.382	3.706				
3	2.382	3.795				
4	2.382	3.805				
5	2.382	3.805				
6	2.382	3.803				
7	2.382	3.809				
8	2.382	3.811				
9	2.382	3.801				
10	2.382	3.780				
11	2.382	3.757				
12	2.382	3.739				
13	2.382	3.722				
14	2.382	3.695				
15	2.382	3.592				
16	2.382	3.571				

FACE: EAST (90)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.571	[redacted]			
2	2.382	3.593				
3	2.382	3.696				
4	2.382	3.723				
5	2.382	3.740				
6	2.382	3.758				
7	2.382	3.782				
8	2.382	3.803				
9	2.382	3.812				
10	2.382	3.811				
11	2.382	3.805				
12	2.382	3.806				
13	2.382	3.806				
14	2.382	3.796				
15	2.382	3.707				
16	2.382	3.698				

FACE: SOUTH (180)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.289	[redacted]			
2	2.382	3.326				
3	2.382	3.438				
4	2.382	3.479				
5	2.382	3.510				
6	2.382	3.541				
7	2.382	3.576				
8	2.382	3.609				
9	2.382	3.630				
10	2.382	3.639				
11	2.382	3.645				
12	2.382	3.655				
13	2.382	3.664				
14	2.382	3.660				
15	2.382	3.577				
16	2.382	3.571				

FACE: WEST (270)

ROD	BOL GAP (in.)	CY 1 FLUENCE (E>0.821)	EOC-1 SH. GAP (in.)	GAP DECREASE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.571	[redacted]			
2	2.382	3.577				
3	2.382	3.660				
4	2.382	3.665				
5	2.382	3.657				
6	2.382	3.647				
7	2.382	3.641				
8	2.382	3.633				
9	2.382	3.611				
10	2.382	3.578				
11	2.382	3.542				
12	2.382	3.511				
13	2.382	3.480				
14	2.382	3.439				
15	2.382	3.327				
16	2.382	3.289				

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) AVERAGE GUIDE TUBE GROWTH= [redacted]
3) AVERAGE GUIDE TUBE FLUENCE= 3.072
4) AVG. BOL ROD ACTIVE LENGTH= 150 in.

NOTE: ALL REPORTED FLUENCE NUMBERS ARE X 10 EE 21 N/CM**2
FLUENCES CALCULATED FOR E>0.821 ARE ADJUSTED TO ACTUAL BURNUP OF 448 EFPD