PALO VERDE NUCLEAR GENERATING STATION - UNIT 1
END-OF-CYCLE 2 FUEL EXAMINATION REPORT
CEN-390(V)-NP

October, 1989

A Report to
Arizona Public Services Company

from

Combustion Engineering, Inc.
Nuclear Power Systems
Windsor, Connecticut

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1.0 INTRODUCTION

This report documents fuel examinations conducted during the End-of-Cycle 2 refueling outage at Palo Verde Nuclear Generating Station-Unit 1. The inspections were performed to fulfill examination requirements for EOC-2 that are specified by the Palo Verde-1 operating license. The inspections performed were dimensional measurements to characterize fuel rod and assembly growth. A total of 10 fuel assemblies were inspected. Table 1 lists the assemblies and provides pertinent data for each.

Table 1

Palo Verde-1 Fuel Assemblies Inspected[1] at EOC-2

Assembly+ Serial Number	Number of Cycles Irradiated	Discharged @ EOC-2	Cycle-2 Core Location	EOC-2 Assembly Avg. Burnup (GWd/MTU)
B120*[2]	2	x	H13	30.3
P2B233[2]	2	x	P7	31.1
C002	2		J5	24.9
C005[2]	2		J8	24.8
C017	2		K14	22.3
C025[2]	2		M6	24.2
C039	2		H9	24.8
P2C114	2	x	K15	30.2
D001*	1		P15	11.5
D002*	1		R14	11.5

+ Serial numbers prefixed by P1 unless otherwise noted.

* Characterized fuel assembly.

[1] Peripheral fuel rod shoulder gap and guide tube length measurements.

[2] Assembly previously measured at EOC-1.

2.0 FUEL ASSEMBLY DIMENSIONAL CHANGE EVALUATION

Fuel rod shoulder gap (distance between the top of the fuel rods and the bottom of the upper end fitting) and guide tube length measurements were made at Palo Verde-1 during the EOC-2 outage. A total of ten fuel assemblies were measured; two Batch B, six Batch C, and two Batch D. The specific fuel assemblies inspected are identified in Table 1. The shoulder gap of peripheral fuel rods on the four faces of each fuel assembly was measured optically using a periscope, while each of the four outer guide tubes was measured using the guide-tube length measurement tool.

2.1 Pre-Shutdown Evaluation

The shoulder gap evaluation for Palo Verde-1 Cycle 3 fuel is identical to the method used for Palo Verde-1 Cycle 2 (Reference 1), i.e., remaining shoulder gap predictions were based on the minimum available shoulder gap at the beginning of life, a conservatively high fuel rod growth prediction, and a conservatively low guide tube growth prediction. These parameters are discussed in more detail below:

a. The minimum available shoulder gap at the beginning of life accounted for component dimensional tolerances, elastic compression of the guide tubes, and differential thermal expansion between the fuel rods and the guide tubes.

b. The conservatively low guide tube growth prediction utilized the lower 95% value calculated using the methods described in Reference 2.

c. The conservatively high fuel rod growth prediction was taken from the ANO-2 Batch C data as 0.21 inches of growth per unit of fluence (unvt or nvt x 10^{-21}) (Reference 3). This growth rate represents more growth than the 95/95 upper limit for the

distribution of Batch C data from ANO-2. These data represent the fuel whose high fluence rods had the highest observed growth rate of any fuel examined by C-E.

Implementation of this approach for the Palo Verde-1 fuel assemblies showed that all shoulder gaps were predicted to have clearance at the end of Cycle 3. Therefore, if shoulder gap and guide-tube length measurements taken on the ten Palo Verde-1 fuel assemblies support the applicability of the design basis, the third cycle fuel would be justified for Cycle 3 operation.

2.2 Dimensional Change Data

The individual shoulder gap measurements are tabulated in Appendix A Tables A-1 through A-10, along with a table of the length change for each measured guide tube, Table A-11. For each shoulder gap measured, the tabulation in Appendix A also contains the initial shoulder gap (measured value if available, otherwise the nominal value from the design drawings), the resulting shoulder gap change (initial gap - EOC-2 gap), the inferred fuel rod growth (shoulder gap change plus guide tube growth), fuel rod growth strain (fuel rod growth/nominal BOL rod 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 Figures 1, 2, and 3, respectively. Also plotted on these figures are data obtained from the measurement of Palo Verde-1 fuel assemblies inspected during the EOC-1 outage (Reference 1).

2.3 Post-Shutdown Evaluation

Guide tube length change data are shown in Figure 2 along with the limiting (lower 95% and upper 95%) length change predictions resulting

from the method described in Reference (2). The figure shows that the measured data are all above the lower 95% predicted growth so it is concluded that it is conservative to use the guide tube length change model when predicting limiting shoulder gap changes.

Fuel rod growth data are shown in Figure 3 along with the growth prediction taken from the ANO-2 Batch C data (0.21 inches/unvt). The figure shows that the higher fluence data are all below the design 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.

The predictive models for guide tube growth and fuel rod growth have been shown to be conservative relative to the Palo Verde-1 data. Therefore, the shoulder gap evaluation technique is acceptable for determining the fluence capabilities for Palo Verde fuel. The fluence capabilities calculated by the technique for all fuel assemblies in Cycle 3 exceed the peak fuel rod fluence at EOC-3. Therefore, the shoulder gap provided is sufficient and the fuel's operation in Cycle 3 will not cause complete closure of any fuel rod shoulder gap.

FIGURE 1

PALO VERDE 1 SHOULDER GAP DECREASE

AT EOC-1 AND EOC-2

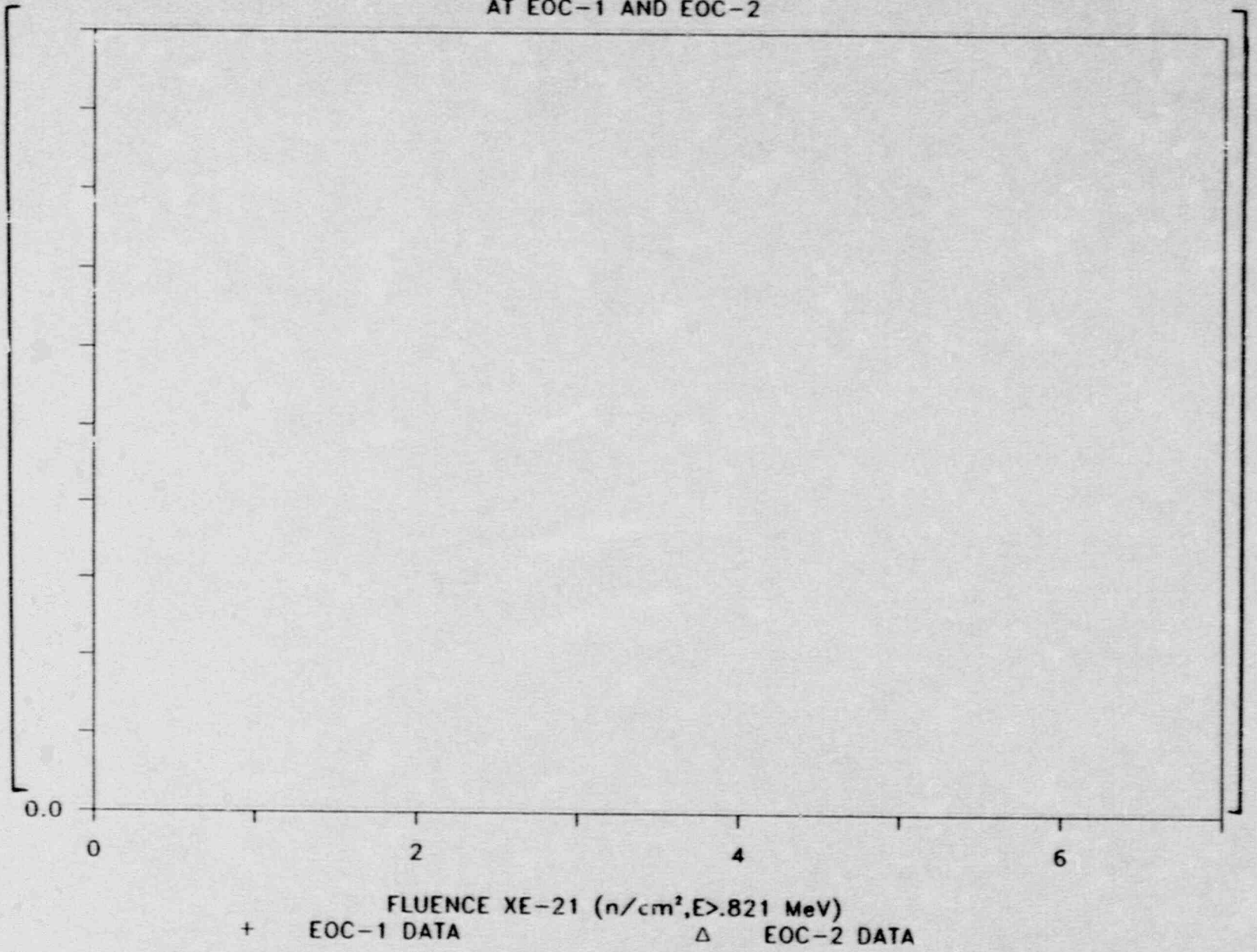


FIGURE 2

PALO VERDE 1 GUIDE TUBE GROWTH

AT EOC-1 AND EOC-2

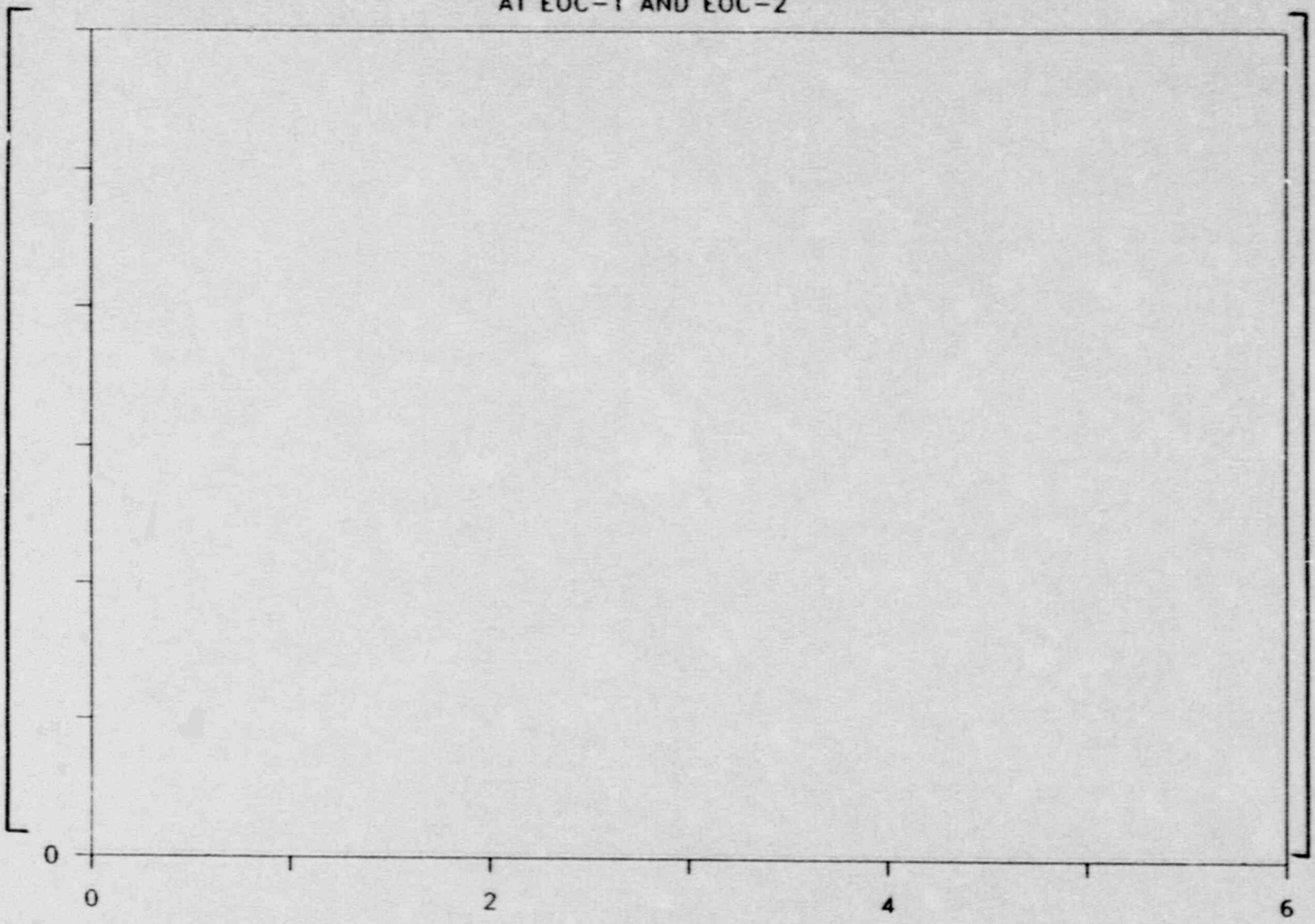
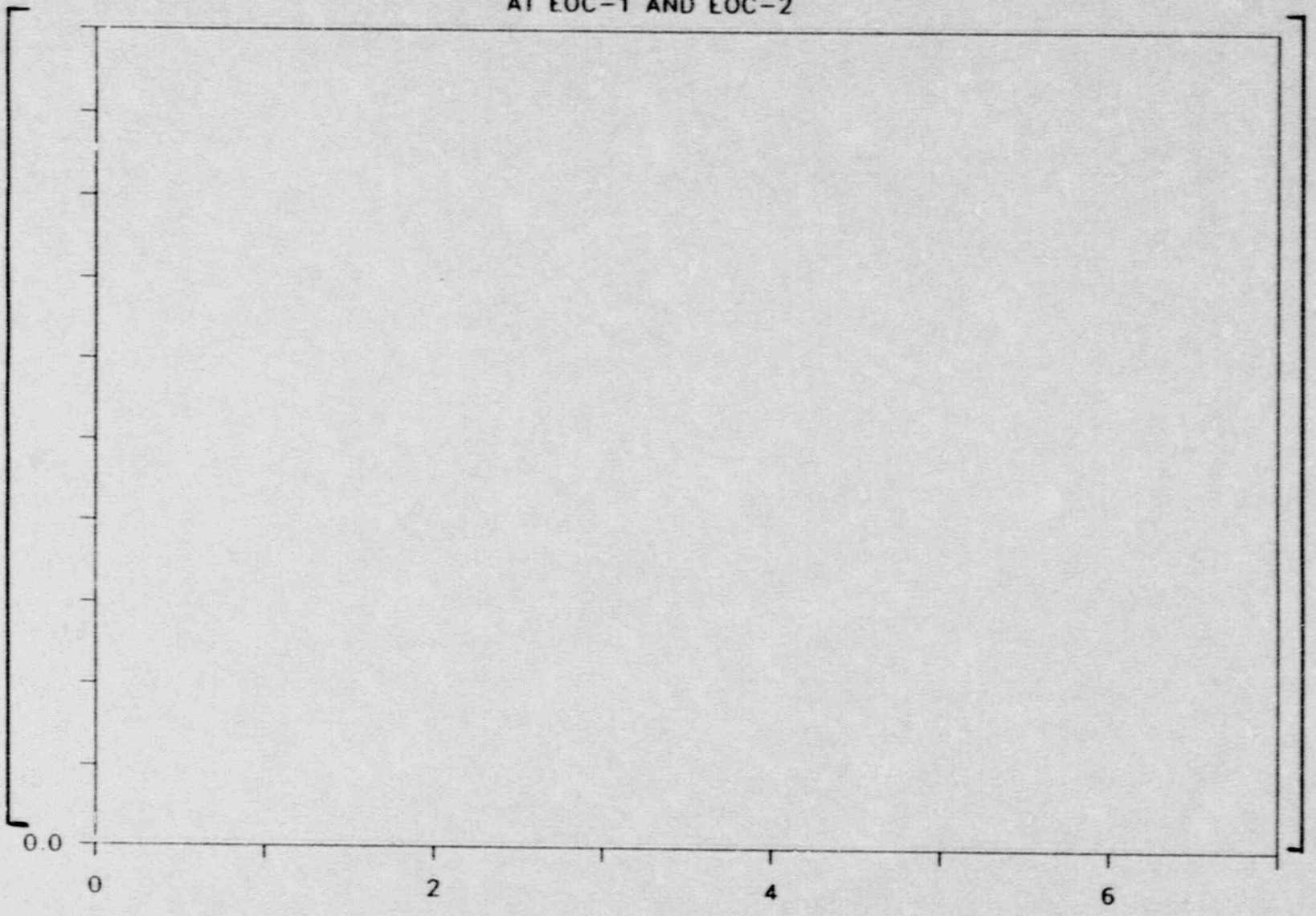


FIGURE 3

PALO VERDE 1 FUEL ROD GROWTH

AT EOC-1 AND EOC-2



3.0 SUMMARY AND CONCLUSIONS

Dimensional measurements of peripheral fuel rod shoulder gap and guide tube length were performed on 10 Palo Verde-1 fuel assemblies following Cycle 2. Fuel rod growth data, determined from the measurements, indicates 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 increased margin between rod growth and the design basis at higher fluences. Guide tube length measurements indicate that the measured assemblies grew from[ ]to[ ]inches during two cycles of exposure with average guide tube fluences up to 5.49×10^{21} n/cm^2 ($E > .821$ MeV) and assembly average burnups up to 31.1 GWd/MTU. The measured guide tube growth is greater than the lower 95% predicted growth that was used to determine design limits for shoulder gap.

Based on the fuel assembly dimensional measurements performed at EOC-2, the predictive models for guide tube and fuel rod growth have been shown to be conservative for Palo Verde-1 assemblies. As a result, adequate margin for shoulder gap reduction exists in all fuel assemblies designated for operation in Palo Verde-1 Cycle 3.

4.0 REFERENCES

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

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

(3) CEN-309 (A)-P, "Arkansas Nuclear One, Unit 2 Cycle 5 Shoulder Gap Evaluation", issued July, 1985.

APPENDIX A

Palo Verde 1 Cycle 2

Fuel Assembly Dimensional Change Data

NOTE: "ERR" on Tables A-1 through A-10 identifies values that could not be determined. The rod shoulder gap could not be measured because the gap was so large it was outside the range of optical measurement. Fuel rod growth strains were calculated using nominal BOL rod length.

Table A-1

ASSEMBLY SERIAL NO P18120

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.469	5.780	[			]
2	2.453	5.809				
3	2.453	5.928				
4	2.453	5.977				
5	2.437	5.978				
6	2.437	5.972				
7	2.437	6.012				
8	2.437	6.042				
9	2.453	6.011				
10	2.437	5.963				
11	2.422	5.908				
12	2.422	5.898				
13	2.406	5.881				
14	2.406	5.816				
15	2.406	5.679				
16	2.422	5.629				]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.500	5.700	[			]
2	2.516	5.736				
3	2.500	5.859				
4	2.516	5.914				
5	2.484	5.921				
6	2.500	5.924				
7	2.469	5.974				
8	2.484	6.018				
9	2.484	6.039				
10	2.484	6.008				
11	2.469	5.970				
12	2.469	5.979				
13	2.453	5.980				
14	2.469	5.932				
15	2.453	5.813				
16	2.500	5.780				]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.453	5.644	[			]
2	2.422	5.668				
3	2.422	5.771				
4	2.422	5.800				
5	2.422	5.804				
6	2.422	5.798				
7	2.437	5.838				
8	2.437	5.874				
9	2.422	5.900				
10	2.437	5.871				
11	2.422	5.837				
12	2.453	5.848				
13	2.453	5.855				
14	2.500	5.822				
15	2.453	5.721				
16	2.500	5.700				]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.422	5.629	[			]
2	2.422	5.633				
3	2.422	5.723				
4	2.437	5.750				
5	2.453	5.738				
6	2.437	5.725				
7	2.437	5.760				
8	2.437	5.792				
9	2.437	5.779				
10	2.484	5.751				
11	2.500	5.720				
12	2.437	5.738				
13	2.453	5.755				
14	2.453	5.732				
15	2.437	5.645				
16	2.453	5.644				]

1) NOMINAL BOL SHOULDER GAP= CHARACTERIZED [ ]in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ]in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 5.486 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-2

ASSEMBLY SERIAL NO P26233

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	5.859	[			]
2	1.682	5.878				
3	1.682	5.983				
4	1.682	6.020				
5	1.682	6.015				
6	1.682	6.006				
7	1.682	6.044				
8	1.682	6.076				
9	1.682	6.056				
10	1.682	6.026				
11	1.682	5.992				
12	1.682	6.004				
13	1.682	6.014				
14	1.682	5.982				
15	1.682	5.884				
16	1.682	5.869				

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	5.956	[			]
2	1.682	5.986				
3	1.682	6.108				
4	1.682	6.159				
5	1.682	6.158				
6	1.682	6.149				
7	1.682	6.188				
8	1.682	6.218				
9	1.682	6.213				
10	1.682	6.169				
11	1.682	6.116				
12	1.682	6.110				
13	1.682	6.096				
14	1.682	6.033				
15	1.682	5.898				
16	1.682	5.855				

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	5.857	[			]
2	1.682	5.889				
3	1.682	6.005				
4	1.682	6.054				
5	1.682	6.059				
6	1.682	6.058				
7	1.682	6.103				
8	1.682	6.141				
9	1.682	6.168				
10	1.682	6.140				
11	1.682	6.106				
12	1.682	6.116				
13	1.682	6.122				
14	1.682	6.084				
15	1.682	5.977				
16	1.682	5.956				

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	1.682	5.869	[			]
2	1.682	5.898				
3	1.682	6.012				
4	1.682	6.059				
5	1.682	6.060				
6	1.682	6.056				
7	1.682	6.096				
8	1.682	6.130				
9	1.682	6.127				
10	1.682	6.094				
11	1.682	6.053				
12	1.682	6.056				
13	1.682	6.053				
14	1.682	6.005				
15	1.682	5.889				
16	1.682	5.857				

1) NOMINAL BOL SHOULDER GAP= 1.682 in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 5.666 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-3

ASSEMBLY SERIAL NO P1CD02

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.329	[			]
2	2.382	5.385				
3	2.382	5.445				
4	2.382	5.472				
5	2.382	5.485				
6	2.382	5.491				
7	2.382	5.493				
8	2.382	5.486				
9	2.382	5.486				
10	2.382	5.493				
11	2.382	5.491				
12	2.382	5.485				
13	2.382	5.472				
14	2.382	5.445				
15	2.382	5.385				
16	2.382	5.329	[			]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.403	[			]
2	2.382	3.633				
3	2.382	3.865				
4	2.382	4.069				
5	2.382	4.251				
6	2.382	4.418				
7	2.382	4.575				
8	2.382	4.723				
9	2.382	4.816				
10	2.382	4.936				
11	2.382	5.044				
12	2.382	5.143				
13	2.382	5.226				
14	2.382	5.288				
15	2.382	5.312				
16	2.382	5.329	[			]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.403	[			]
2	2.382	3.430				
3	2.382	3.453				
4	2.382	3.455				
5	2.382	3.453				
6	2.382	3.449				
7	2.382	3.444				
8	2.382	3.432				
9	2.382	3.432				
10	2.382	3.444				
11	2.382	3.449				
12	2.382	3.453				
13	2.382	3.455				
14	2.382	3.453				
15	2.382	3.430				
16	2.382	3.403	[			]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.329	[			]
2	2.382	5.312				
3	2.382	5.288				
4	2.382	5.226				
5	2.382	5.143				
6	2.382	5.044				
7	2.382	4.936				
8	2.382	4.816				
9	2.382	4.723				
10	2.382	4.575				
11	2.382	4.418				
12	2.382	4.251				
13	2.382	4.069				
14	2.382	3.865				
15	2.382	3.633				
16	2.382	3.403	[			]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 4.412 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-4

ASSEMBLY SERIAL NO P1C005

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.292	[			]
2	2.382	3.322				
3	2.382	3.348				
4	2.382	3.354				
5	2.382	3.356				
6	2.382	3.358				
7	2.382	3.360				
8	2.382	3.356				
9	2.382	3.356				
10	2.382	3.360				
11	2.382	3.358				
12	2.382	3.356				
13	2.382	3.354				
14	2.382	3.348				
15	2.382	3.322				
16	2.382	3.292				]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.356	[			]
2	2.382	5.336				
3	2.382	5.306				
4	2.382	5.237				
5	2.382	5.144				
6	2.382	5.033				
7	2.382	4.908				
8	2.382	4.767				
9	2.382	4.742				
10	2.382	4.566				
11	2.382	4.387				
12	2.382	4.203				
13	2.382	4.003				
14	2.382	3.783				
15	2.382	3.537				
16	2.382	3.292				]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.356	[			]
2	2.382	5.383				
3	2.382	5.417				
4	2.382	5.422				
5	2.382	5.414				
6	2.382	5.403				
7	2.382	5.397				
8	2.382	5.393				
9	2.382	5.393				
10	2.382	5.397				
11	2.382	5.403				
12	2.382	5.414				
13	2.382	5.422				
14	2.382	5.417				
15	2.382	5.383				
16	2.382	5.356				]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.292	[			]
2	2.382	3.537				
3	2.382	3.783				
4	2.382	4.003				
5	2.382	4.203				
6	2.382	4.387				
7	2.382	4.566				
8	2.382	4.742				
9	2.382	4.767				
10	2.382	4.908				
11	2.382	5.033				
12	2.382	5.144				
13	2.382	5.237				
14	2.382	5.306				
15	2.382	5.336				
16	2.382	5.356				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 4.384 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-5

ASSEMBLY SERIAL NO P1C017

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.247	[			]
2	2.382	5.225				
3	2.382	5.197				
4	2.382	5.134				
5	2.382	5.052				
6	2.382	4.958				
7	2.382	4.857				
8	2.382	4.748				
9	2.382	4.667				
10	2.382	4.533				
11	2.382	4.391				
12	2.382	4.242				
13	2.382	4.079				
14	2.382	3.897				
15	2.382	3.688				
16	2.382	3.482	[			]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	4.003	[			]
2	2.382	4.188				
3	2.382	4.365				
4	2.382	4.505				
5	2.382	4.624				
6	2.382	4.730				
7	2.382	4.829				
8	2.382	4.918				
9	2.382	4.970				
10	2.382	5.037				
11	2.382	5.097				
12	2.382	5.154				
13	2.382	5.203				
14	2.382	5.237				
15	2.382	5.240				
16	2.382	5.247	[			]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	2.777	[			]
2	2.382	2.861				
3	2.382	2.948				
4	2.382	3.019				
5	2.382	3.086				
6	2.382	3.154				
7	2.382	3.225				
8	2.382	3.297				
9	2.382	3.356				
10	2.382	3.435				
11	2.382	3.517				
12	2.382	3.607				
13	2.382	3.707				
14	2.382	3.813				
15	2.382	3.905				
16	2.382	4.003	[			]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.482	[			]
2	2.382	3.478				
3	2.382	3.471				
4	2.382	3.441				
5	2.382	3.404				
6	2.382	3.364				
7	2.382	3.321				
8	2.382	3.272				
9	2.382	3.236				
10	2.382	3.191				
11	2.382	3.138				
12	2.382	3.082				
13	2.382	3.022				
14	2.382	2.953				
15	2.382	2.866				
16	2.382	2.777	[			]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 3.915 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-6

ASSEMBLY SERIAL NO P1C025

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	2.916	[			]
2	2.382	3.038				
3	2.382	3.159				
4	2.382	3.261				
5	2.382	3.360				
6	2.382	3.457				
7	2.382	3.552				
8	2.382	3.643				
9	2.382	3.715				
10	2.382	3.811				
11	2.382	3.907				
12	2.382	4.006				
13	2.382	4.110				
14	2.382	4.212				
15	2.382	4.292				
16	2.382	4.367				]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	4.366	[			]
2	2.382	4.291				
3	2.382	4.212				
4	2.382	4.110				
5	2.382	4.006				
6	2.382	3.907				
7	2.382	3.811				
8	2.382	3.715				
9	2.382	3.642				
10	2.382	3.552				
11	2.382	3.457				
12	2.382	3.360				
13	2.382	3.262				
14	2.382	3.159				
15	2.382	3.037				
16	2.382	2.916	[			]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.575	[			]
2	2.382	5.572				
3	2.382	5.570				
4	2.382	5.533				
5	2.382	5.481				
6	2.382	5.420				
7	2.382	5.357				
8	2.382	5.285				
9	2.382	5.213				
10	2.382	5.119				
11	2.382	5.020				
12	2.382	4.918				
13	2.382	4.806				
14	2.382	4.677				
15	2.382	4.519				
16	2.382	4.366	[			]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	4.367	[			]
2	2.382	4.519				
3	2.382	4.677				
4	2.382	4.806				
5	2.382	4.918				
6	2.382	5.019				
7	2.382	5.118				
8	2.382	5.212				
9	2.382	5.283				
10	2.382	5.356				
11	2.382	5.420				
12	2.382	5.481				
13	2.382	5.534				
14	2.382	5.570				
15	2.382	5.573				
16	2.382	5.575	[			]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 4.299 X1E21, n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-7

ASSEMBLY SERIAL NO: P1C039

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.356	[			]
2	2.382	5.336				
3	2.382	5.300				
4	2.382	5.237				
5	2.382	5.144				
6	2.382	5.033				
7	2.382	4.908				
8	2.382	4.767				
9	2.382	4.742				
10	2.382	4.566				
11	2.382	4.387				
12	2.382	4.203				
13	2.382	4.003				
14	2.382	3.783				
15	2.382	3.537				
16	2.382	3.292				]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.356	[			]
2	2.382	5.383				
3	2.382	5.417				
4	2.382	5.422				
5	2.382	5.414				
6	2.382	5.403				
7	2.382	5.397				
8	2.382	5.393				
9	2.382	5.393				
10	2.382	5.397				
11	2.382	5.403				
12	2.382	5.414				
13	2.382	5.422				
14	2.382	5.417				
15	2.382	5.383				
16	2.382	5.356				]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.292	[			]
2	2.382	3.537				
3	2.382	3.783				
4	2.382	4.003				
5	2.382	4.203				
6	2.382	4.387				
7	2.382	4.566				
8	2.382	4.742				
9	2.382	4.767				
10	2.382	4.909				
11	2.382	5.033				
12	2.382	5.144				
13	2.382	5.237				
14	2.382	5.306				
15	2.382	5.336				
16	2.382	5.356				]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	3.292	[			]
2	2.382	3.322				
3	2.382	3.348				
4	2.382	3.354				
5	2.382	3.356				
6	2.382	3.358				
7	2.382	3.360				
8	2.382	3.356				
9	2.382	3.356				
10	2.382	3.360				
11	2.382	3.358				
12	2.382	3.356				
13	2.382	3.354				
14	2.382	3.348				
15	2.382	3.322				
16	2.382	3.292				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 4.384 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-8

ASSEMBLY SERIAL NO P2C114

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.276	[			]
2	2.382	5.285				
3	2.382	5.327				
4	2.382	5.327				
5	2.382	5.279				
6	2.382	5.218				
7	2.382	5.190				
8	2.382	5.153				
9	2.382	5.107				
10	2.382	5.008				
11	2.382	4.903				
12	2.382	4.830				
13	2.382	4.746				
14	2.382	4.617				
15	2.382	4.456				
16	2.382	4.328				]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.752	[			]
2	2.382	5.785				
3	2.382	5.859				
4	2.382	5.893				
5	2.382	5.877				
6	2.382	5.851				
7	2.382	5.862				
8	2.382	5.860				
9	2.382	5.841				
10	2.382	5.773				
11	2.382	5.696				
12	2.382	5.657				
13	2.382	5.604				
14	2.382	5.503				
15	2.382	5.366				
16	2.382	5.276				]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	5.575	[			]
2	2.382	5.629				
3	2.382	5.734				
4	2.382	5.802				
5	2.382	5.820				
6	2.382	5.829				
7	2.382	5.881				
8	2.382	5.927				
9	2.382	5.913				
10	2.382	5.896				
11	2.382	5.869				
12	2.382	5.886				
13	2.382	5.896				
14	2.382	5.859				
15	2.382	5.782				
16	2.382	5.752				]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	4.328	[			]
2	2.382	4.493				
3	2.382	4.697				
4	2.382	4.867				
5	2.382	4.987				
6	2.382	5.089				
7	2.382	5.221				
8	2.382	5.342				
9	2.382	5.412				
10	2.382	5.462				
11	2.382	5.500				
12	2.382	5.570				
13	2.382	5.623				
14	2.382	5.624				
15	2.382	5.580				
16	2.382	5.575				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ]in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 5.214 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-9

ASSEMBLY SERIAL NO P10001

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.474	1.834	[			]
2	2.469	1.815				
3	2.463	1.799				
4	2.450	1.764				
5	2.469	1.723				
6	2.440	1.679				
7	2.472	1.634				
8	2.469	1.587				
9	2.452	1.553				
10	2.426	1.494				
11	2.466	1.432				
12	2.461	1.367				
13	2.472	1.299				
14	2.455	1.226				
15	2.465	1.140				
16	2.432	1.057				]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.440	2.228	[			]
2	2.449	2.244				
3	2.442	2.262				
4	2.458	2.259				
5	2.445	2.249				
6	2.452	2.234				
7	2.431	2.217				
8	2.449	2.194				
9	2.449	2.182				
10	2.451	2.147				
11	2.438	2.110				
12	2.442	2.070				
13	2.466	2.025				
14	2.470	1.973				
15	2.470	1.901				
16	2.474	1.834				]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.442	1.969	[			]
2	2.442	2.032				
3	2.420	2.098				
4	2.428	2.144				
5	2.438	2.182				
6	2.410	2.215				
7	2.425	2.245				
8	2.431	2.271				
9	2.432	2.278				
10	2.420	2.294				
11	2.404	2.303				
12	2.434	2.307				
13	2.431	2.306				
14	2.401	2.297				
15	2.438	2.263				
16	2.440	2.228				]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.462	1.057	[			]
2	2.454	1.149				
3	2.449	1.243				
4	2.467	1.324				
5	2.439	1.401				
6	2.429	1.475				
7	2.438	1.546				
8	2.439	1.619				
9	2.433	1.656				
10	2.412	1.712				
11	2.433	1.767				
12	2.458	1.821				
13	2.458	1.871				
14	2.446	1.914				
15	2.464	1.940				
16	2.442	1.969				]

1) NOMINAL BOL SHOULDER GAP= CHARACTERIZED
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ]in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 1.867 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-10

ASSEMBLY SERIAL NO P1D002

FACE: 0

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.446	1.969	[			]
2	2.428	1.940				
3	2.400	1.914				
4	2.430	1.871				
5	2.435	1.821				
6	2.390	1.767				
7	2.430	1.712				
8	2.432	1.656				
9	2.435	1.615				
10	2.392	1.566				
11	2.435	1.475				
12	2.431	1.401				
13	2.435	1.324				
14	2.388	1.243				
15	2.436	1.149				
16	2.447	1.057				]

FACE: 90

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.420	2.228	[			]
2	2.428	2.263				
3	2.413	2.297				
4	2.418	2.306				
5	2.405	2.307				
6	2.382	2.303				
7	2.403	2.294				
8	2.420	2.278				
9	2.396	2.271				
10	2.412	2.245				
11	2.385	2.215				
12	2.402	2.182				
13	2.423	2.144				
14	2.425	2.098				
15	2.421	2.032				
16	2.446	1.969				]

FACE: 180

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.435	1.834	[			]
2	2.431	1.901				
3	2.410	1.973				
4	2.402	2.025				
5	2.418	2.070				
6	2.397	2.110				
7	2.394	2.147				
8	2.404	2.182				
9	2.431	2.194				
10	2.415	2.217				
11	2.428	2.234				
12	2.419	2.249				
13	2.399	2.259				
14	2.402	2.262				
15	2.418	2.244				
16	2.420	2.228				]

FACE: 270

ROD	BOL GAP (in.)	EOC-2 FLUENCE* (n/sq.cm)	EOC-2 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.447	1.057	[			]
2	2.418	1.140				
3	2.387	1.226				
4	2.430	1.299				
5	2.403	1.367				
6	2.429	1.432				
7	2.420	1.494				
8	2.424	1.553				
9	2.421	1.587				
10	2.420	1.634				
11	2.423	1.679				
12	2.428	1.723				
13	2.434	1.764				
14	2.420	1.799				
15	2.440	1.815				
16	2.435	1.834				]

1) NOMINAL BOL SHOULDER GAP= CHARACTERIZED
2) EOC-2 AVG GUIDE TUBE GROWTH= [ ]in.
3) EOC-2 AVG GUIDE TUBE FLUENCE= 1.867 X1E21,n/sq.cm.
4) BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV

Table A-11

PALO VERDE-1 EOC-2 GUIDE TUBE GROWTH DATA

Assembly	Average G.T. Fluence*	GUIDE TUBE GROWTH (in.) G.T. # 1	G.T. # 2	G.T. # 3	G.T. # 4	Average Growth (in.)
P1B120	5.49	[redacted]				
P1C002	4.41					
P1C005	4.38					
P1C017	3.92					
P1C025	4.30					
P1C039	4.38					
P1D001+	1.87					
P1D002+	1.87					
P2B233	5.67					
P2C114	5.21					

* FLUENCE XE-21, n/sq. cm., E>0.821MeV
\+ CHARACTERIZED ASSEMBLY
GUIDE TUBE IDENTIFICATION: #1-NE, #2-SE, #3-SW, #4-NW.