PALO VERDE NUCLEAR GENERATING STATION - UNIT 1
END-OF-CYCLE 3 FUEL EXAMINATION REPORT
CEN-419(V)-NP

July 31, 1992

A Report to
Arizona Public Services Company

from

ABB Combustion Engineering Nuclear Fuel
Windsor, Connecticut

LEGAL NOTICE

THIS REPORT WAS PREPARED AS AN ACCOUNT OF WORK PERFORMED BY ABB COMBUSTION ENGINEERING NUCLEAR POWER. NEITHER COMBUSTION ENGINEERING NOR ANY PERSON ACTING ON ITS BEHALF:

A. MAKES ANY WARRANTY OR REPRESENTATION, EXPRESSED OR IMPLIED INCLUDING THE WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY, WITH RESPECT TO THE ACCURACY, COMPLETENESS, OR USEFULNESS OF THE INFORMATION CONTAINED IN THIS REPORT, OR THAT THE USE OF ANY INFORMATION, APPARATUS, METHOD, OR PROCESS DISCLOSED IN THIS REPORT MAY NOT INFRINGE PRIVATELY OWNED RIGHTS; OR

B. ASSUMES ANY LIABILITIES WITH RESPECT TO THE USE OF, OR FOR DAMAGES RESULTING FROM THE USE OF, ANY INFORMATION, APPARATUS, METHOD OR PROCESS DISCLOSED IN THIS REPORT.

Table of Contents

List of Tables

List of Figures

1.0 INTRODUCTION

This report documents fuel examinations conducted during the End-of-Cycle 3 refueling outage at Palo Verde Nuclear Generating Station-Unit 1. The inspections were performed to fulfill examination requirements 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.

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-3 outage. A total of ten fuel assemblies were measured; seven Batch C, two Batch D, and one Batch E. 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 Shoulder Gap Design Basis

The design of Palo Verde-1 fuel assemblies, relative to the accommodation of fuel rod and assembly growth without interference between the top of the rods and the upper end fitting flow plate, was based on conservative assumptions and predictions. These assumptions are:

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

2. The guide tube growth prediction was based on the lower 95% value calculated using the methods described in Reference 1.

3. Fuel rod growth was predicted to be[ ]inches of growth per unit of fluence (nvt x 10^{21}). This growth rate predicts more growth than the upper 95% limit for the distribution of Batch C rods from ANO-2. These data represent the highest observed growth rate of any fuel examined by CE (Reference 2).

Table 1

Palo Verde-1 Fuel Assemblies Inspected[1] at EOC-3

Assembly[+] Serial Number	Number of Cycles Irradiated	Discharged @ EOC-3	Cycle-3 Core Location	EOC-3 Assembly Avg. Burnup (GWd/MTU)
C002[2]	3	x	J7	42.1
C005[2]	3	x	J15	42.3
C017[2]	3	x	G11	41.0
C025[2]	3	x	E13	39.8
C039[2]	3	x	R9	42.3
D001*[2]	2		N7	34.4
D002*[2]	2		G13	34.3
P2C027	3	x	C9	42.3
P2C028	3	x	J3	42.3
E312*	1		M9	24.7

+ Serial numbers prefixed by P1 unless otherwise noted.

* Characterized fuel assembly.

(1) Peripheral fuel rod shoulder gap and guide tube length measurements.

(2) Assemblies previously measured at EOC-1 and/or EOC-2.

Following Cycles 1 and 2, measurements and evaluations were performed to determine the availability of shoulder gap clearance for fuel assemblies that would be irradiated in Cycle 3 for a third cycle. These evaluations were reported in References 3 and 4. The conclusions developed by these evaluations were:

1. Fuel rod growth in Palo Verde assemblies is less than the growth predicted by the model used to determine design limits for shoulder gap.

2. Guide tube growth is greater than the lower 95% predicted growth that was used to determine the design limits for shoulder gap.

3. Adequate shoulder gap margin is available in Palo Verde assemblies, designed for irradiation through 3 cycles, to permit their irradiation in Cycle 3.

Examinations of fuel assemblies were performed after Cycle 3 to characterize shoulder gap and confirm the evaluation and predictions made after Cycle 2.

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-3 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 previous outages (Peferences 3 and 4).

2.3 Shoulder Gap 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 (1). The figure shows that the measured growth data continue to be greater than the lower 95% predicted growth. Therefore, it is concluded that the model used to predict guide tube length change is conservative 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[

]. The figure shows that the higher fluence data are all below the design basis. In addition, the data continue to indicate 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. The shoulder gap provided in assemblies designed for 3 cycles of operation was sufficient so that operation to an assembly average burnup of 42.3 GWd/MTU did not result in closure of any fuel rod shoulder gap.

FIGURE 1

PALO VERDE 1 SHOULDER GAP DECREASE

AT EOC-1, 2, AND 3

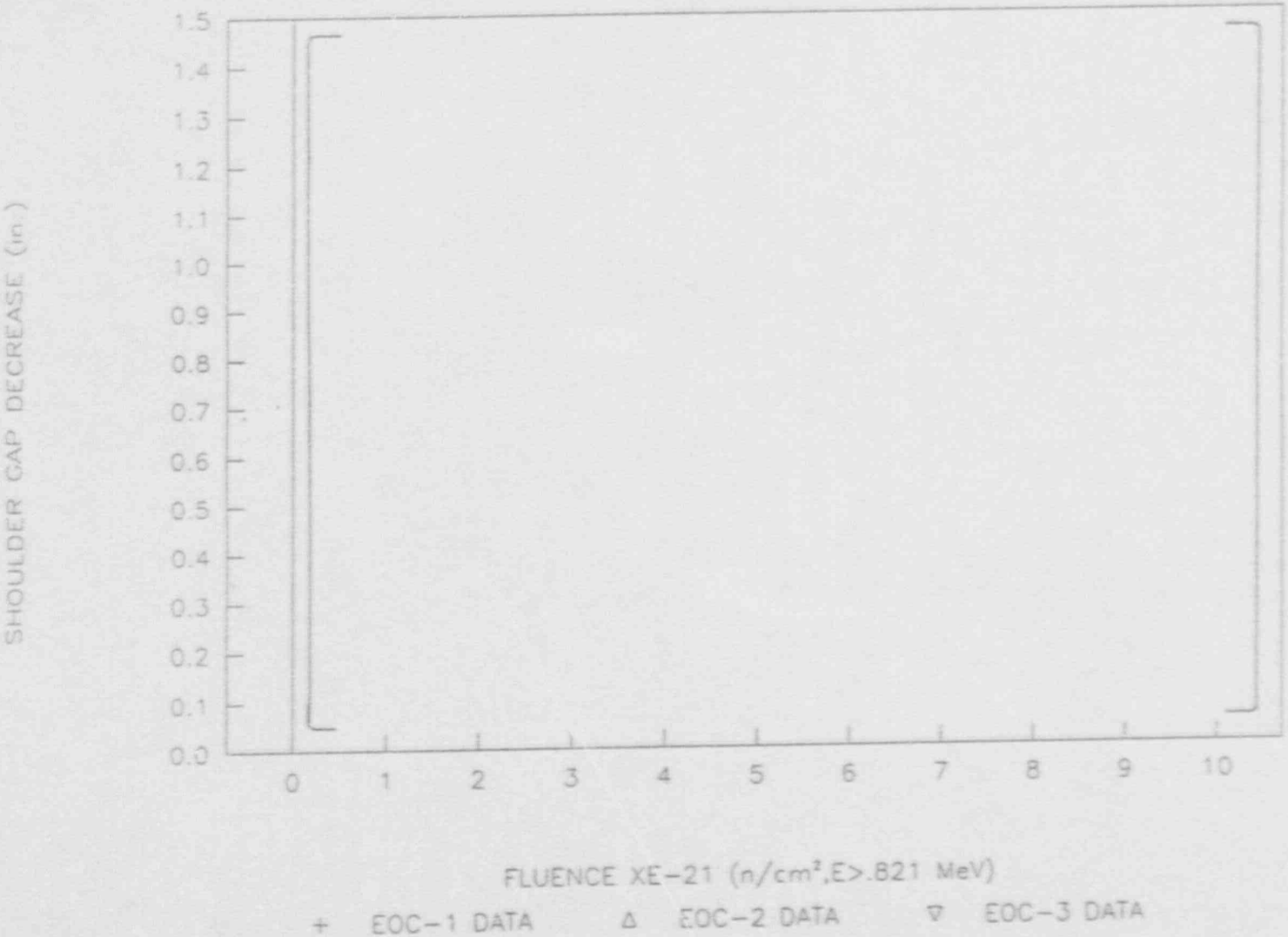


FIGURE 2

PALO VERDE 1 GUIDE TUBE GROWTH

AT EOC-1, 2, AND 3

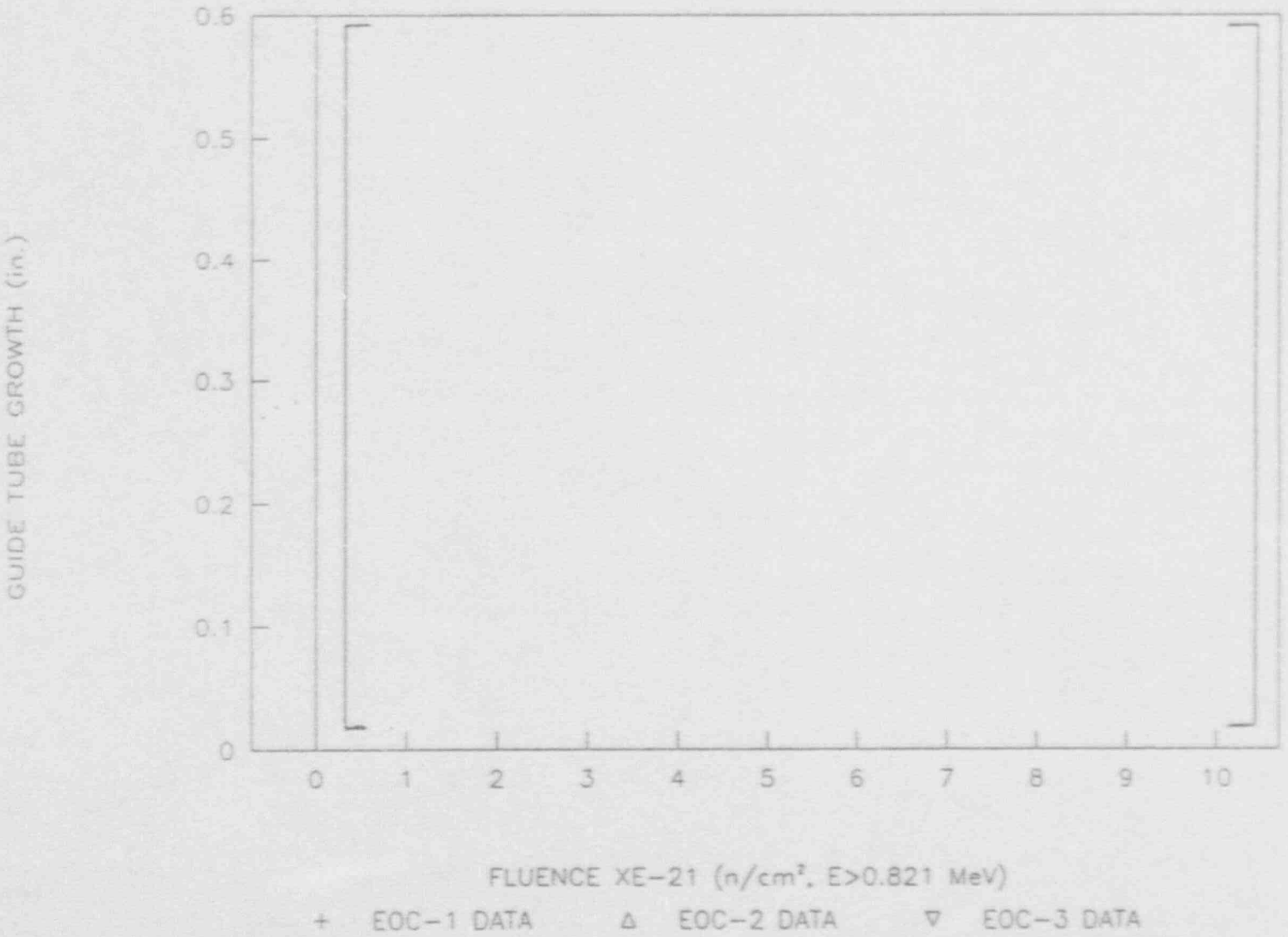
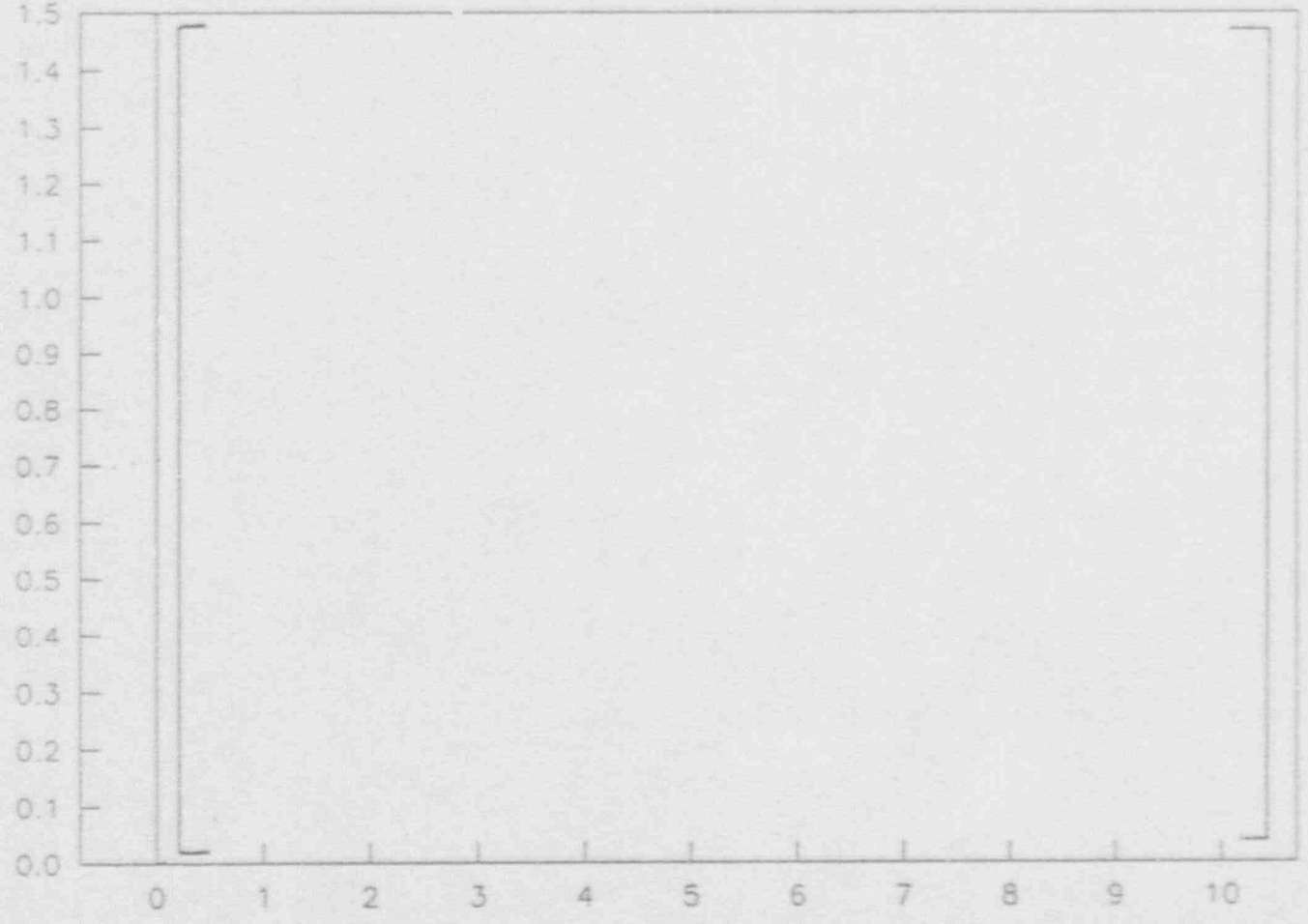


FIGURE 3

PALO VERDE 1 FUEL ROD GROWTH

AT EOC-1, 2, AND 3



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 3. Fuel rod growth data, determined from the measurements, indicates that the growth of fuel rods to a fluence of $\sim 9.5 \times 10^{21}$ n/cm^2 (E>0.821 MeV) 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 with increasing fluence. Guide tube length measurements indicate that the measured assemblies grew from [ ] to [ ] inches during three cycles of exposure with average guide tube fluences up to 8.18×10^{21} n/cm^2 (E >0.821 MeV) and assembly average burnups up to 42.3 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-3, 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 has been demonstrated for fuel assemblies designated for operation in Palo Verde to assembly average burnups of 44 GWd/MTU.

4.0 REFERENCES

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

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

(3) CE NPSD-426-P, "Palo Verde Nuclear Generating Station-Unit 1, End-of-Cycle 1 Fuel Examination Report, issued December, 1987.

(4) CEN-390(V)-P, "Palo Verde Nuclear Generating Station Unit 1 End of Cycle 2 Fuel Examination Report", issued October, 1989.

APPENDIX A

Palo Verde 1 Cycle 3

Fuel Assembly Dimensional Change Data

NOTE: Fuel rod growth strains were calculated using nominal BOL rod length.

ASSEMBLY SERIAL NO P1C002

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.278	[			]
2	2.382	9.295				
3	2.382	9.326				
4	2.382	9.323				
5	2.382	9.312				
6	2.382	9.303				
7	2.382	9.296				
8	2.382	9.282				
9	2.382	9.297				
10	2.382	9.281				
11	2.382	9.260				
12	2.382	9.240				
13	2.382	9.220				
14	2.382	9.192				
15	2.382	9.130				
16	2.382	9.082				]

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.592	[			]
2	2.382	7.621				
3	2.382	8.056				
4	2.382	8.249				
5	2.382	8.419				
6	2.382	8.574				
7	2.382	8.723				
8	2.382	8.857				
9	2.382	8.914				
10	2.382	9.013				
11	2.382	9.098				
12	2.382	9.178				
13	2.382	9.246				
14	2.382	9.289				
15	2.382	9.286				
16	2.382	9.278				]

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.481	[			]
2	2.382	7.534				
3	2.382	7.590				
4	2.382	7.614				
5	2.382	7.629				
6	2.382	7.644				
7	2.382	7.661				
8	2.382	7.670				
9	2.382	7.630				
10	2.382	7.639				
11	2.382	7.640				
12	2.382	7.644				
13	2.382	7.652				
14	2.382	7.653				
15	2.382	7.621				
16	2.382	7.592				]

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.082	[			]
2	2.382	9.074				
3	2.382	9.064				
4	2.382	9.010				
5	2.382	8.937				
6	2.382	8.856				
7	2.382	8.772				
8	2.382	8.677				
9	2.382	8.625				
10	2.382	8.499				
11	2.382	8.360				
12	2.382	8.217				
13	2.382	8.065				
14	2.382	7.894				
15	2.382	7.684				
16	2.382	7.481				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 8.095 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.
* FLUENCE E > 0.821 MeV, X1E-21.

Table A-2

ASSEMBLY SERIAL NO P1C005

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.507	[			]
2	2.382	7.532				
3	2.382	7.561				
4	2.382	7.559				
5	2.382	7.554				
6	2.382	7.553				
7	2.382	7.558				
8	2.382	7.555				
9	2.382	7.536				
10	2.382	7.541				
11	2.382	7.537				
12	2.382	7.537				
13	2.382	7.542				
14	2.382	7.543				
15	2.382	7.514				
16	2.382	7.489				]

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.445	[			]
2	2.382	9.426				
3	2.382	9.404				
4	2.382	9.337				
5	2.382	9.247				
6	2.382	9.144				
7	2.382	9.035				
8	2.382	8.908				
9	2.382	8.916				
10	2.382	8.747				
11	2.382	8.573				
12	2.382	8.398				
13	2.382	8.210				
14	2.382	7.999				
15	2.382	7.749				
16	2.382	7.507	[			]

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.426	[			]
2	2.382	9.454				
3	2.382	9.493				
4	2.382	9.498				
5	2.382	9.489				
6	2.382	9.480				
7	2.382	9.481				
8	2.382	9.480				
9	2.382	9.500				
10	2.382	9.500				
11	2.382	9.498				
12	2.382	9.507				
13	2.382	9.516				
14	2.382	9.512				
15	2.382	9.472				
16	2.382	9.445				]

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.489	[			]
2	2.382	7.731				
3	2.382	7.980				
4	2.382	8.191				
5	2.382	8.378				
6	2.382	8.552				
7	2.382	8.725				
8	2.382	8.890				
9	2.382	8.883				
10	2.382	9.013				
11	2.382	9.123				
12	2.382	9.226				
13	2.382	9.317				
14	2.382	9.384				
15	2.382	9.407				
16	2.382	9.426	[			]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 8.180 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21

Table A-3

ASSEMBLY SERIAL NO 91C017

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.460	[			]
2	2.382	9.444				
3	2.382	9.429				
4	2.382	9.370				
5	2.382	9.291				
6	2.382	9.206				
7	2.382	9.119				
8	2.382	9.021				
9	2.382	8.971				
10	2.382	8.840				
11	2.382	8.698				
12	2.382	8.553				
13	2.382	8.396				
14	2.382	8.216				
15	2.382	7.998				
16	2.382	7.785				]

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	8.281	[			]
2	2.382	8.470				
3	2.382	8.656				
4	2.382	8.794				
5	2.382	8.909				
6	2.382	9.013				
7	2.382	9.115				
8	2.382	9.203				
9	2.382	9.231				
10	2.382	9.289				
11	2.382	9.335				
12	2.382	9.386				
13	2.382	9.433				
14	2.382	9.464				
15	2.382	9.458				
16	2.382	9.460				]

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.161	[			]
2	2.382	7.251				
3	2.382	7.349				
4	2.382	7.418				
5	2.382	7.479				
6	2.382	7.543				
7	2.382	7.613				
8	2.382	7.681				
9	2.382	7.708				
10	2.382	7.776				
11	2.382	7.844				
12	2.382	7.925				
13	2.382	8.020				
14	2.382	8.120				
15	2.382	8.194				
16	2.382	8.281				]

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.785	[			]
2	2.382	7.790				
3	2.382	7.799				
4	2.382	7.774				
5	2.382	7.740				
6	2.382	7.707				
7	2.382	7.676				
8	2.382	7.635				
9	2.382	7.624				
10	2.382	7.581				
11	2.382	7.528				
12	2.382	7.475				
13	2.382	7.421				
14	2.382	7.354				
15	2.382	7.255				
16	2.382	7.161				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 7.880 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21.

Table A-4

ASSEMBLY SERIAL NO P1C025

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	6.178	[			]
2	2.382	6.300				
3	2.382	6.425				
4	2.382	6.526				
5	2.382	6.627				
6	2.382	6.736				
7	2.382	6.849				
8	2.382	6.961				
9	2.382	7.020				
10	2.382	7.144				
11	2.382	7.272				
12	2.382	7.411				
13	2.382	7.563				
14	2.382	7.722				
15	2.382	7.857				
16	2.382	7.998				]

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.997	[			]
2	2.382	7.856				
3	2.382	7.721				
4	2.382	7.562				
5	2.382	7.410				
6	2.382	7.271				
7	2.382	7.143				
8	2.382	7.018				
9	2.382	6.960				
10	2.382	6.848				
11	2.382	6.735				
12	2.382	6.627				
13	2.382	6.526				
14	2.382	6.425				
15	2.382	6.360				
16	2.382	6.178				]

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.508	[			]
2	2.382	9.485				
3	2.382	9.468				
4	2.382	9.410				
5	2.382	9.336				
6	2.382	9.257				
7	2.382	9.182				
8	2.382	9.093				
9	2.382	9.045				
10	2.382	8.926				
11	2.382	8.796				
12	2.382	8.669				
13	2.382	8.535				
14	2.382	8.380				
15	2.382	8.186				
16	2.382	7.997				]

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.998	[			]
2	2.382	8.188				
3	2.382	8.382				
4	2.382	8.536				
5	2.382	8.670				
6	2.382	8.797				
7	2.382	8.926				
8	2.382	9.045				
9	2.382	9.093				
10	2.382	9.182				
11	2.382	9.258				
12	2.382	9.337				
13	2.382	9.411				
14	2.382	9.468				
15	2.382	9.486				
16	2.382	9.508				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 7.588 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21.

ASSEMBLY SERIAL NO P1C039

Table A-5

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.445	[			]
2	2.382	9.426				
3	2.382	9.404				
4	2.382	9.337				
5	2.382	9.247				
6	2.382	9.144				
7	2.382	9.035				
8	2.382	8.908				
9	2.382	8.916				
10	2.382	8.747				
11	2.382	8.573				
12	2.382	8.398				
13	2.382	8.210				
14	2.382	7.999				
15	2.382	7.749				
16	2.382	7.507				]

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.426	[			]
2	2.382	9.454				
3	2.382	9.493				
4	2.382	9.498				
5	2.382	9.489				
6	2.382	9.480				
7	2.382	9.481				
8	2.382	9.480				
9	2.382	9.500				
10	2.382	9.500				
11	2.382	9.498				
12	2.382	9.507				
13	2.382	9.516				
14	2.382	9.512				
15	2.382	9.472				
16	2.382	9.445				]

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.489	[			]
2	2.382	7.731				
3	2.382	7.900				
4	2.382	8.191				
5	2.382	8.378				
6	2.382	8.552				
7	2.382	8.725				
8	2.382	8.890				
9	2.382	8.883				
10	2.382	9.013				
11	2.382	9.123				
12	2.382	9.226				
13	2.382	9.317				
14	2.382	9.384				
15	2.382	9.407				
16	2.382	9.426				]

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.507	[			]
2	2.382	7.532				
3	2.382	7.561				
4	2.382	7.559				
5	2.382	7.554				
6	2.382	7.553				
7	2.382	7.558				
8	2.382	7.555				
9	2.382	7.536				
10	2.382	7.541				
11	2.382	7.537				
12	2.382	7.537				
13	2.382	7.542				
14	2.382	7.543				
15	2.382	7.514				
16	2.382	7.489				]

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 8.180 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21.

ASSEMBLY SERIAL NO PZC027

Table A-6

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.489				
2	2.382	7.731				
3	2.382	7.980				
4	2.382	8.191				
5	2.382	8.378				
6	2.382	8.552				
7	2.382	8.725				
8	2.382	8.890				
9	2.382	8.883				
10	2.382	9.013				
11	2.382	9.123				
12	2.382	9.226				
13	2.382	9.317				
14	2.382	9.384				
15	2.382	9.407				
16	2.382	9.426				

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.507				
2	2.382	7.532				
3	2.382	7.561				
4	2.382	7.559				
5	2.382	7.554				
6	2.382	7.553				
7	2.382	7.558				
8	2.382	7.555				
9	2.382	7.536				
10	2.382	7.541				
11	2.382	7.537				
12	2.382	7.537				
13	2.382	7.542				
14	2.382	7.543				
15	2.382	7.514				
16	2.382	7.489				

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.445				
2	2.382	9.426				
3	2.382	9.404				
4	2.382	9.337				
5	2.382	9.247				
6	2.382	9.144				
7	2.382	9.035				
8	2.382	8.908				
9	2.382	8.916				
10	2.382	8.747				
11	2.382	8.573				
12	2.382	8.398				
13	2.382	8.210				
14	2.382	7.999				
15	2.382	7.749				
16	2.382	7.507				

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.426				
2	2.382	9.454				
3	2.382	9.493				
4	2.382	9.498				
5	2.382	9.489				
6	2.382	9.480				
7	2.382	9.481				
8	2.382	9.480				
9	2.382	9.500				
10	2.382	9.500				
11	2.382	9.498				
12	2.382	9.507				
13	2.382	9.516				
14	2.382	9.512				
15	2.382	9.472				
16	2.382	9.445				

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 8.18 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21.

Table A-7

ASSEMBLY SERIAL NO P2C028

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.426				
2	2.382	9.454				
3	2.382	9.493				
4	2.382	9.498				
5	2.382	9.489				
6	2.382	9.480				
7	2.382	9.481				
8	2.382	9.480				
9	2.382	9.500				
10	2.382	9.500				
11	2.382	9.498				
12	2.382	9.507				
13	2.382	9.516				
14	2.382	9.512				
15	2.382	9.472				
16	2.382	9.445				

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.489				
2	2.382	7.731				
3	2.382	7.980				
4	2.382	8.191				
5	2.382	8.378				
6	2.382	8.552				
7	2.38.	8.725				
8	2.382	8.890				
9	2.362	8.883				
10	2.382	9.013				
11	2.382	9.123				
12	2.382	9.226				
13	2.382	9.317				
14	2.382	9.384				
15	2.382	9.407				
16	2.382	9.426				

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	7.507				
2	2.382	7.532				
3	2.382	7.561				
4	2.382	7.559				
5	2.382	7.554				
6	2.382	7.553				
7	2.382	7.558				
8	2.382	7.555				
9	2.382	7.536				
10	2.382	7.541				
11	2.382	7.537				
12	2.382	7.537				
13	2.382	7.542				
14	2.382	7.543				
15	2.382	7.514				
16	2.382	7.489				

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.382	9.445				
2	2.382	9.476				
3	2.382	9.404				
4	2.382	9.337				
5	2.382	9.247				
6	2.382	9.144				
7	2.382	9.035				
8	2.302	8.908				
9	2.382	8.916				
10	2.382	8.747				
11	2.382	8.573				
12	2.382	8.398				
13	2.382	8.210				
14	2.382	7.999				
15	2.382	7.749				
16	2.382	7.507				

1) NOMINAL BOL SHOULDER GAP= 2.382 in.
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 8.18 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21.

ASSEMBLY SERIAL NO P10001

Table A-8

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.474	6.468	[			]
2	2.469	6.491				
3	2.443	6.524				
4	2.450	6.509				
5	2.469	6.478				
6	2.440	6.442				
7	2.472	6.406				
8	2.469	6.362				
9	2.452	6.303				
10	2.426	6.222				
11	2.466	6.131				
12	2.461	6.037				
13	2.472	5.938				
14	2.455	5.823				
15	2.465	5.663				
16	2.432	5.505				

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.440	6.803	[			]
2	2.449	6.864				
3	2.442	6.938				
4	2.458	6.963				
5	2.445	6.973				
6	2.452	6.979				
7	2.431	6.984				
8	2.449	6.980				
9	2.449	6.948				
10	2.451	6.908				
11	2.438	6.861				
12	2.442	6.813				
13	2.466	6.760				
14	2.470	6.690				
15	2.470	6.574				
16	2.474	6.468				

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.442	6.381	[			]
2	2.442	6.505				
3	2.420	6.632				
4	2.428	6.710				
5	2.438	6.773				
6	2.410	6.829				
7	2.425	6.884				
8	2.431	6.931				
9	2.432	6.965				
10	2.420	6.981				
11	2.404	6.983				
12	2.434	6.981				
13	2.431	6.973				
14	2.401	6.949				
15	2.438	6.874				
16	2.440	6.803				

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.462	5.505	[			]
2	2.454	5.615				
3	2.449	5.738				
4	2.467	5.822				
5	2.439	5.899				
6	2.429	5.974				
7	2.438	6.048				
8	2.439	6.116				
9	2.433	6.176				
10	2.412	6.222				
11	2.433	6.264				
12	2.458	6.307				
13	2.458	6.348				
14	2.446	6.379				
15	2.464	6.371				
16	2.442	6.381				

1) NOMINAL BOL SHOULDER GAP= CHARACTERIZED
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 6.24 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.138 in.

* FLUENCE E > 0.821 MeV, X1E-21.

ASSEMBLY SERIAL NO P10002

Table A-9

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.446	6.371				
2	2.428	6.359				
3	2.400	6.367				
4	2.420	6.334				
5	2.435	6.293				
6	2.390	6.249				
7	2.430	6.206				
8	2.432	6.159				
9	2.435	6.100				
10	2.392	6.033				
11	2.435	5.960				
12	2.431	5.884				
13	2.435	5.806				
14	2.388	5.720				
15	2.436	5.597				
16	2.447	5.488				

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.420	6.758				
2	2.428	6.826				
3	2.413	6.900				
4	2.418	6.924				
5	2.405	6.935				
6	2.382	6.939				
7	2.403	6.940				
8	2.420	6.928				
9	2.396	6.895				
10	2.412	6.854				
11	2.385	6.804				
12	2.402	6.751				
13	2.423	6.693				
14	2.425	6.618				
15	2.421	6.494				
16	2.446	6.371				

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.435	6.447				
2	2.431	6.553				
3	2.410	6.669				
4	2.402	6.738				
5	2.418	6.790				
6	2.397	6.837				
7	2.394	6.882				
8	2.404	6.918				
9	2.431	6.950				
10	2.415	6.955				
11	2.428	6.948				
12	2.419	6.940				
13	2.399	6.927				
14	2.402	6.900				
15	2.418	6.823				
16	2.420	6.758				

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.447	5.488				
2	2.418	5.646				
3	2.387	5.806				
4	2.430	5.919				
5	2.403	6.017				
6	2.429	6.109				
7	2.420	6.200				
8	2.424	6.280				
9	2.421	6.342				
10	2.420	6.386				
11	2.423	6.422				
12	2.428	6.458				
13	2.434	6.488				
14	2.420	6.502				
15	2.440	6.470				
16	2.435	6.447				

1) NOMINAL BOL SHOULDER GAP= CHARACTERIZED
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 6.22 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21.

ASSEMBLY SERIAL NO P1E312

Table A-10

FACE: 0

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.442	4.293				
2	2.419	4.331				
3	2.387	4.390				
4	2.390	4.438				
5	2.381	4.451				
6	2.380	4.463				
7	2.382	4.510				
8	2.385	4.556				
9	2.379	4.553				
10	2.375	4.535				
11	2.390	4.515				
12	2.382	4.531				
13	2.397	4.544				
14	2.384	4.522				
15	2.396	4.488				
16	2.417	4.477				

FACE: 90

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.422	4.285				
2	2.433	4.286				
3	2.391	4.308				
4	2.379	4.323				
5	2.383	4.308				
6	2.378	4.296				
7	2.373	4.322				
8	2.369	4.349				
9	2.380	4.359				
10	2.378	4.331				
11	2.375	4.305				
12	2.381	4.317				
13	2.379	4.332				
14	2.388	4.317				
15	2.417	4.295				
16	2.442	4.293				

FACE: 180

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.440	4.481				
2	2.416	4.490				
3	2.379	4.522				
4	2.365	4.544				
5	2.385	4.530				
6	2.369	4.512				
7	2.386	4.531				
8	2.369	4.547				
9	2.387	4.551				
10	2.376	4.505				
11	.372	4.457				
12	2.377	4.445				
13	2.380	4.431				
14	2.378	4.383				
15	2.436	4.324				
16	2.422	4.285				

FACE: 270

ROD	BOL GAP (in.)	EOC-3 FLUENCE* (n/sq.cm)	EOC-3 SH. GAP (in.)	GAP CLOSURE (in.)	ROD GROWTH (in.)	GROWTH STRAIN (%)
1	2.417	4.477				
2	2.421	4.496				
3	2.390	4.537				
4	2.383	4.568				
5	2.377	4.565				
6	2.379	4.561				
7	2.389	4.594				
8	2.383	4.626				
9	2.373	4.626				
10	2.385	4.596				
11	2.381	4.564				
12	2.394	4.569				
13	2.374	4.573				
14	2.399	4.542				
15	2.431	4.501				
16	2.440	4.481				

1) NOMINAL BOL SHOULDER GAP= Characterized
2) EOC-3 AVG GUIDE TUBE GROWTH= [ ] in.
3) EOC-3 AVG GUIDE TUBE FLUENCE= 4.23 X1E21,n/sq.cm.
4) AVERAGE BOL ROD LENGTH= 161.168 in.

* FLUENCE E > 0.821 MeV, X1E-21.

Table A-11

PALO VERDE-1 EOC-3 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.)
P1E312+	4.23	[redacted]				
P1C002	8.09					
P1C005	8.18					
P1C017	7.88					
P1C025	7.58					
P1C039	8.18					
P1D001+	6.24					
P1D002+	6.22					
P2C027	8.18					
P2C028	8.18					

* FLUENCE XE-21, n/sq. cm., E>0.821MeV

\+ CHARACTERIZED ASSEMBLY

GUIDE TUBE IDENTIFICATION: #1-NE, #2-SE, #3-SW, #4-NW.