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SAXTON PLUTONIUM PROJECT
QUARTERLY PROGRESS REPORT FOR THE PERIOD
ENDING DECEMBER 31, 1970

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SECTION 1

INTRODUCTION AND SUMMARY

1.1 SCOPE

This quarterly report covers work completed on the Saxton Plutonium Project during the period October through December 1970.

1.2 OBJECTIVES

The overall purpose of the Saxton Plutonium Project is to develop information concerning the utilization of plutonium enriched fuel in pressurized water reactor systems. The program includes design, fabrication, operation and post-irradiation examination of a partial plutonium core. The in-pile performance of the fuel will be evaluated and compared with analytical predictions.

1.3 PROJECT ADMINISTRATION

The quarterly report for the July-September, 1970, period was written, reviewed, and released. The revised work program was approved by the AEC. In addition, the AEC approved an extension of Core III operating time to 6000-7000 effective full power hours with a mid-life shutdown at about 3500 EFPH. Final editing of the following two topical reports was completed:

1. WCAP-3385-55 (EURAE 2108), "Saxton Core II Nuclear Operations Summary."
2. WCAP-3385-56, "Saxton Core II Fuel Performance Evaluation, Part II; Evaluation of Mass Spectrometric and Radiochemical Analyses of Irradiated Saxton Plutonium Fuel."

Check copies of these two reports were prepared and submitted to the AEC for patent and technical release. WCAP-3385-56, Part II was revised to show the effect of corrected Pu-239/U-238 ratios on all burnup values and measured versus calculated abundances.

1.4 SUMMARY OF PROGRESS DURING THE PERIOD

The Saxton reactor operated at power for approximately 43 days during the quarter. As of December 31, 1970 the cumulative energy generated in Core III was 3033 megawatt days, with a total of 345 load follow cycles. The peak burnups in the loose lattice region were:

1. For peak power rod	32,200 MWD/MTM
2. For highest burnup rod	41,100 MWD/MTM

The post-irradiation examination of rod RR continued with the following tasks being completed:

1. Evaluation of gamma scan data
2. Length measurements
3. Profilometry
4. Fission gas collection and analysis
5. Sectioning
6. Burnup analysis
7. Metallography

The results of these examinations are given in Section 3.0 of this report.

SECTION 2

CORE III OPERATIONS

(C. E. Palmer & R. L. Stover)

During October the reactor was operated for 20 days and was shut down 11 days for maintenance and training. In November it was operated for 13 days and shut down for 17 days. During December the reactor was operated for ten days and was shut down for 21 days, primarily for operator training and licensing.

As of December 31, 1970 the cumulative energy generated in Core III was 3033 megawatt days with a fourth quarter total of 900 megawatt days. An additional 161 load follow cycles were achieved, resulting in a total of 345 since the beginning of Core III.

An unexplained shift in the primary flow meter calibration resulted in slight errors (approximately 4 percent low) in the primary thermal power as calculated for August through November, 1970. During a maintenance shutdown the primary flow instrumentation was calibrated. The errors in the Core III burnup data were corrected, resulting in an agreement between the accumulated core burnup based on primary and secondary power within 0.13 percent.

Flux map data were analyzed to provide relative assembly and rod power levels at a Core III peak burnup of 38,000 MWD/MTM. Figure 2-1 shows the measured values for all assemblies in the core and compares them with the predicted power levels. Table 2-1 summarizes the operating history of key rods in the loose lattice region of Core III during the last quarter; it includes the best estimate peak linear power achieved during the quarter and burnup of the lead rods.

Figure 2-2 shows the boron follow curve through November 23, 1970. The extrapolated core life is 6000 effective full power hours. Core life can be extended to 6800 effective full power hours with coastdown to 50 percent power.

TABLE 2-1

SUMMARY OF SAXTON CORE III OPERATING HISTORY - FOURTH QUARTER 1970

	Through Sept. 30	During Oct. Nov. & Dec.	Cumulative to Dec. 31
Energy generated, MWD	2,133	900	3,033
Number of Load Cycles	184	161	345
Peak Linear Power, kw/ft (a)			
1. Peak Power Rod	19.0	19.0	----
2. Peak Burnup Rod (in center 3 x 3)	15.6	16.2	----
3. Peak Burnup Rod Outside Center 3 x 3	9.8	9.6	----
Peak Pellet Burnup, MWD/MTM ^(b)			
1. Peak Power Rod	27,600	4,600	32,200
2. Peak Burnup Rod	37,100	4,000	41,100
3. Peak Burnup Rod Outside Center 3 x 3	33,500	2,300	35,800

(a) Best Estimate, Thermal Basis (Thermal = 0.974 of Fission)

(b) Best Estimate, Fission Basis

- (1) PREDICTED
 (2) MEASURED
 (3) $\frac{\text{MEASURED} - \text{PREDICTED}}{\text{PREDICTED}} \times 100$

ROD 2 = 17 INCHES (OUT = 36.6 INCHES)

Figure 2-1. Relative Assembly Power for Saxton Core III

Figure 2-2. Saxton Core III Boron Curve

SECTION 3

EVALUATION OF CORE III FUEL

(J. T. Barnes, D. Durigon, J. R. Guthridge, J. F. Mellor,
N. R. Metcalf, G. W. Parry, E. S. Schwartz,
W. R. Smalley, and D. Workman)

3.1 NON-DESTRUCTIVE EXAMINATION OF ROD RR

The gamma scan data were plotted (Figure 3-1) and used to select the location of metallographic and burnup samples. The effect of the four grids is evident in the gamma scan at approximately 5, 15, 25 and 35 inches from the bottom of the rod.

Rod length measurements were completed. The length data indicate an increase of 0.22 percent which is equal to the maximum measured length change observed at the end of Core II. ⁽¹⁾

Rod RR was scanned with the in-cell profilometer, and no abnormalities such as blisters, ridging etc. were observed. The reduced profilometry data (average minimum and maximum diameter vs. axial position) are presented in Figure 3-2.

3.2 DESTRUCTIVE EXAMINATION OF ROD RR

3.2.1 Fission Gas Release

The rod was punctured for collection and analysis of the fission product gases, with the results summarized in Table 3-1. Preliminary evaluation of the data indicates a fractional release of 30 to 35 percent.

(1) W. R. Smalley, "Saxton Plutonium Program Semi-Annual Progress Report for the Period Ending June 30, 1969," WCAP-3385-20, October 1969.

Figure 3-1. Rod RR Gamma Scan Data Plot

Figure 3-2. Saxton Fuel Rod RR Profilometry at Waltz Mill

TABLE 3-1

MASS SPECTROMETRIC ANALYSIS OF FISSION GAS FROM ROD RR

Gas Volume 123.1 cm³ (STP)

Composition		Isotopic Analyses	
Gas	Mole-%	Isotope	Atom-%
H ₂	0.15	Kr-82	0.09
He	8.94	83	16.50
N ₂	0.78	84	30.02
O ₂	0.007	85	5.73
Ar	0.27	86	47.66
Kr	5.99		
Xe	83.87	Xe-128	0.03
		130	0.10
		131	12.45
		132	20.67
		134	27.70
		136	39.04

3.2.2 Sample Preparation

Copper plating was applied to certain areas to help preserve edges of corrosion films. The rod was then sectioned, and samples were prepared for metallographic, burnup, and hydrogen analyses.

3.2.3 Metallography

Two transverse sections of the rod were examined metallographically to determine the thickness of the corrosion oxide film, extent of hydride precipitation, evidence of fuel-clad interaction, and general fuel microstructure. These two samples, taken from positions 12.5 in. and 17.5 in. from the bottom of the rod, represent the peak power locations indicated by the gamma scan and in-core flux maps. The major microstructural features observed were as follows:

1. The oxide films on the outer surfaces of the cladding were relatively thick. Typically these films were 0.8-0.9 mil (Figure 3-3), but varied from 0.4 to 0.9 mil at the 12.5 inch location and from 0.5 to 1.0 mil at the 17.5 inch location. These film thicknesses are slightly greater than the maximum of ~0.8 mil observed on rods at the end of Saxton Core II.⁽²⁾
2. The extent of clad hydride precipitation was not significantly greater than in samples examined at end of Core II. Actual hydrogen concentrations will be checked by analysis of gases extracted from ring sections of cladding during the next period.
3. There was much evidence of inner surface oxidation of the cladding. The thickness of the gray ZrO_2 layer was typically 0.2 to 0.4 mil, similar to that observed on mixed oxide fuel at the end of Core II.⁽¹⁾ In addition, one of the sections exhibited local areas at the inner surface of the clad where the grain boundaries appeared to be oxidized. This condition will be evaluated further during the next quarter.

(1) W. R. Smalley, "Saxton Plutonium Program Semi-Annual Progress Report for the Period Ending June 30, 1969," WCAP-3385-20, October 1969.

(2) W. R. Smalley, "Saxton Plutonium Program Semi-annual Progress Report for the Period Ending December 31, 1969," WCAP-3385-22, March 1970.

Figure 3-3. O.D. Corrosion Film on Rod RR

4. Numerous areas were observed where the fuel appeared to be bonded to the clad inner surface (Figure 3-4).
5. Consistent with the higher linear power operation achieved in Core III, there was evidence of higher fuel temperatures than in the highest burnup Core II samples. A larger fraction of fuel exhibited equiaxed grain growth and metallic fission product precipitates. In addition, there was some evidence of columnar grains, numerous radially oriented pores, and a collection of large pores near the center of both samples. These conditions are illustrated in Figure 3-5.

3.2.4 Burnup Analysis

Two burnup samples from rod RR were dissolved and analyzed by mass spectrometric techniques. The data are presented in Table 3-2. The results of an evaluation to determine burnup and isotopic changes will be presented in the next quarterly report.

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Figure 3-4. Rod RR: Local Bonding of Fuel to Inner Surface of Cladding

Figure 3-5. Rod RR Fuel Cross Section, Edge to Center

TABLE 3-2

MASS SPECTROMETRIC ANALYSIS ROD RR

Sample Location (In. From Bottom Of Fuel Rod)	U Atom Percent Abundance				Pu Atom Percent Abundance ^a					Atom Ratio	
	U-234	U-235	U-236	U-238	Pu-238	Pu-239	Pu-240	Pu-241	Pu-242	Nd-148/U-238 (x 10 ⁴)	Pu-239/U-238 (x 10 ²)
11.0-11.5	0.00431	0.486	0.0506	99.459	0.315	61.411	28.084	8.627	1.563	5.943	3.097
18.5-19.0	0.00434	0.476	0.0530	99.467	0.346	60.302	28.673	8.984	1.695	6.062	2.972

^aDate of Analysis: December 10, 1970