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SAXTON PLUTONIUM PROJECT
QUARTERLY PROGRESS REPORT FOR THE PERIOD
ENDING MARCH 31, 1971

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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 January through March, 1971.

1.2 OBJECTIVES

The overall purpose of the Saxton Plutonium Project is to develop information concerning the utilization of plutonium enriched fuels 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 October-December, 1970, period was written, reviewed, and released. The following topical reports were released:

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."

The draft of the Core II materials evaluation topical report (WCAP-3385-56 Part I) was completed and submitted for internal review.

1.4 SUMMARY OF PROGRESS DURING THE PERIOD

The Saxton reactor operated at power for approximately 34 days during the quarter. As of March 31, 1970, the cumulative energy generated

in Core III was 3,637 MWD, with a total of 464 load follow cycles. The peak burnups in the loose lattice region were:

1. For peak power rod 32,900 MWD/MTM
2. For highest burnup rod 41,900 MWD/MTM

The Core III midlife post-irradiation examination rod sampling plan was prepared. The rod identities and planned examinations will be transmitted to the AEC early next quarter.

The post-irradiation examination of rod RR continued, with additional metallography samples being mounted and examined. The results of metallography and all progress during the quarter are summarized in Section 3.0 of this report.

SECTION 2

CORE III OPERATIONS

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

During January, the reactor was operated for 27 days and was shutdown for four days for testing and repairs. In February, it was operated for five days and was shutdown for 23 days in order to load special, short-term irradiation tests into the reactor. During March, the reactor was operated two days and shutdown for 29 days. Midlife shutdown began March 12, 1971. As of March 31, 1971, the cumulative energy generated in Core III was 3,637 MWD, with a first quarter 1971 total of 604 megawatt days. An additional 119 load follow cycles were achieved, resulting in a total of 464 since the beginning of Core III.

Flux map data were analyzed to provide relative assembly and rod power levels at a Core III energy production of 36000 MWD. Figure 2-1 shows the measured values for all assemblies in the core and compares them with the predicted power levels. The calculations are generally within 10 percent of measurement, with an overprediction of 9 percent in the center assembly power and an underprediction of power in peripheral assembly B-2 by 13 percent. 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 best estimate peak pellet burnup.

Figure 2-2 shows the boron follow curve to 3700 EFPH (midlife shutdown). The follow data continues to substantiate the estimated Core III end-of-life (zero boron) at 6000 EFPH $\pm$ 5 percent.

The prediction of axial power shapes from in-core flux data generally assumes that the number density of fissile nuclides is constant along the rod length. This assumption is not applicable to high burnup rods.

LEGEND:

(1) PREDICTED

(2) MEASURED

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

Figure 2-1. Relative Assembly Powers for Saxton Core III at a Core III Energy Production of 3600 MWD (Rod 2 at 17 Inches, Out = 36.6 Inches)

TABLE 2-1

SUMMARY OF SAXTON CORE III OPERATING HISTORY FIRST QUARTER 1971

	<u>Through Dec. 31, 1970</u>	<u>During Jan., Feb., March</u>	<u>Cumulative to March 31, 1971</u>
Energy generated, MWD	3,033	604	3,637
Number of load cycles	345	119	464
Peak Linear Power, kw/ft ^(a)			
1. Peak power rod	19.0	18.4	---
2. Peak burnup rod (in center 3x3)	16.2	15.7	---
3. Peak burnup rod (outside center 3x3)	13.1	12.2	---
Peak Pellet Burnup, MWD/MTM ^{(b)(c)}			
1. Peak power rod	29,900	3,000	32,900
2. Peak burnup rod	39,400	2,500	41,900
3. Peak burnup rod (outside center 3x3)	34,400	2,000	36,400

(a) Best estimate, thermal basis (thermal = 0.974 of fission)

(b) Best estimate, fission basis

(c) Burnup estimates reflect Core II EOL burnup adjustment

Figure 2-2. Saxton Core III Boron Curve

Calculations are now in progress to determine axial correction factors to apply to Core II and Core III predicted axial power shapes. The effect of these corrections is to depress the peak pellet power on the order of ten percent, while leaving the rod average power unchanged.

SECTION 3

EVALUATION OF CORE III FUEL (M. G. Balfour, G. W. Parry, W. R. Smalley)

3.1 DESTRUCTIVE EXAMINATION OF ROD RR

3.1.1 Clad Metallography, I.D. Reaction Zones

Discovery of a clad reaction zone where local grain boundary attack had occurred on the inner surface was reported previously.⁽¹⁾ One of two sections originally examined (at 17.5 inches from the bottom) exhibited this condition; the other (at 12.5 inches) did not. Further transverse (T) and longitudinal (L) sections were examined at 1.8-2.8 inches (L), 15.5-16.5 inches (L), 22.0 inches (T), 24.5-25.5 inches (L), 26.3-27.3 inches (L), 28.3 inches (T), and 36.0-37.6 inches (L, plenum region) from the bottom, respectively. Of these new sections, only the extreme positions did not show evidence of I.D. reaction zones. The remaining sections, between 15.5 and 28.3 inches from the bottom, all exhibited varying amounts of this condition. The peak heat flux section (12.5 inches) previously examined was reground ~200 mils and again was free of reaction zones, indicating that there is not a correlation with fuel rod power.

A typical I.D. reaction zone is shown in Figure 3-1. The zones are semi-elliptical in shape, and typically extend ~3 mils in length and ~1 mil in depth, although lengths up to 14 mils and depths up to 3 mils have been observed. The zones typically occur at several places around the clad circumference, with no consistent pattern. The clad is characterized by an apparent attack along the grain boundaries, and, in some cases, some of the grains have cracked or broken away from the rest of the Zircaloy clad (Figure 3-2). Etching of the specimen in Figure 3-1 revealed a "coring"

(1) W. R. Smalley, "Saxton Plutonium Project Quarterly Progress Report for the Period Ending December 31, 1970," WCAP-3385-26,

(500X)

Figure 3-1. Clad I.D. Reaction Zone Etched with Chromic Acid-Oxalic Acid

AS-POLISHED (500X)

Figure 3-2. I. D. Reaction Zone Showing Pullout of Clad Grains

effect within the grain boundaries. The intergranular nature of the attack has been confirmed by polarized light metallography and replication and electron microscopy. The size of the grains within the reaction zone is the same as the normal surrounding metal.

The reaction zones are usually associated with a locally thick I.D. oxide film that has partially pulled away (Figure 3-1). In general, there tends to be a greater bonding between the fuel and the ZrO_2 film than between the latter and the attacked clad regions. Several regions have been observed, however, where there is a uniformly thick, tightly adherent oxide film at the reaction zone.

Metallographic polishing of the specimens indicated that the reaction zones were more resistant, i.e. harder, than the surrounding material. Micro-hardness indentations (100 gm loads) confirmed this: the base metal produced hardness values of approximately 200 DPH, whereas, the reaction zone yielded values of 400-600 DPH.

This Zircaloy reaction condition may be similar to that observed by BNWL on a hyperstoichiometric mixed-oxide, hot-pressed pellet fuel specimen.⁽²⁾ Further evaluation will be performed in conjunction with examination of similar rods which will be removed during the Core III midlife shutdown, scheduled for April-July, 1971.

3.1.2 Clad Metallography, Hydrogen Analysis

None of the metallographic sections exhibited unusual amounts of clad hydride precipitation. Hot extraction hydrogen analyses of quarter-inch rings of clad will be performed during the next quarter.

3.1.3 Clad Metallography, Profilometry Evaluation

A longitudinal section was taken at 1-3/8 - 2-3/8 inches from the bottom of the rod to investigate a slight anomaly in the profilometer trace. The clad near the bottom of the fuel column down to the lower end plug showed an unusual average diametral increase of 1.2 mils and an ovality of ~3 mils (maximum)

(2) BNWL-1522-1, "Technical Activities Quarterly Report, AEC Reactor Development and Technology Program, July, August, September 1970," October 1970.

compared to ovality ≤ 1.5 mils at higher axial stations. Metallographic examination of a section of rod ML which had a similar profilometer trace revealed an unfailed hydride Zircaloy region.⁽³⁾ No hydriding of the Zircaloy clad or I.D. reaction zone was observed in the metallographic section, but one of the fuel pellets showed a large fuel-to-clad gap compared to the adjacent pellets. Extended reactor operation with this pellet-clad configuration could result in the relatively high ovality noted on the profilometer trace.

3.1.4 Fuel Metallography: Autoradiographs at Peak Heat Flux Positions

The previous Saxton Plutonium Quarterly Report⁽⁴⁾ presented evidence of incipient columnar grain formation and center voids at the peak heat flux locations of 12.5 (Core III) and 17.5 (Core II) inches from the bottom of the rod, respectively. A β - γ autoradiograph of the 12.5 inch section (Figure 3-3) shows a very slight annular depleted region about the center, which in a greater stage of development is characteristic of columnar grain growth. The 17.5 inch section β - γ autoradiograph did not exhibit this effect. The α -autoradiograph showed similar evidence of grain growth limits.

3.1.5 Burnup Analyses

Final reduction of the burnup results on rod RR, which requires crosschecking of the radiochemical analyses, will be reported in the next Quarterly report.

(3) W. R. Smalley, "Saxton Plutonium Project Quarterly Progress Report for the Period Ending March 31, 1970," WCAP-3385-23.

(4) W. R. Smalley, "Saxton Plutonium Project Quarterly Progress Report for the Period Ending December 31, 1970," WCAP-3385-26.

Figure 3-3. Photomacrograph β - γ Autoradiograph of Fuel Rod RR Transverse Section, Peak Heat Flux Zone, 12.5 Inches from Bottom of Rod