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SAXTON PLUTONIUM PROJECT
QUARTERLY PROGRESS REPORT FOR THE PERIOD
ENDING DECEMBER 1971

by

T. E. Caye
Project Engineer

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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, 1971.

1.2 OBJECTIVES

The overall objective 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 inpile performance of the fuel will be evaluated and compared with analytical predictions.

1.3 PROJECT ADMINISTRATION

The quarterly report for the July through September, 1971 (WCAP-3385-29) period was written, reviewed, and prepared for publication. Copies were transmitted for AEC patent release.

The report, "Saxton Core II Fuel Performance Evaluation Part I: Materials," WCAP-3385-56, was transmitted for AEC patent release.

1.4 SUMMARY OF PROGRESS DURING THE PERIOD

Post midlife physics operations commenced in November and were completed in December, 1971. Power operation, including load cycling, resumed in December. The cumulative energy generated as of December 31, 1971, was 4419 megawatt days, with a total of 503 load cycles. The peak burnups in the loose lattice region were:

1. For peak power rod	21,100 MWD/MTM
2. For highest burnup rod	45,500 MWD/MTM

The post irradiation examination of the seven loose lattice rods, which were removed during midlife shutdown, was essentially completed. Details of the work performed during the period are included in Section 3. Evaluation of the data is continuing.

SECTION 2

CORE III OPERATIONS

(C. E. PALMER, R. L. STOVER, AND T. E. CAYE)

The reactor was shutdown throughout the month of October, and from November 1 through November 17, 1971. Post-midlife at-power physics operation commenced on November 18, 1971. A total of 203 megawatt days of operation were accumulated during the month of November. At-power physics tests were completed on December 6, 1971. During December, the reactor operated at power for 25 days, with 6 days lost for AEC operator examinations and reactor scrams. As of December 31, 1971, the cumulative energy generated in Core III was 4419 megawatt days, with a last quarter total of 782 megawatt days. An additional 39 load follow cycles were achieved, resulting in a total of 503 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 3840 megawatt days. Figure 2-1 shows the post-midlife measured values for all assemblies in the core and compares them with the predicted power levels. Peak pellet powers and burnups through December 31, 1971 are shown in Table 2-1. Peak pellet burnup is 45,500 MWD/MTM in center 3 x 3 rod PF. The previously reported peak burnup rod (LZ) was removed from the core during the midlife shutdown.

Pre-midlife and post-midlife assembly relative powers are shown in Figure 2-2. The post-midlife measured powers, as shown in Figure 2-2, reflect rod and assembly loading changes which were effected during the midlife shutdown. The largest change (+13.5 percent) occurred where a fresh 5 w/o PuO_2 - UO_2 assembly was inserted for a depleted 5.7 w/o UO_2 assembly.

Figure 2-3 shows the boron follow curve to 3922 EFPH. The measured boron data extrapolates to 5700 EFPH.

TABLE 2-1

SUMMARY OF SAXTON CORE III OPERATION HISTORY
THROUGH DECEMBER 31, 1971

	<u>Through Sept. 30, 1971</u>	<u>During Oct., Nov. & Dec.</u>	<u>Cumulative to Dec. 31, 1971</u>
Energy generated, MWD	3,637	782	4,419
Number of load cycles	464	39	503
Peak linear power, kw/ft			
1. Peak power rod (b)	-----	21.2 (a)	-----
2. Peak burnup rod (in- center 3 x 3)	16.7	14.3 (a)	-----
3. Peak burnup rod (outside center 3 x 3)	13.0	12.2 (a)	-----
Peak pellet burnup, MWD/MTM(c)			
1. Peak power rod (b)	16,800	4,300	21,100
2. Peak burnup rod (in center 3 x 3)	42,600	2,900	45,500
3. Peak burnup rod (out- side center 3 x 3)	40,000	2,500	42,500

(a) Best estimate, thermal basis (thermal = 0.974 of fission) at core power of 25.0 MW_t.

(b) Inserted at MOL shutdown October 1971.

(c) Best estimate, fission basis.

KEY:

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

NOV. 30, 1971

Figure 2-1. Post-Midlife Assembly Powers

KEY:

- (1) MEASURED PRE-MOL (JAN. 1971)
 (2) MEASURED POST-MOL (NOV. 1971)
 (3) PERCENT CHANGE = $\frac{2-1}{1} \times 100$

Figure 2-2. Relative Assembly Powers for Saxton Core III

Figure 2-3. Saxton Core III Boron Curve

SECTION 3

EVALUATION OF CORE III FUEL*

(M. G. Balfour, N. R. Metcalf, G. W. Parry, A. C. Hott,
and T. E. Caye)

Effort during the last quarter of 1971 was concentrated on data collection. This emphasis resulted in the completion of most planned examinations. A comprehensive data reduction/evaluation effort has begun. Interpretation of the overall midlife results will continue into the next quarter.

Progress in data collection and summaries of preliminary evaluation of the data are presented in the following paragraphs for each of the PIE tasks.

3.1 NONDESTRUCTIVE EXAMINATIONS OF MIDLIFE RODS

3.1.1 Visual Examinations

As reported previously⁽¹⁾, all rods were visually examined and photographed to document clad surface conditions and crud distribution. No blisters, ridges, or other anomalies were observed in the clad or the end plug weld regions.

3.1.2 Profilometry Measurements

The profilometry measurements were completed on all seven loose lattice rods. The profiles consist of a continuous helical scan from approximately one inch from the bottom of each rod to the plenum region at the top. A preliminary evaluation of the profiles gave no indication of clad anomalies such as blisters, or ridges. Figure 3-1 shows a typical section of the helical profilometer trace from loose lattice rod NI. Reduction of the data has been initiated and the results will be compared to Core II values. A summary of these comparisons and midlife diametral data will be presented in the next quarterly report.

* Hot cell operation conducted by BMI, Columbus, under contract to Westinghouse Nuclear Fuel Division.

Figure 3-1. Typical Section of Profilometry Trace, Fuel Rod NI, Near Peak Heat Flux Position

3.1.3 Length Measurements

Length measurements have been completed on all seven loose lattice fuel rods. Table 3-1 summarized the length history of the rods included in the midlife sampling plan. Length data are tabulated for beginning of life Saxton Core II, end-of-life Saxton Core III, and middle-of-life Saxton Core III. Rod RR, which was removed from the center 3 x 3 subassembly in July, 1970, is included in the tabulation. Measurement uncertainty is estimated to be ± 0.002 in. for the preirradiation data, the end of Saxton Core II data and the 70-I shutdown data (rod RR). The observed length increases in Core III are consistent with the trend observed in Core II.

3.1.4 Gamma Scans

As reported previously, gamma scans of rods LZ, NI and FS were completed during the third quarter of 1971. The remaining four rods (BO, GL, MQ and RD) were gamma scanned during this quarter to complete the planned work scope. The system used has a calibrated specimen translation system which permits accurate correlation of rod axial positions with relative gamma activities. A preliminary review of the scans revealed no anomalies in the activity distribution of the loose lattice rods. A typical full length scan (rod BO) is included as Figure 3-2.

3.2 DESTRUCTIVE EXAMINATIONS OF MIDLIFE RODS

3.2.1 Fission Gas Collection

Rod puncture, fission gas collection, and mass spectrometric analysis of fission gas samples have been completed for all seven loose lattice fuel rods. Rods LZ and NI had been punctured prior to the last quarterly report, and the collection data were reported⁽¹⁾. The total volume of collected gas (corrected to STP) for each of the seven rods is listed in Table 3-2. Evaluation of the collection and mass spectrometric data is in progress and will be completed during the next quarter. Minor inconsistencies in the mass spectrometry data will be evaluated by analyzing duplicate gas samples.

TABLE 3-1

SAXTON MID-LIFE PIE LENGTH DATA

<u>Rod ID</u>	<u>Fabricated Length (inches)</u>	<u>Reconstitution (1) Length (inches)</u>	<u>Core III MOL Length (inches)</u>	<u>Core III Incremental Length Increase %ΔL/L_o</u>	<u>Total Length Increase %ΔL/L_o</u>
RR	39.083	39.159	39.168(2)	0.023	0.217
LZ	39.059	39.148	39.167	0.046	0.277
BO	30.064	39.119	39.140	0.054	0.195
FS	39.062	-----	39.148	-----	0.220
GL	39.057	-----	39.138	-----	0.207
MQ	39.060	39.146	39.159	0.033	0.253
NI	39.056	39.139	39.154	0.038	0.251
RD	39.082	39.129	39.139	0.026	0.146

NOTES:

(1) FS and GL were not measured at Reconstitution (Core III BOL)

(2) RR was removed for PIE at the Saxton July, 1970 shutdown.

Figure 3-2. Rod BO Gamma Scan Data Plot

TABLE 3-2

FISSION GAS COLLECTION RESULTS

<u>Rod ID No.</u>	<u>Peak Linear (1) Power KW/FT (BOL/MOL)</u>	<u>Burnup (2) Best Estimate Rod Average (MWD/MTM)</u>	<u>Total Volume Of Gas Collected (STP-cc)</u>
LZ	17.3/14.6	33,100	161
MQ	10.7/9.6	28,100	6
RO	21.0/17.8	25,500	138
NI	18.3/15.8	25,300	131
FS	15.4/13.0	25,000	98
GL	15.3/13.4	24,300	108
RD	17.1/15.2	24,100	122
RR	16.6/	25,100	123

(1) Powers are Core III beginning-of-life/midlife best estimate, thermal values at 23.5 MW reactor power.

(2) Burnups are best estimate fission values at discharge.

The low gas release observed in rod MQ will be further investigated. Preliminary review of the collection and mass spectrometry data indicates a possible failed rod. A careful review of all rod MQ post irradiation data (destructive and nondestructive) will be conducted in an effort to clarify the condition of the rod at the time of removal from the reactor.

3.2.2 Metallography

Two metallographic sections were prepared for each test rod. These samples were examined to determine the extent of clad oxidation and hydride precipitation, evidence of fuel clad interaction and general fuel microstructure. Preliminary evaluation of the metallographic sections may be summarized as follows:

Clad Metallography

1. The external corrosion film was generally moderate and uniform at the peak burnup locations. The maximum film thickness observed was 1.4 mils at the peak burnup location of rod LZ. This condition is illustrated in Figure 3-3.
2. The observed maximum external oxide thicknesses are consistent with the trend established by the lead Core II rods, and by rod RR which was removed and examined after the July, 1970, Core III shutdown.
3. Clad hydriding was generally light; the precipitates are circumferentially oriented on the midlife rods. The peak burnup rod LZ showed light-to-moderate hydride levels (See Figure 3-4.)

Fuel Metallography

1. Preliminary examination indicates that the fuel microstructures are generally very similar to Core II microstructures, except where sections have operated at higher power ratings. Sections from rods BO and NI which operated at peak power ratings in excess of 18 kw/ft, contain columnar grains and a well defined zone of large fission product particles near the center of the samples (see Figure 3-5). This section from BO contains a small

NOTE: THE OXIDE FILM HAS CRACKED PARALLEL TO THE CLAD. THE MAXIMUM THICKNESS (EXCLUDING THE CRACK) IS 1.40 MILS.

Figure 3-3. Maximum O.D. Oxide Film, Fuel Rod LZ, 20.75 Inches from Bottom

NOTE: THE O.D. OXIDE FILM IS PARTIALLY CRACKED ALONG THE CIRCUMFERENCE. PART OF THE LAYER OF NICKEL PLATING CAN BE SEEN ON TOP OF THE OXIDE IN THE RIGHT CENTER OF THE PICTURE.

Figure 3-4. Clad Hydriding, Fuel Rod LZ, Peak Heat Flux Location, 12 Inches from Bottom

Ng-B0-17

X. 16

Figure 3-5. Macrograph of Fuel Rod BO at Approximately 17 Inches from the Bottom of the Rod

3.2.2 (Continued)

central void. The sections from rods LZ and RD, which operated at peak powers (BOL) of 17 kw/ft show evidence of incipient columnar grain growth. The microstructure of rods FS and GL is similar to peak power rods examined at Core II end-of-life. The sections from rod MQ, which operated at a lower power in Core III than in Core II show microstructures which are indistinguishable from those observed in EOL Core II sections of comparable power.

2. The residual volume of the fuel-to-clad gaps and fuel cracks are smaller than observed in Core II fuel. All sections contain a normal pattern of cracks.

3.2.3 Clad Hydrogen and Manganese-54 Fast Flux Measurement

A total of eight Mn-54 and seven clad hydrogen samples were cut and prepared for examination. Selected quarter inch sections of clad will be analyzed for total hydrogen by hot vacuum extraction. The eight cladding samples will be analyzed for manganese-54 activity and iron content to determine fast fluence.

3.2.4 Burnup Analysis

All nine burnup samples, including one radial drill section, were cut, dissolved and sent for analysis. Mass spectrometric analyses of all samples were completed. Reduction of the isotopic data is in progress.

3.2.5 Autoradiography

All six autoradiographs were completed. A preliminary review revealed no unusual effects.

3.2.6 Clad Mechanical Properties

Burst and tensile tests were completed during the quarter. The burst tests were conducted at 675°F using hydraulic pressurization at a stress ratio of 2/1 (σ hoop/ σ long). The fuel was left intact for the tests. The tests were performed with no difficulties. The test data, which has not yet been reduced, will be evaluated during the next quarter. A transverse metallographic section

3.2.6 (Continued)

of the burst test specimen from rod NI is shown in Figure 3-6.

Specimen strains were monitored by measuring the specimen volume change during the test. A typical pressure/volume change curve is included as Figure 3-7.

Figure 3-6. Burst Test Specimen, Rod NI Transverse Metallographic Section

Figure 3-7. Pressure versus Specimen Volume Change, Rod GL at 675°F

SECTION 4

REFERENCES

1. T. E. Caye, "Saxton Plutonium Program Semi Annual Progress Report for the period ending September 30, 1971", WCAP-3385-29.