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MASTER

SAXTON PLUTONIUM PROJECT
QUARTERLY PROGRESS REPORT
FOR THE PERIOD ENDING
JUNE 30, 1970

By

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TABLE OF CONTENTS

Section	Title	Page
1.0	INTRODUCTION AND SUMMARY.	1-1
1.1	Scope.	1-1
1.2	Objectives	1-1
1.3	Project Administration	1-1
1.4	Summary of Progress During the Period.	1-1
2.0	POST-IRRADIATION EXAMINATION OF CORE II FUEL.	2-1
2.1	Burnup and Isotopic Analyses	2-1
2.2	Investigation of Local Hydriding	2-3
3.0	SAXTON CORE III OPERATIONS.	3-1
APPENDIX A	CORRECTED PLUTONIUM-239 TO URANIUM-238 MASS RATIOS OF IRRADIATED SAXTON CORE II FUEL SAMPLES	A-1

LIST OF TABLES

Table	Title	Page
2-1	Summary of Plutonium To-Uranium Ratios - Saxton Archive Fuel Sample OR-1	2-2
3-1	Summary of Saxton Core III Operations - Second Quarter 1970	3-1

SECTION 1

INTRODUCTION AND SUMMARY

1.1 SCOPE

This quarterly report covers work completed on the Saxton Plutonium Project during the period April through June 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 January-March 1970 period was written, reviewed, and released. Progress and expenditures for each of the program tasks were reviewed regularly during the quarter. A Work Program for Fiscal Year 1971 covering the extended burnup phase of the Saxton Plutonium Project was prepared. Except for preparation of the topical reports, all work relating to the evaluation of Core II fuel was terminated on June 30. For this cost-shared program, the AEC funding ended June 30, 1970. The balance of the program is funded by Westinghouse; however, reporting procedures remain unchanged.

1.4 SUMMARY OF PROGRESS DURING THE PERIOD

During the quarter, evaluation of all Core II post-irradiation data was completed, and the major portions of the topical report were written.

The discrepancy in beginning-of-life Pu:U ratios was investigated further, and the apparent source of the problem was determined. Appropriate corrections, where required, have been applied to all isotopic data. Further studies of archive fuel confirmed that rods containing batch #3 pellets were not locally hydrided prior to irradiation.

The Saxton reactor operated at full power, with load follow type cycling, for about 30 days during the quarter and was shutdown, as planned, on May 14. As of that date, the cumulative energy generated during Core III operation was 1685 megawatt-days, with a total of 138 load follow cycles. The calculated peak burnups in the loose lattice region as of the same date are as follows:

1. For the peak power rod	25,300 MWD/MTM
2. For the highest burnup rod	35,000 MWD/MTM

SECTION 2

POST-IRRADIATION EXAMINATION OF CORE II FUEL

(M. G. Balfour, J. L. Corbett, D. T. Galm, R. S. Miller, R. J. Nodvik,
W. R. Smalley, G. D. Workman)

2.1 BURNUP AND ISOTOPIC ANALYSES

The differences in beginning-of-life Pu/U ratios discussed in the last quarterly report^[1] were further studied to identify the source of the problem and possible effects on inferred burnup values. A sample of archive fuel (pellet batch OR-1) was sent to General Electric's Vallecitos Nuclear Center for a cross check of mass spectrometric analysis. The results for Pu-239/U-238 ratio were about 3 percent higher than those obtained earlier by the Westinghouse Advanced Reactors Division (WARD), but agreed within 1 percent of the fuel manufacturer's data. In addition, the WARD Mass Spectrometry Laboratory performed triplicate analyses on a well-characterized PuO₂-UO₂ sample from the New Brunswick Laboratory of the AEC. Again, the WARD results for Pu/U appeared to be biased low (by about 2 percent).

As a result of these discrepancies in Pu-to-U mass ratio, WARD completely recalibrated the ASTM triple spike solution used in the isotopic analyses. The data from this recalibration showed that the WARD calibration previously used for Pu/U ratio was low by 1.82 percent; it also revealed good agreement with the original calibration for Nd/U ratio. Therefore, all previously reported Pu-239/U-238 ratios in this program had to be increased by a factor of 1.0182. The effect of this correction on the re-analyzed archive samples from pellet batch OR-1 is shown in Table 2-1. Similar corrections have been applied to the data on irradiated samples and are presented in Appendix A.

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

TABLE 2-1

SUMMARY OF PLUTONIUM-TO-URANIUM RATIOS
SAXTON ARCHIVE FUEL SAMPLE OR-1

<u>Laboratory</u>	<u>Date of Analysis</u>	<u>Analytical Method</u>	<u>Pu/U Mass Ratio</u>
Numec	February 1965	Pu Assay ^(a)	0.0714
Numec	February 1965	Differential Spectrophotometry	0.0701
WARD	November 1969	Mass Spectrometry	0.0687 ^(b) 0.0700 ^(c)
WARD	March 1970	Mass Spectrometry	0.0689 ^(b) 0.0701 ^(c)
WARD	March 1970	Mass Spectrometry	0.0688 ^(b) 0.0701 ^(c)
GE-Val.	May 1970	Mass Spectrometry	0.0708

(a) Pu/U ratio calculated from Pu assay, oxygen to metal ratio, and total metallic impurities.

(b) Uncorrected value.

(c) Corrected value, based on most recent spike calibration.

During the period, all burnup and isotopic data on Core II fuel samples were evaluated and compared with predicted values. The comparison of burnup values was determined by two independent methods -- 1) Heavy element isotopic and 2) Nd-148 fission product concentration. It showed agreement to within one percent, thus verifying the internal consistency of the mass spectrometric data and the validity of the data-reduction methods.

Pellet burnups inferred from Cs-137 activity showed a -4 percent bias and indicated the possibility of about one percent Cs axial migration from the center to the ends of the fuel rod. Evaluation of Cs-137 data from radial microsamples showed a high degree of radial migration within the pellet, with inferred burnups being 70 percent lower at the center and 15 to 20 percent higher at the periphery than the burnups determined by the Nd-148 and heavy element methods.

Comparisons between unit cell calculations and measurements for the main chain uranium and plutonium isotopes showed agreement to within about 3 percent.

The calculations tend to underpredict the Pu-239 concentration by 3 percent; however, some of this discrepancy is attributed to uncertainties in the initial isotopic composition and plutonium concentration of the pre-irradiated fuel.

In the case of the special isotopes (i.e., those not included in the uranium and plutonium main chains), the unit cell calculations were in good agreement with measured values of Pu-236 and Am-241, and showed gross discrepancies for Np-237 and Pu-238. The calculations overpredicted Pu-236 by 8 percent and underpredicted Am-241 by 4 percent, both differences being well within the uncertainties of the measurements. The calculations underpredicted Np-237 and Pu-238 by about 30 percent.

All results of the burnup and isotopic analyses, the data reduction methods, unit cell calculations, and bases for the comparison of predicted vs. measured values are included in a topical report, "Evaluation of Irradiated Saxton Plutonium Fuel," WCAP-3385-56, to be issued during the next quarter.

2.2 INVESTIGATION OF LOCAL HYDRIDING

As reported previously,^[1] the investigation of local hydriding in rod ML indicated that stray hydrogenous contamination introduced during fabrication was the probable cause. Also, because of the suspect nature of fuel from pellet batch #3, archive rod MZ (containing batch #3 pellets) had been characterized for internal gas content, moisture in the fuel, and hydrogen in both fuel and cladding. These tests showed that pre-irradiation moisture contents and hydrogen levels were well below specified limits. Thus, it did not appear likely that pellet batch #3 as a whole had been contaminated by moisture or other hydrogenous impurity. As a further check to assure that rods containing batch #3 fuel had not been locally hydrided during fabrication, four pieces of tubing representing about 32 inches of cladding, were neutron radiographed at Battelle Memorial Institute (Columbus). The results confirmed the absence of local hydriding.

(1) Ibid.

SECTION 3

SAXTON CORE III OPERATIONS

(C. E. Palmer, R. J. Stover, D. M. Woodall)

After a one-month shutdown for repairs, maintenance, and training, the reactor was returned to power on April 9 and operated at full power (20.7 MWt)* with load follow cycling until April 17. It was then shut down for six days for further maintenance. From April 23 until the planned shutdown on May 14, the reactor was at 100 percent power (22.6 MWt)*, with load cycling. The reactor remained shut down from May 14 until the end of the period.

The following table summarizes the operating history of the extended burnup rods in the loose lattice region of Core III:

TABLE 3-1

SUMMARY OF SAXTON CORE III OPERATIONS - SECOND QUARTER 1970

	<u>Through March 31</u>	<u>During April</u>	<u>During May</u>	<u>Cumulative, to May 14</u>
Energy Generated, MWD	1098	317	270	1685
No. of Load Cycles	36	44	58	138
Max. Linear Power**kw/ft				
1. Peak Power Rod	18.2	19.6	19.8	-----
2. Peak Burnup Rod	15.0	16.1	16.3	-----
Burnup, MWD/MTM				
1. Peak Power Rod	22,100	1700	1500	25,300
2. Peak Burnup Rod	32,400	1400	1200	35,000

*Flux maps taken on April 13-15, 1970 showed that load follow cycling did not increase axial peaking factors substantially (only 1 percent). Thus, "100 percent power" was increased from 20.7 MWt to 22.6 MWt beginning April 23.

**Best estimate, thermal

APPENDIX A

CORRECTED PLUTONIUM-239 TO URANIUM-238 MASS RATIOS OF IRRADIATED SAXTON CORE II FUEL SAMPLES

Rod Number	Location - Inches From Bottom of Rod	$\frac{\text{Pu}^{239}}{\text{U}^{238}} \text{ Mass Ratio} \times 10^2$	
		Previously Reported ^(a)	Corrected
JF	8.8- 9.8	4.557	4.640
JF	17.8-18.8	4.364	4.443
MY	8.8- 9.8	4.559	4.642
MY	18.8-19.8	4.305	4.383
MY	28.8-29.8	4.814	4.902
RI	2.0- 2.8	5.359	5.457
RI	8.8- 9.8	4.556	4.639
RI	16.8-17.8	4.338	4.417
RI	18.8-19.8	4.331 ^(b)	4.410
RI	20.8-21.8	4.394	4.474
RI	23.8-24.8	4.727	4.813
RI	28.8-29.8	4.852	4.940
RI	35.3-36.0	5.518	5.618
TE	8.8- 9.8	3.837	3.907
TE	18.8-19.8	3.601	3.667
TE	28.8-19.8	4.238	4.315
TI	18.8-19.8	3.676	3.743
TP	18.8-19.8	3.603	3.669
TT	18.8-19.8	3.663	3.730
LA	18.8-19.8	3.733	3.801
K4	18.8-19.8	3.509	3.573
N1	18.8-19.8	3.510	3.574
N3	18.8-19.8	3.740	3.808
P0	8.8- 9.8	4.759	4.846
P0	16.8-17.8	4.246	4.323
P0	18.8-19.8	4.212	4.289
P0	28.8-29.8	4.481	4.563
S1	2.0- 2.8	5.240	5.335
S1	8.8- 9.8	4.439	4.520
S1	18.8-19.8	4.246	4.323
S1	28.8-29.8	4.763	4.850
S1	35.0-36.0	5.366	5.464

(a) Originally in Appendix A of WCAP-3385-22, Semi-annual Report for the Period Ending December 31, 1969.

(b) Average of three analyses.