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SAXTON PLUTONIUM PROJECT
QUARTERLY PROGRESS LETTER
FOR THE PERIOD
ENDING SEPTEMBER 30, 1969

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SECTION 1
PROJECT ADMINISTRATION AND SUMMARY

This letter covers the work done during the third quarter of Calendar 1969 and is in keeping with the previously approved procedure of issuing a limited distribution quarterly progress letter, instead of a bound report, while fuel irradiation continues.

During the period work resumed in the Hot Laboratory on the destructive examination of samples from Core II fuel rods. Examination and photomicrography of five additional metallographic samples were completed. All burnup samples were dissolved and aliquots of each transferred to the Analytical Laboratories. Five burnup samples and one archive sample were analyzed. Cross-check burnup analyses indicated a bias in Westinghouse data for $\text{Pu}^{239}/\text{U}^{238}$ and $\text{Nd}^{148}/\text{U}^{238}$, necessitating a recalibration. A one-inch long section of fuel rod was gamma scanned before and after removing the fuel to determine the contribution of the cladding to gross gamma activity. Ring sections of cladding were analyzed for hydrogen content and Mn^{54} activity, the latter to determine fast flux exposure. Twenty-two tensile samples of cladding and nine burst specimens were tested.

The Saxton reactor systems were functionally checked out early in the period, and Core III achieved criticality on July 15. Zero power physics testing continued throughout most of the period and flux data were successfully reduced with the INCORE code. Initial reactor operator training and examination commitments were completed in September.

A draft of the Semi-annual Report for the Period Ending June 30, 1969, (WCAP-3385-20) was written.

SECTION 2
POST-IRRADIATION EXAMINATION OF CORE II FUEL RODS

2.1 Metallography

Examination and photomicrography of the following metallographic samples were completed during the period:

1. Two grid contact areas, one of which showed significant fretting,
2. Peak heat flux region of lead Vipac rod (K4), and
3. Two samples with locally adherent corrosion product.

The examination of grid contact areas revealed normal concentration and orientation of hydrides. In addition, oxide film thicknesses were essentially the same as those on rods of similar temperature history in non-grid areas. The sample with significant fretting (4.25 in. from bottom of Rod K4) exhibited two fret marks, 90° apart, the largest of which was 0.123" long, 0.116" wide, and 0.009" deep. There was no evidence of any oxide film at the fretted surface.

The peak power section from the lead Vipac rod showed that in-pile sintering had occurred from the center to about 80% of the fuel radius. Limited columnar grain growth was also evident on this sample, indicating higher center temperatures than on pelleted rods of comparable burnup. In addition, most of the inner surface of the cladding exhibited an oxide-type layer, with apparent bonding of the fuel to the layer in many locations.

One of the pellet-fuel rods, which during visual examination showed dark patches of adherent crud, was sectioned in two locations to provide transverse samples for metallographic studies. The outer surfaces of both sections exhibited intermittent, semi-porous layers from 0.3 to 0.7 mil thick. The thick, porous nature of these layers suggest that they are corrosion product deposits (crud), as opposed to thin, relatively high density zirconium oxide films resulting from normal oxidation of Zirca-loy cladding.

Metallographic examination of five transverse sections removed from peak power locations (three pellet rods, two Vipac samples) was started.

2.2 Burnup Analysis

All 34 axial burnup samples and three unirradiated archive samples were dissolved, and diluted aliquots of each were transferred to the Analytical Laboratories. A multi-reagent system assured that all residues were dissolved. Six of the samples, including one archive, were analyzed but results were not reported because of further problems in mass spectrometric analysis. Although cross check burnup analyses received from General Electric and Idaho Nuclear were in good agreement with the Westinghouse heavy element isotopic abundances, they showed a bias of 1.9% and 3.4% (high) in the Westinghouse data for $\text{Pu}^{239}/\text{U}^{238}$ and $\text{Nd}^{148}/\text{U}^{238}$, respectively. A complete re-calibration of the spike solution was started to eliminate the bias. Resolution of the problem is expected during the next quarter.

Results of the mass spectrometric analysis of the initial burnup samples were processed with the REBUF data-reducing code.⁽¹⁾ This code, originally developed to process data for UO_2 , was modified for $\text{UO}_2\text{-PuO}_2$ fuel. As a means of estimating rod average burnup and axial burnup distributions, the pellet burnups were correlated with gross gamma activity for several key rods. On the assumption that the burnup-gamma activity correlation is linear, the rod average burnup for each rod in the program was determined and is listed in Table 1.

Single and multi-channel gamma scans of a one-inch long section from near the peak power region of Rod RI were completed. Fuel was removed from the sample, and the scans were repeated on the cladding. The results showed that the Zr-Nb^{95} in the cladding contributed about 2% to the gross gamma activity.

(1) R. J. Nodvik, "Evaluation of Mass Spectrometric and Radiochemical Analyses of Yankee Core I Spent Fuel," WCAP-6068, March 1966.

2.3 Hydrogen Analyses

Eight ring samples removed from three fuel rods were analyzed for hydrogen by hot vacuum extraction. The results, as given in Table 2, show slightly lower hydrogen levels than those obtained earlier on samples from Rod QE. The reason for the difference has not been determined, but is probably due to differences in hydrogen content at the beginning of life. Further evaluation of these data is currently in progress.

2.4 Fast Flux Dosimetry

Six sets of cladding samples were analyzed for Mn^{54} activity and iron content to determine fast flux exposure based on the Fe^{54} (n, p) Mn^{54} reaction. These samples represented six different axial positions in the highest burnup rods from Saxton Core II. The Mn^{54} activity measurements and the resulting fast fluence values are summarized in Table 3.

2.5 Mechanical Testing

All scheduled tensile tests of cladding samples were completed in the Mechanical Test Facility. The results, shown in Table 4, indicate similar strength levels for all samples, with no obvious correlation with fluence or location in Core II. In addition, all samples exhibited good ductility, as revealed by moderately high elongation (min. of 2.5% uniform elongation) and reduction of area (26 to 67%).

The in-cell burst test equipment was modified to facilitate remote manipulations and improve the accuracy of the strain measurement system. The test setup was checked out, and burst tests at 675°F were completed on nine cladding samples. The burst strength data from these tests are shown in Table 5. These results will be evaluated in the next semi-annual report.

SECTION 3
SAXTON OVERPOWER TEST

All operating data, core flux maps, and rod power calculations related to the overpower test were re-evaluated. As a result, the best estimate of peak linear power in rods A and B was revised to 18.7 kw/ft. A summary of the power levels achieved during various steps in the overpower test is shown in Table 6.

The principal reasons for the reduction in linear power levels from those previously reported are:

1. Previous power levels contained a 1.045 engineering factor, which is not consistent with a "best estimate" basis.
2. Axial variation in fission cross sections caused an error of ~4% in the measured axial power peaking factors in rods A and B.

The nominal peak linear power of 18.7 kw/ft appears to be consistent with the observed fuel microstructures in the overpower test rods. Further calculations are in progress to determine center temperatures and thermal gradients, based on the 18.7 kw/ft peak linear power.

SECTION 4

SAXTON CORE III OPERATION

Functional checkout of all reactor systems was completed early in July, and Core III achieved criticality on July 15, 1969. Nuclear constants required for interpretation of Core III flux map data were generated and used in analyzing the zero power physics measurements. Comparison of flux data reduction with the CDC-6600 and an on-site computer showed good agreement.

The zero power physics measurements indicated sufficient Core III lifetime to achieve the objective of 5000 effective full power hours. They also revealed an apparent 10% over-prediction of the loose lattice power levels due to greater measured power sharing in the assemblies near the periphery of Core III. Alternate control rod operating modes are being considered to increase the power level in the loose lattice region.

The initial reactor operator training and examination commitments were completed. On September 19, the reactor was cooled down for repair of an instrument conoseal port.

Table 1
Preliminary Estimate of Saxton Rod Average Burnup

<u>Rod I.D.</u>	<u>Fuel Type</u>	<u>Rod Average^(a) Gamma Activity, c/10-sec (x 10⁻⁵)</u>	<u>Estimated Rod^(b) Average Burnup (MWD/MTM)</u>
JF	Pellet	5.898	16,700
RI	Pellet	5.907	16,700
MY	Pellet	5.905	16,700
QE	Pellet	7.796	22,100
TE	Pellet	7.800	22,100
TI	Pellet	6.698	19,000
EC	Pellet	7.284	20,600
TT	Pellet	7.585	21,500
TP	Pellet	7.451	21,100
CH	Pellet	7.753	21,900
S1	Vipac	6.105	17,300
P0	Vipac	6.037	17,100
K4	Vipac	7.722	21,800
N3	Vipac	7.353	20,800
N1	Vipac	7.796	22,100
LA	Pellet	6.760	19,100
A	Pellet	7.814	17,400
B	Pellet	7.798	17,400
D	Pellet	4.485	10,600

Notes: (a) Referenced to January 28, 1969.

(b) Assumes linear correlation of burnup and gamma activity.

Table 2
Hydrogen in Irradiated Saxton Core II Fuel Cladding

<u>Rod Number</u>	<u>Axial Location of Sample, In. (a)</u>	<u>Power Relative to Rod Peak</u>	<u>Hydrogen Content^(b), ppm</u>
TI	17.6	1.00	76
TI	9.1	0.90	71
LA	17.6	1.00	80
LA	9.1	0.90	64
K4	17.6	1.00	51
K4	25.1	0.93	54
K4	30.1	0.75	66
K4	3.8	0.60	74
QE	17.8	1.00	93
QE	25.1	0.93	88
QE	30.1	0.75	71
QE	35.1	0.45	78

(a) Distance from bottom of fuel rod.

(b) Based on average of two or four determinations per ring sample.

Table 3
Summary of Fast Flux Dosimetry, Saxton Core II Fuel Cladding

<u>Rod Number</u>	<u>Axial Location of Sample, In. (a)</u>	<u>Mn⁵⁴ Activity, dpm/gm of Fe</u>	<u>Fluence (>1 Mev), n/cm²</u>
QE	25.1	5.17×10^7	2.8×10^{21}
QE	35.1	2.54×10^7	1.4×10^{21}
TT	1.9	3.15×10^7	1.7×10^{21}
TT	14.1	6.87×10^7	3.7×10^{21}
LA	9.1	5.27×10^7	2.9×10^{21}
LA	17.6	5.96×10^7	3.3×10^{21}

(a) Distance from bottom of fuel rod

Table 4
Tensile Test Results on Irradiated Saxton Core II Cladding

Sample Rod No.	Identification Axial Location, Inches (a)	Fluence (>1 Mev), n/cm^2 (b)	Test Tempera- ture, °F	0.2% Yield Strength, kpsi	Ultimate Strength, kpsi	Uniform Elonga- tion, %	Total Elonga- tion, %	Reduction of Area, %
TE	9.8-16.8	3.2×10^{21}	675	46.2	54.2	3.6	9.3	27
TI	3.0-9.0	2.3×10^{21}	675	54.2	61.7	5.2	9.3	48
TP	7.0-14.0	3.1×10^{21}	675	52.0	59.6	2.5	6.0	44
TT	2.0-8.0	2.3×10^{21}	675	49.1	57.9	6.0	11.3	31
TT	8.0-14.0	3.3×10^{21}	675	48.4	54.6	2.6	8.0	53
LA	3.0-9.0	2.3×10^{21}	675	48.4	58.1	7.1	15.1	50
LA	19.8-25.8	3.1×10^{21}	675	52.5	60.4	4.9	9.8	26
N1	8.0-14.0	3.1×10^{21}	675	51.6	64.8	5.6	18.4	46
N3	8.0-14.0	3.1×10^{21}	675	54.3	65.3	5.7	14.9	56
TE	2.0-8.8	2.1×10^{21}	675	67.0	73.1	2.9	12.2	48
JF	2.0-8.8	1.7×10^{21}	675	40.1	45.9	11.5	13.6	44
RI	2.8-8.8	2.0×10^{21}	675	56.9	65.9	6.1	19.5	53
S1	2.8-8.8	2.0×10^{21}	675	48.2	58.2	7.2	19.3	37
S1	9.8-16.8	3.2×10^{21}	675	56.7	67.8	3.6	7.9	37
P0	2.0-8.8	2.0×10^{21}	675	53.2	72.4	7.3	12.5	65
P0	9.8-16.8	3.2×10^{21}	675	42.3	62.0	3.5	11.1	67
P0	29.8-37.0	1.5×10^{21}	675	52.2	61.6	4.0	8.9	49
K4	30.3-36.5	1.8×10^{21}	675	48.3	52.0	3.3	10.4	64
N1	2.0-8.0	2.1×10^{21}	675	49.3	63.3	4.8	8.6	37
N3	2.0-8.0	2.1×10^{21}	675	45.8	59.2	4.1	10.1	58
TI	19.8-25.8	3.1×10^{21}	700	53.8	57.3	4.3	9.0	36
TP	1.0-7.0	1.9×10^{21}	700	44.8	53.8	4.2	18.2	60

(a) Distance of specimen ends from bottom of rod.

(b) Interpolated fluence at center of sample, based on data in Table 3.

Table 5
Burst Test Results on Irradiated Saxton Core II Cladding

<u>Rod Number</u>	<u>Sample Identification Axial Location, Inches (a)</u>	<u>Fluence (>1 Mev), n/cm² (b)</u>	<u>Burst Strength kpsi</u>
TE	19.8-27.8	3.0×10^{21}	60.4
TI	25.8-33.8	2.2×10^{21}	75.0
TP	22.0-30.0	3.0×10^{21}	74.4
TT	20.5-28.5	3.4×10^{21}	Leaked
TT	28.5-36.5	2.2×10^{21}	48.0
LA	9.5-17.5	3.2×10^{21}	70.0
LA	25.8-33.8	2.2×10^{21}	63.2
N1	21.0-29.0	3.3×10^{21}	76.8
N3	21.0-29.0	2.8×10^{21}	39.2

(a) Distance of Sample ends from bottom of rod.

(b) Interpolated fluence at center of sample, based on data in Table 3.

Table 6
Overpower Test Rod Operating History

<u>Period</u>	<u>Reactor Power, MWt</u>	<u>Best Estimate Test Rod Peak Power, kw/ft</u>
July 2-3	Escalating	0-15.9
July 4-11	22.3	15.8
August 9-11	21.8	15.4
August 13-19	22.6	15.9
August 19-23	25.6	17.7
September 3-6	22.6	15.9
September 6-21	25.6	17.7
October 17-18	26.7	18.7