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SAXTON PLUTONIUM PROGRAM

Quarterly Progress Report
for the period ending September 30, 1965

by

N.R. NELSON
(Westinghouse Atomic Power Division)

1966

EURATOM/US Agreement for Cooperation

EURAEC Report No. 1415 prepared by the Westinghouse Electric Corporation, Pittsburgh, Pa. - USA

AEC Contract No. AT(30-1)-3385

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Brussels, February 1966 - 90 pages - 22 figures - FB 125

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All fuel assemblies have been completed and shipped to Saxton. The 3 × 3 subassembly, which was completed during the previous quarter, has continued satisfactory operation in Saxton Core I and has accumulated an exposure of about 1,400 MWD/t (U + Pu).

The Saxton license amendment, allowing operation with plutonium bearing new fuel, was issued on September 20, 1965.

Final plans for zero power and startup tests were completed.

A detailed sampling plan was prepared and submitted to the AEC.

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SUMMARY

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SAX-100 Project Administration

N. R. Nelson

All project work up to the stage of refueling Saxton with Core II has been completed except for the issuance of topical reports. These reports will be expedited during the next quarter after refueling, which will start during the first week in October.

After startup and after analysis of startup data, there will be a period of over a year and a half of routine reactor operation with occasional shutdowns. During this time, nuclear core follow and some thermal and hydraulics follow will be carried out. However, there will not be a great deal of technical information generated. Consequently, it is being suggested to the AEC that semi-annual reports, instead of quarterly reports, be issued during that time.

Revised Work Programs have been submitted to the AEC and approval, with some restrictions, has been obtained through the first half of fiscal year 1966.

Manuscript received on December 10, 1965.

SAX-220 Fuel Design - Mechanical, Thermal & Hydraulic

H. N. Andrews, E. A. McCabe, N. J. Georges, E. A. Bassler

Manufacture of the plutonium fuel assemblies and inspection of the channel spacing between adjacent fuel rods and between fuel rods and fuel assembly enclosure were completed during this period.

The nominal design channel spacing between fuel rods and between fuel rod and assembly enclosure were .189 and .149 inches respectively. Minimum rod to enclosure spacings of .135 inch average along the length of the rod and .123 inch local were established as inspection requirements. The fuel assembly enclosures were reworked as necessary to meet these requirements. The inspection data are now being used by the Thermal-Hydraulics Design Group to establish engineering hot channel subfactors for fuel rod bow and channel spacing in the as-fabricated fuel assemblies.

A topical report in the Mechanical and Thermal-Hydraulic area will be prepared during the next quarter.

SAX-230 <u>Fuel Design - Materials</u>

R. J. Allio, A. Biancheria

The work under this sub-task has been completed. A topical report is in preparation. Issuance of this report, which was scheduled for the first quarter of fiscal 1966 has been delayed until the second quarter.

SAX-250 Planning and Analysis of Critical Experiments

F. L. Langford, W. L. Orr, H. I. Sternberg, P. Deramaix*, L. Bindler**

A. Introduction and Summary

1. Introduction

The objective of this task was to plan, design, and analyze the critical experiments carried out at the Westinghouse Reactor Evaluation Center (WREC) to verify the Saxton nuclear design. The fuel rods used in these experiments also will be used in the nine central fuel assemblies of the second Saxton reactor core for a period of about two years.

The WREC critical experiments program and the supporting program of analysis have been completed. Much of the post-critical comparison of analysis with experiment was reported in the previous quarterly report.[1] Comparisons were made in the following functional areas:

a. Reactivity and Criticality

b. Power Peaking Effects

c. Power Sharing

Work continued in these areas during the quarter with the emphasis placed on the analysis of the multi-region experiments.

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*On leave from Belgo-Nucleaire, Brussels, Belgium and CEN, Mol, Belgium** working on the Saxton Plutonium Program in the scope of the EURATOM/AEC/ Westinghouse Contract.

2. Summary

The following statements briefly summarize the work completed during the quarter.

a. The analysis of the multi-region experiments was completed. The analysis of the remaining power sharing configurations confirm the comparisons reported previously.[1] The PDQ-3[2] analysis and the measured power distributions determined using factors from foil irradiation experiments to relate measured gamma activity to rod power for the two different fuel types agree within approximately 1%. The agreement between analysis and measurements is within 5% using factors determined by a thermal method.

b. Comparisons of analysis with experiment were made for a wide range of multi-region reactivity measurements. The comparisons include fuel substitution experiments, core perturbations such as water slots, poison worth measurements, and temperature coefficient measurements. In general, close agreement was obtained.

c. A draft of the final topical report was completed and is currently being reviewed. This report will be issued in the next quarter bringing to a close the work under this task.

The work of this quarter is reported according to the following functional headings:

(1) Reactivity Measurements and Analysis

(2) Special Power Sharing Experiment

(3) Final Criticality Comparisons

B. Analysis/Experiment Comparisons

1. Reactivity Measurements and Analysis

During the experimental program, extensive reactivity measurements were made in both single and multi-region configurations. In general, these measurements can be grouped into four categories:

a. Reactivity worth of changes in core geometry for step changes in loading from a one-zone core to a two-zone core.

b. Reactivity worth of core perturbations such as water slots.

c. Reactivity worth of control rods and soluble poison.

d. Temperature coefficient measurements.

(1) Fuel Substitution Experiments

The fuel substitution experiments were of two types. First, insert experiments were carried out in which a relatively small number of fuel rods in the center of the core were replaced by fuel rods of a different type, as in a central 3 x 3 region. Second, changes in core configuration were made in small steps as in changing from a single region core to a multi-region core by replacing one fuel type with the other fuel type. The reactivity change was measured for each step. Consequently, experimental information is available for a number of different multi-region configurations.

The fuel substitution experiments provide an excellent test of the analysis methods and cross sections. The LEOPARD[3]-PDQ-3 sequence using cross sections reported by Wescott[4] at the 1964 Geneva Conference was used to determine the reactivity effect of each core change. Since a larger discrepancy between analysis and experiment was found for the PuO_2-UO_2 fueled reference core than for the reference core fueled with UO_2, it was necessary to consider the effect of the difference in the size of the induced error in evaluating core changes involving both fuels. The correction was based on the relative number of neutrons produced by fissioning in each fuel as determined from a

PDQ-3 calculation for the configuration involved and the size of the reactivity discrepancy for each reference core. Figure 250.1 compares the measured and calculated reactivity changes for a series of fuel substitution experiments. The figure shows that the analysis and experiment are in good agreement.

(2) Perturbation Experiments

The effect on reactivity and local power peaking resulting from core perturbations such as water slots was described in the previous quarterly report. Analytic comparisons were made with the experimental results from the single region experiments. Similar comparisons have now been completed for the multi-region perturbation experiments.

It is interesting to compare the measured and calculated reactivity worth of a water slot as a function of radial position for cores containing a variation in the fuel distribution. Table 250.1 contains a comparison for two different multi-region cores. The first core contains a central PuO_2-UO_2 region (11 x 11) surrounded by an outer UO_2 region forming

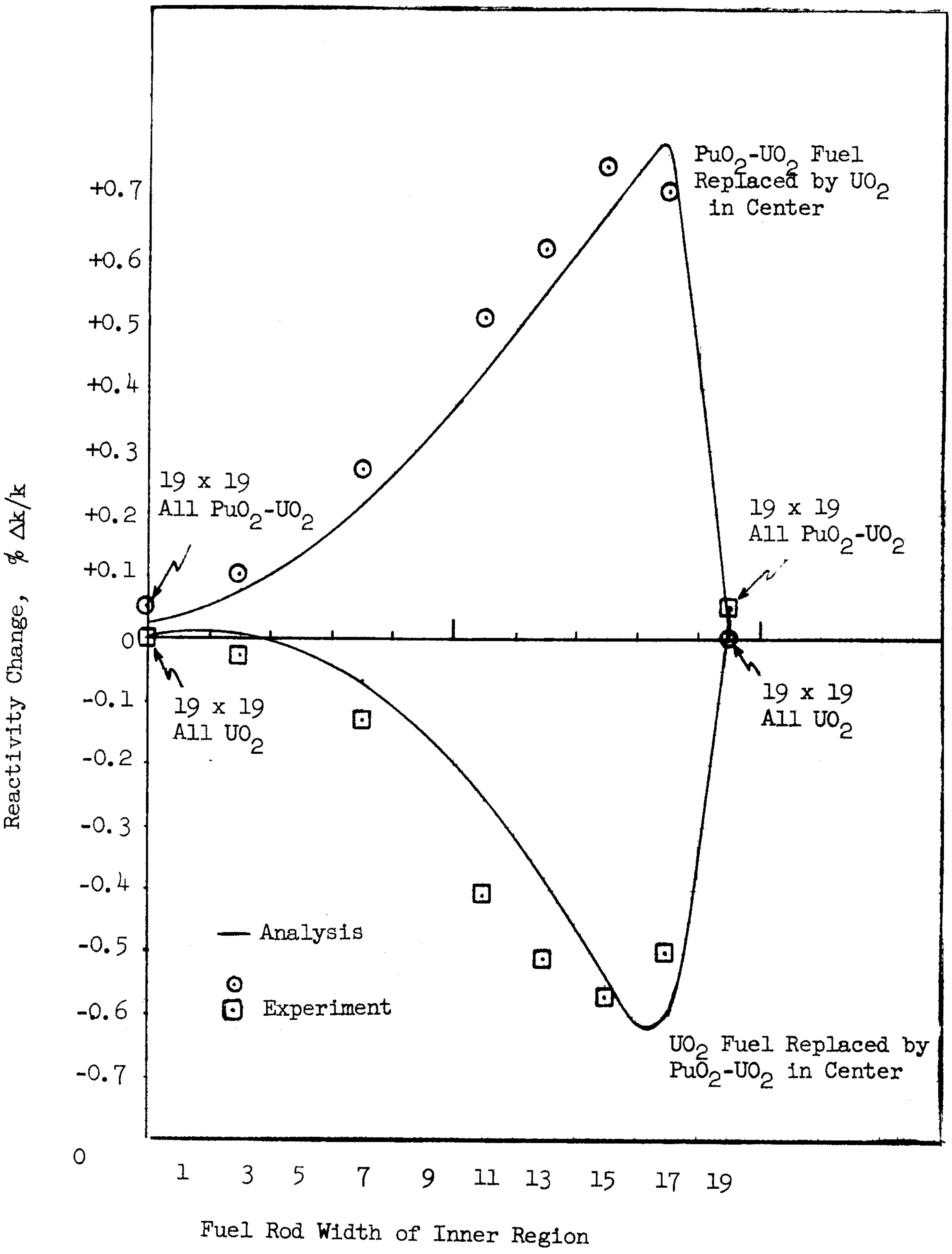


Figure 250.1 A Comparison of Analysis with Experiment for Fuel Substitution Experiments in a Multi-Region 19x19 Core.

Table 250.1

Water Slot Reactivity Effects - Analysis and Experiment

Core Size	Region 1		Region 2	Multi-Region Cores		
	Size	Fuel	Fuel	Water Slot Location	Measured % Δk/k	Calculated % Δk/k
21 x 21	11 x 11	PuO_2-UO_2	UO_2	5 Center Rods Removed(PuO_2-UO_2)	+ 0.46	+ 0.46
21 x 21	11 x 11	PuO_2-UO_2	UO_2	5 PuO_2-UO_2 Rods at Fuel Interface Removed	+ 0.27	+ 0.38
21 x 21	11 x 11	PuO_2-UO_2	UO_2	5 UO_2 Rods at Fuel Interface Removed	+ 0.20	+ 0.32
21 x 21	11 x 11	UO_2	PuO_2-UO_2	5 Center Rods Removed (UO_2)	+ 0.20	+ 0.19
21 x 21	11 x 11	UO_2	PuO_2-UO_2	5 UO_2 Rods at Fuel Interface Removed	+ 0.28	+ 0.37
21 x 21	11 x 11	UO_2	PuO_2-UO_2	5 PuO_2-UO_2 Rods at Fuel Interface Removed	+ 0.25	+ 0.37

a 21 x 21 core overall. In the second core, the fuel positions are reversed with UO_2 in the inner region (11 x 11) and PuO_2-UO_2 in the outer region. The reactivity worth of each water slot was determined in separate experiments by removing; (a) five fuel rods in the center of the core, (b) five fuel rods at the fuel interface (inner region rods removed) and (c) five fuel rods at fuel region interface (outer region fuel rods removed). The LEOPARD-PDQ-3 sequence was used for the analysis. Group constants for the slot were determined by the use of an extra region in a fueled LEOPARD calculation in an effort to account for the effect on the water slot spectrum of the surrounding fuel. A different Dancoff calculation from that of the normal lattice was used for the fuel rods surrounding the slot. Satisfactory agreement between analysis and experiment was obtained for the central water slot in the multi-region cores. However, the comparison was unsatisfactory for the water slot worth at the fuel interface.

(3) Control Rod and Soluble Poison Worth

The reactivity worth of control rods and soluble poison were determined in both single region and multi-region configurations. Tables 250.2 and 250.3 contain comparisons of the measurements with the appropriate PDQ-3 calculations.

Table 250.2

Control Rod* Worth - Analysis and Experiment**

Single Region Core

Core Size	Type Fuel	Control Rod Position	Rod Worth: Measured % $\Delta k/k$	Rod Worth: Calculated k_{eff}	Rod Worth: Calculated % $\Delta k/k$
21 x 21	UO_2	5 Rods in Center	- 4.50	Ref: = 1.003477 Rods: = 0.95804	- 4.63
21 x 21	PuO_2-UO_2	5 Rods in Center	- 3.92	Ref: = 1.012429 Rods: = 0.978187	- 3.45

Multi-Region Core

Core Size	Region 1 Size	Region 1 Fuel	Region 2 Fuel	Control Rod Position	Rod Worth: Measured % $\Delta k/k$	Rod Worth: Calculated k_{eff}	Rod Worth: Calculated % $\Delta k/k$
21 x 21	11 x 11	PuO_2-UO_2	UO_2	5 Rods in Center	- 3.65	Ref: = 1.008326 Rods: = 0.972443	- 3.62
21 x 21	11 x 11	PuO_2-UO_2	UO_2	5 Rods - PuO_2-UO_2 Interface	- 2.92	Rods = 0.981933	- 2.65
21 x 21	11 x 11	PuO_2-UO_2	UO_2	5 Rods - UO_2 Interface	- 2.60	Rods: = 0.983037	- 2.54

*Control Rods (unclad)

O.D. = 0.403 inch
Composition = .05 Ag, .15 In, .80 Cd

**Data Being Evaluated

Table 250.3

Soluble Poison Worth - Analysis and Experiment

Single Region Core					
				Poison Worth	
				Calculated	
Core Size	Type Fuel	Δ Boron (ppm)	Measured % Δk/k	k_{eff}	% Δk/k
19 x 19	PuO_2-UO_2	0 - 50 ppm	- 0.79	Ref: = 1.011479 ΔBoron: = 1.00374	- 0.77

Multi-Region Core							
						Poison Worth	
	Region 1		Region 2			Calculated[1]	
Core Size	Size	Fuel	Fuel	Δ Boron (ppm)	Measured % Δk/k	k_{eff}	% Δk/k
27 x 27	19 x 19	PuO_2-UO_2	UO_2	1166 - 1388	- 1.49	Ref: = 1.0400 ΔBoron: = 1.0247	- 1.48
27 x 27	19 x 19	PuO_2-UO_2	UO_2	116 - 1453	- 1.95	ΔBoron: = 1.0206	- 1.88

[1] PDQ Group Constants were Determined using Leonard Cross Sections

(4) Temperature Coefficient

Temperature coefficient measurements were made at atmospheric pressure for a range of temperatures from approximately 15°C to a maximum of 70°C. The analysis and experiment for a multi-region configuration are compared in the following list. A discrepancy of approximately 8% was found.

Core Size	Single Region Size	Single Region Fuel	Region 2 Fuel	Temperature Coefficient ($\times 10^5$, %$\Delta k/k/°C$) Measured	Temperature Coefficient ($\times 10^5$, %$\Delta k/k/°C$) Calculated	Temperature Range, °C
19 x 19	11 x 11	PuO_2-UO_2	UO_2	10.25	9.5	18-70

2. Special Power Sharing Experiment

The method used in the past to determine power distributions in the Saxton reactor has been to measure the activation of manganese wire in flux wire thimbles at fixed locations in the core. The activation measurements are then translated to rod power by means of a PDQ-3 calculation of activation and power for the appropriate configuration. An experiment was conducted at the WREC to determine whether any additional uncertainty in the translation from activation to power is introduced in a core containing two different fuel types. To approximate the measurement conditions in the Saxton reactor, two L-shaped arrays of UO_2 fuel rods were installed in the central PuO_2-UO_2 fuel region to simulate the control rod fuel followers and aluminum rods containing manganese wire inserts were inserted at positions corresponding to the location of the flux wire thimbles. Figure 250.2 is a diagram of the core showing the location of the manganese wires and the rods that were gamma scanned. A PDQ-3 calculation was carried out for this assembly. Table 250.4 includes a comparison of the measured and calculated power and wire activities. These comparisons of analysis with experiment do not indicate the existence of any special difficulty that might limit the usefulness of the method in determining rod power in the Saxton design core.

3. Summary of Criticality Results

A criticality study for a number of Hanford and WREC mixed-oxide (PuO_2-UO_2) critical experiments was carried out using the LASER[6] and LEOPARD programs. An improved version of LASER is available which includes a variation of the thermal energy mesh. The improved mesh consists of very fine energy intervals under the Pu-239 and Pu-240 resonances and thus eliminates the necessity of using weighted effective cross section data in the thermal library. The effect of the revised mesh for both Hanford and WREC experiments is to improve the reactivity correlation as well as to eliminate

Configuration: 27 x 27 Core

19 x 19 PuO_2-UO_2 Inner Region

UO_2 Outer Region

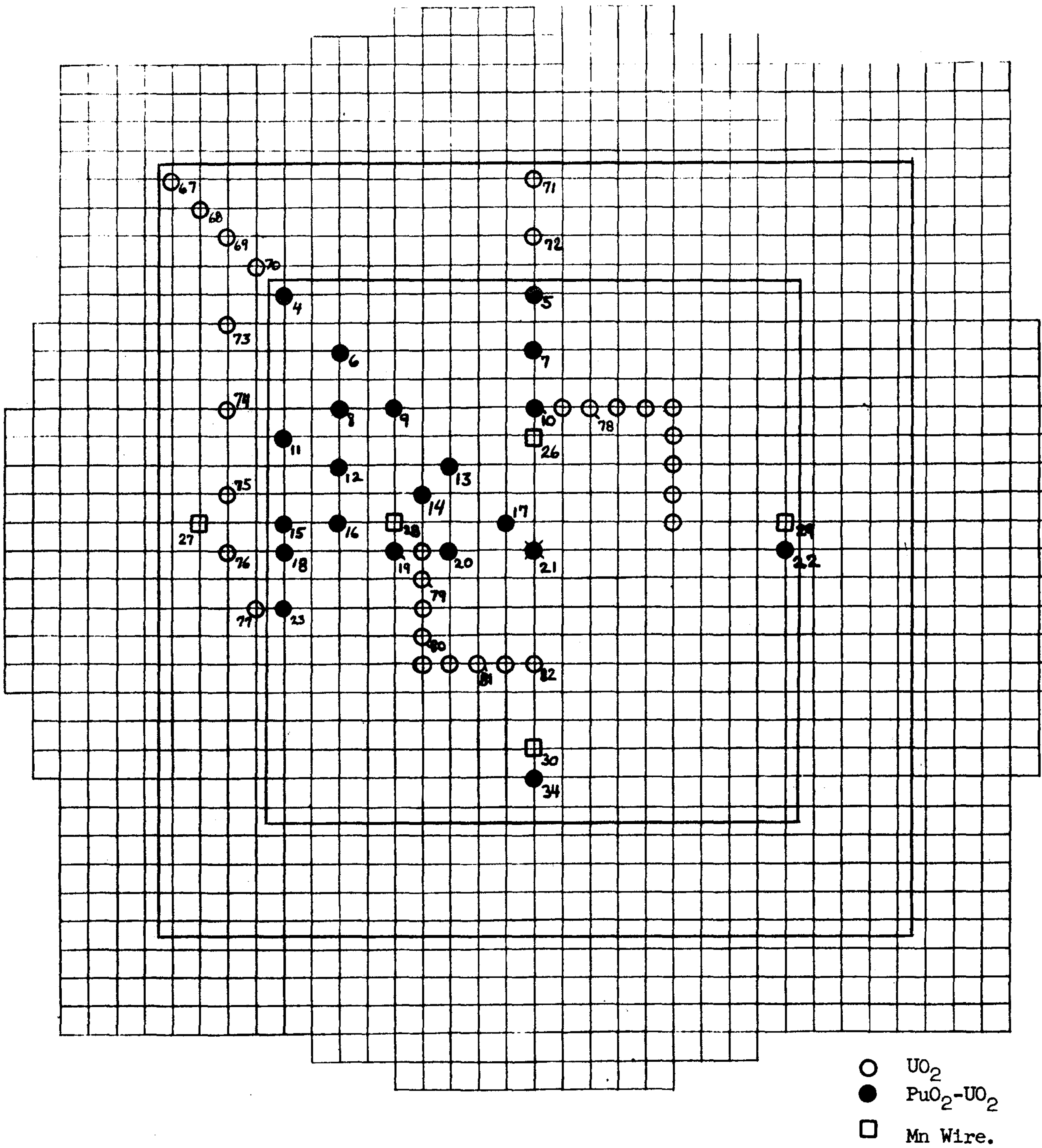


Figure 250.2 Core Diagram for Two-Region Power Shaping Experiment Containing Simulated Fuel Followers and Flux Wire Thimbles.

Table 250.4

Special Power Sharing Experiment - Analysis and Experiment

Mn Wire

No.	Experiment	Analysis
26	1.426	1.426
27	1.031	1.015
28	1.344	1.363
29	1.144	1.115
30	1.192	1.174

PuO_2-UO_2 Fuel Rods

No.	Experiment	Analysis
21	1.000	1.000
20	1.052	1.033
19	1.061	1.093
18	0.762	0.742
17	0.998	0.992
13	0.951	0.928
9	0.807	0.803
6	0.643	0.640
4	0.552	0.542
10	1.049	1.085
7	0.826	0.804
5	0.763	0.745
11	0.706	0.693
12	0.792	0.770
14	0.974	0.969
15	0.756	0.740
16	0.836	0.807
23	-	0.729
34	0.848	0.873
22	0.857	0.856

UO_2 Fuel Rods

	Experiment		
No.	Foil Method	Thermal Method	Analysis
67	0.302	0.286	0.321
68	0.277	0.263	0.253
69	0.323	0.307	0.303
70	0.381	0.361	0.375
71	0.591	0.560	0.617
72	0.567	0.538	0.554
73	0.421	0.399	0.411
74	0.522	0.495	0.496
75	0.573	0.543	0.565
76	0.593	0.563	0.573
77	-	-	0.560
78	0.755	0.716	0.754
79	0.810	0.768	0.794
80	0.792	0.751	0.777
81	0.796	0.755	0.784
82	0.780	0.740	0.760

the apparent trend with pitch present in earlier calculations. Two cross-section sets, Winfrith[7] and SHER 1965[8], in addition to those reported previously, Leonard[9] and Wescott, were investigated during the quarter using the revised LASER. A complete summary of the results obtained with LASER using the Nelkin scattering kernel for the various cross-section sets is included in Table 250.5. LEOPARD results are summarized in Table 250.6.

A comparison was made of the results obtained with LASER and LEOPARD, by computing the average discrepancy and the standard deviations for the various mixed oxide experiments that were analyzed. These results are listed in Table 250.7. The comparison shows somewhat better agreement from the standpoint of both the average discrepancy and standard deviation for the LASER code.

TABLE 250.5

LASER Reactivity Comparisons with Different Thermal Cross Sections

Lattice Pitch (in)	Fuel Rod Diameter (in)	Moderator/ Fuel Vol. Ratio	H/Pu Atom Ratio	LASER (NELKIN, LEONARD)	LASER (NELKIN, WESTCOTT)	LASER (NELKIN, WINFRITH)	LASER (NELKIN SHER, 1965)
Hanford							
0.55	0.372	1.10	230	1.0095	1.0002	0.9923	1.0009
0.60	0.372	1.56	326	1.0126	1.0029	0.9946	1.0026
0.71	0.372	2.71	567	1.0170	1.0068	0.9983	1.0058
0.80	0.372	3.79	794	1.0156	1.0053	0.9968	1.0043
0.90	0.372	5.14	1077	1.0159	1.0056	0.9971	1.0044
WREC*							
0.52	0.337	1.68	76	1.0053	0.9970	0.9897	0.9964
0.56	0.337	2.16	98	1.0231	1.0140	1.0062	1.0114
0.735	0.337	4.70	211	1.0194	1.0092	1.0007	1.0067
0.792	0.337	5.67	254	1.0227	1.0122	1.0036	1.0094
1.04	0.337	10.80	486	1.0266	1.0158	1.0069	1.0139

*Aluminum mid-plate omitted.

Table 250.6

LEOPARD Reactivity Comparisons with Different Thermal Cross-Sections

Lattice Pitch (in)	LEOPARD (Leonard)	LEOPARD (Westcott Geneva 1964)	LEOPARD (Sher 1965)
Hanford			
.55	1.0165	1.0039	1.0049
.60	1.0240	1.0102	1.0102
.71	1.0314	1.0170	1.0155
.80	1.0297	-	1.0129
.90	1.0272	1.0133	1.0098
WREC*			
.52	0.9998	0.9890	0.9892
.56	1.0223	1.0103	1.0101
.735	1.0268	1.0128	1.0114
.792	1.0313	1.0175	1.0159
1.04	1.0314	1.0167	1.0143

*Aluminum mid-plate omitted.

TABLE 250.7

Comparison of the Different Standard Deviations Determined from LEOPARD and LASER Calculations

Cross Sections	σ LEOPARD	σ LASER	Lattices	$\overline{K}_{Leop}$	$\overline{K}_{Laser}$
LEONARD	$5.26\ 10^{-3}$	$2.73\ 10^{-3}$	HANFORD	1.0258	1.0141
"	$11.75\ 10^{-3}$	$7.92\ 10^{-3}$	WREC	1.0223	1.0194
"	$9.26\ 10^{-3}$	$6.19\ 10^{-3}$	H & W*	1.02404	1.0168
WESTCOTT	$4.81\ 10^{-3}$	$2.55\ 10^{-3}$	HANFORD	1.0111	1.0039
"	$10.33\ 10^{-3}$	$6.69\ 10^{-3}$	WREC	1.0091	1.0096
"	$8.40\ 10^{-3}$	$5.99\ 10^{-3}$	H & W	1.0100	1.0071
SHER 1965	$3.54\ 10^{-3}$	$1.69\ 10^{-3}$	HANFORD	1.0107	1.0036
"	$9.57\ 10^{-3}$	$6.17\ 10^{-3}$	WREC	1.0076	1.0076
"	$7.37\ 10^{-3}$	$4.93\ 10^{-3}$	H & W	1.0092	1.0056
Winfrith	-	$2.13\ 10^{-3}$	HANFORD	-	0.9958
"	-	$6.25\ 10^{-3}$	WREC	-	1.0014
"	-	$5.40\ 10^{-3}$	H & W	-	0.9986

*Combination of the Hanford and WREC data.

References

1. N. R. Nelson, "Saxton Plutonium Program Quarterly Progress Report for the Period Ending June 30, 1965," WCAP-3385-4 (1965).

2. W. R. Cadwell, et. al., "PDQ-3, A Program for the Solution of the Neutron Diffusion Equations in Two-Dimensions on the IBM-704," WAPD-TM-179 (May 1960).

3. R. F. Barry, "LEOPARD - A Spectrum Dependent Non-Spatial Depletion Code for the IBM-7094," WCAP-3741 (1963).

4. C. H. Westcott, "Survey of Nuclear Data for Reactor Calculations," A/Conf. 28/P. 717 (1964).

5. H. P. Flatt and D. C. Haller, "AIM-5 - A Multi-Group, One-Dimensional Diffusion Equation Code," NAA-SR-4694 (March 1960).

6. C. G. Poncelet, "Burnup Physics of Heterogeneous Reactor Lattices," WCAP-6069 (1965).

7. A. C. Douglas and J. F. Barry, "Neutron Cross Sections of Pu-239 in the Energy Range 1 Kev to 15 Mev," AWRE-0-79/64 (1965).

8. J. R. Stehn, "Thermal-Neutron Cross Sections of Fissile Isotopes," ANS Transactions, Vol. 8, No. 1 (June 1965).

9. B. R. Leonard, Jr., "Plutonium Physics: Contribution to Plutonium Handbook," HW-72947 (March 1962).

SAXF-310 Fuel Fabrication - Materials

R. J. Allio, A. Biancheria, R. N. Stanutz, M. D. Houston

Pelletized Fuel

All pelletized fuel rods fabricated by Numec were received by Westinghouse during the report period. High temperature water, isotopic analysis, rare earth analysis and Pu/U ratio analysis have been completed and received by Westinghouse. The analyses have been confirmed to be within specification. The remaining items to complete the contractual commitments at Numec are:

1. Library samples
2. Scrap recovery

The library samples are ready and will be shipped as soon as the Westinghouse Waltz Mill facility receives a license amendment allowing storage of an increased amount of PuO_2-UO_2 powder. Scrap recovery is expected to be completed by October 15, 1965. In the meantime, Numec has initiated action to transfer accountability for this material from the Westinghouse license to the Numec account.

Vibrationally Compacted Fuel

All vibrationally compacted fuel rods fabricated by the Battelle Northwest Laboratories were received by Westinghouse during the last report period. Fuel library samples have been received at Waltz Mill. The only item required to complete the contract is the return of spare components. This shipment is expected shortly.

Terminal Report

Preparation of a final report on fuel fabrication has been delayed by late completion of fuel assemblies. The report will be completed during the next quarter.

SAXF-320 Fuel Inspection and Assembly

W. E. Ray, A. Biancheria, R. N. Stanutz, M. A. Parker

During this period the core loading pattern of the vibrationally compacted and pelletized fuel rod assemblies and the location of the stainless and Zircaloy-4 rods within these assemblies were reviewed with the Nuclear and Thermal and Hydraulic Design sections. An acceptable loading design was determined and submitted to Mechanical Design for preparation of manufacturing drawings.

Assembly of all 9 x 9 plutonium fuel assemblies was completed during the period. The assemblies have been inspected, approved and shipped to Saxton. The Saxton license amendment to permit operation with plutonium bearing fuel was issued on September 20th. Assemblies will be loaded in the reactor the first week in October.

Cross-section drawings recording the fuel rod identification letters and numbers as installed in lattice spaces in the nine fuel assemblies and in the one 3 x 3 subassembly are included in Figures 320.1 through 320.10. The location of assemblies within the core are shown on Figure 320.11. The symbol X in some of the grid locations indicates flux thimbles, neutron source points, or 9 x 9 removable rods. Since the 9 x 9 removable rods will be inserted at Saxton, the identification numbers of the rods inserted in the grid locations marked X will be recorded during refueling.

OO	MO	J8	J9	X	M3	I6	N4	K3
D9	H8	L4	R1	R8	A6	O5	JO	I7
K6	J1	C4	I5	R5	B5	F6	O1	R2
M4	NO	L2	J4	LO	S2	L1	F8	J3
X	N8	O8	H7	O4	L3	A7	TO	
Q1	I1	T1	K7	I2	G3	KO	N9	
P6	C3	N7	L6	I4	T2	E5	N2	
M2	O6	Q5	B3	N6	M5	M9	E9	
O7	I3	H9	O3					

Zircaloy-4 Clad PuO_2-UO_2 Vipac

Figure 320.1 - Assembly Location 2D
Assembly No. 503-12-5

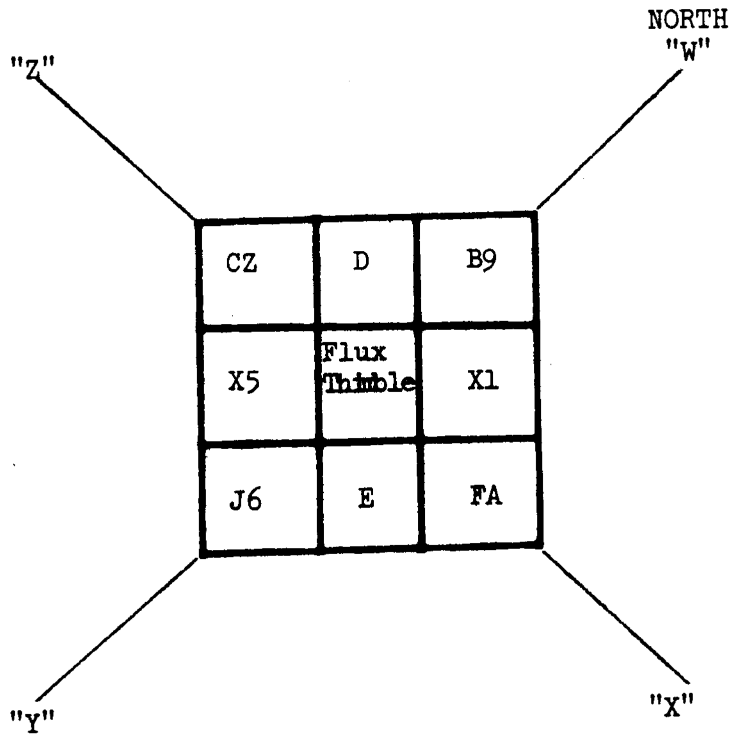
PW	EW	QI	OB	X	TP	VI	PF	TI
RP	FT	EP	HQ	AW	NH	EF	KP	SS
U4	MG	AJ	BQ	PU	FR	PQ	FN	M
TC	PE	AN	3X 3			NZ	ST	X
	MS	MQ	Subassembly			GB	SA	X
	FX	LS				OH	FP	TT
	OE	MT	GD	SU	FI	LD	ND	RY
	LZ	JM	CI	TJ	MD	LP	LJ	MR
					CH	JH	D	RR

Rods U4, V1 304 Stainless Steel Clad PuO_2-UO_2 Vipac

Rods M, D 304 Stainless Steel Clad PuO_2-UO_2 Pellets

Others - Zircaloy-4 Clad PuO_2-UO_2 Pellets

Figure 320.2 - Assembly Location 3D
Assembly No. 503-13-1



Rods CZ, FA - Pelletized Fuel

Rods D, E - Removable Rods - Pelletized Fuel

Rods B9, J6 - Vipac Fuel

Rods X1, X5 - Removable Rods - Vipac Fuel

Zircaloy-4 Clad PuO_2-UO_2 Fuel

Figure 320.3 - 3 x 3 Subassembly
Assembly No. 503-4-26

K4	N3	S3	N2	X	R6	A2	R0	Q2
R7	<u>U1</u>	<u>U0</u>	S9	R4	M1	<u>V0</u>	<u>U6</u>	T3
P2	<u>U5</u>	P3	E0	M7	A3	L7	N5	K1
M8	09	S8	B4	S1	P4	E3	K8	H6
X	A1	<u>U3</u>	R3	P0	Q0	C2	J7	
Q7	S4	L8	G4	L5	S0	E1	I0	
Q3	<u>U9</u>	S5	Q4	I9	D0	S7	Q6	
E2	Q8	<u>U2</u>	P7	P5	R9	A5	Q9	
J2	02	P1	A9					

Zircaloy-4 Clad PuO_2-UO_2 Vipac Fuel

304 Stainless Steel Clad PuO_2-UO_2 Vipac Fuel (Underlined)

Figure 320.4 - Assembly Location 4D
Assembly No. 503-12-1

NJ	KL	LR	IL					
RD	CG	AD	JX	OY	IV	MW	SQ	
LC	ER	LL	MA	LX	CS	QH	KQ	
QG	OI	BC	EU	JB	IG	PR	MJ	
X	PI	RM	MP	OA	IP	JC	FZ	
GE	JT	NI	KZ	MF	SM	DW	EQ	KU
HI	JR	HH	SR	NA	FO	DP	MC	PX
NB	TG	DO	MU	JS	NC	DZ	ML	GF
RC	OP	DY	GZ	X	SF	BZ	MO	EX

Zircaloy-4 Clad PuO_2-UO_2 Pellets

Figure 320.5 - Assembly Location 2C
Assembly No. 503-12-2

					CY	SE	FL	IA
	NN	CW	OR	CP	RA	H	S	ON
	CM	K	C	F	Q	B	P	IK
	DJ	N	LV	QW	JQ	G	OU	GA
	DX	J	OQ	JF	RI	O	RL	X
BN	IR	A	FD	MY	OM	E	GN	TE
SN	T	LM	OG	DQ	KR	JK	I	SC
LI	R	TO	GS	TM	IU	IH	L	IM
PM	TN	NX	LE	X	KY	KT	LW	QE

Zircaloy-4 Clad PuO_2-UO_2 Pellets

304 Stainless Steel Clad PuO_2-UO_2 Pellets (underlined letters)

Figure 320.6 - Assembly Location 3C
Assembly No. 503-12-3

RT	QL	LT	GO					
IO	HT	DR	MB	KG	IF	BB	QP	
DC	FF	HX	GL	IT	LK	GM	DI	
NT	LG	BU	IE	AI	HF	AX	GG	
X	HN	CA	BF	GP	DS	CE	RE	
QM	AB	DL	QF	LO	DD	IQ	HW	GC
BT	DM	KN	PO	BY	ES	HJ	CQ	QJ
JA	BE	FC	DF	DU	RX	AY	MI	SZ
EJ	BS	HP	HR	X	JU	BJ	GY	FB

Zircaloy-4 Clad PuO_2-UO_2 Pellets

Figure 320.7 - Assembly Location 4C
Assembly No. 503-12-7

FK	BA	NU	BG					
TR	RV	TL	QZ	LY	EG	EK	QU	
BR	GK	EN	ED	NF	QX	BO	DK	
QR	BD	PJ	CU	GH	NE	EZ	MM	
X	NV	RK	KF	JZ	BK	PC	PG	
DO	CX	DV	DT	IN	IC	CO	HZ	QD
LN	NY	KW	SH	BW	DA	KJ	HV	SW
MX	RZ	OX	LU	JW	MN	NO	FG	FM
LA	KH	LB	TK	X	KA	OJ	LH	CJ

Zircaloy-4 Clad PuO_2-UO_2 Pellets

Figure 320.8 - Assembly Location 2E
Assembly No. 503-12-4

					RW	HA	NQ	DE
	KC	FY	EO	TS	SJ	RB	PY	ME
	AO	CV	TB	NG	DN	EV	KS	EB
	KV	SB	HG	ID	FV	PH	AL	CC
	DG	CB	MK	OW	PK	QS	HY	X
SP	PD	AA	IX	KO	PA	PV	NW	JG
PN	KX	PT	FJ	GJ	JE	NP	NL	JL
GT	AP	SY	RG	HB	HM	OL	AM	IW
NR	AT	EM	OV	X	GR	OC	FW	OD

Zircaloy-4 Clad PuO_2-UO_2 Pellets

Figure 320.9 – Assembly Location 3E
Assembly No. 503-12-6

SK	CD	HE	LF					
RO	AF	OT	AS	PP	GI	HO	BM	
AU	GV	HD	GU	QT	MV	KD	BV	
JY	FE	PB	RJ	OK	KB	BL	FS	
X	HS	MH	AH	NK	JV	SG	PZ	
EH	FU	AR	TQ	TH	CN	NS	RS	AE
OF	AG	BI	AZ	KM	AQ	AK	PS	LQ
SL	TA	SI	FQ	PL	OS	CF	FH	QV
NM	QA	HK	DB	X	EL	GX	BP	ET

Zircaloy-4 Clad PuO_2-UO_2 Pellets

Figure 320.10 - Assembly Location 4E
Assembly No. 503-12-8

PLAN VIEW OF SAXTON CORE SHOWING FUEL ASSEMBLY LOCATIONS

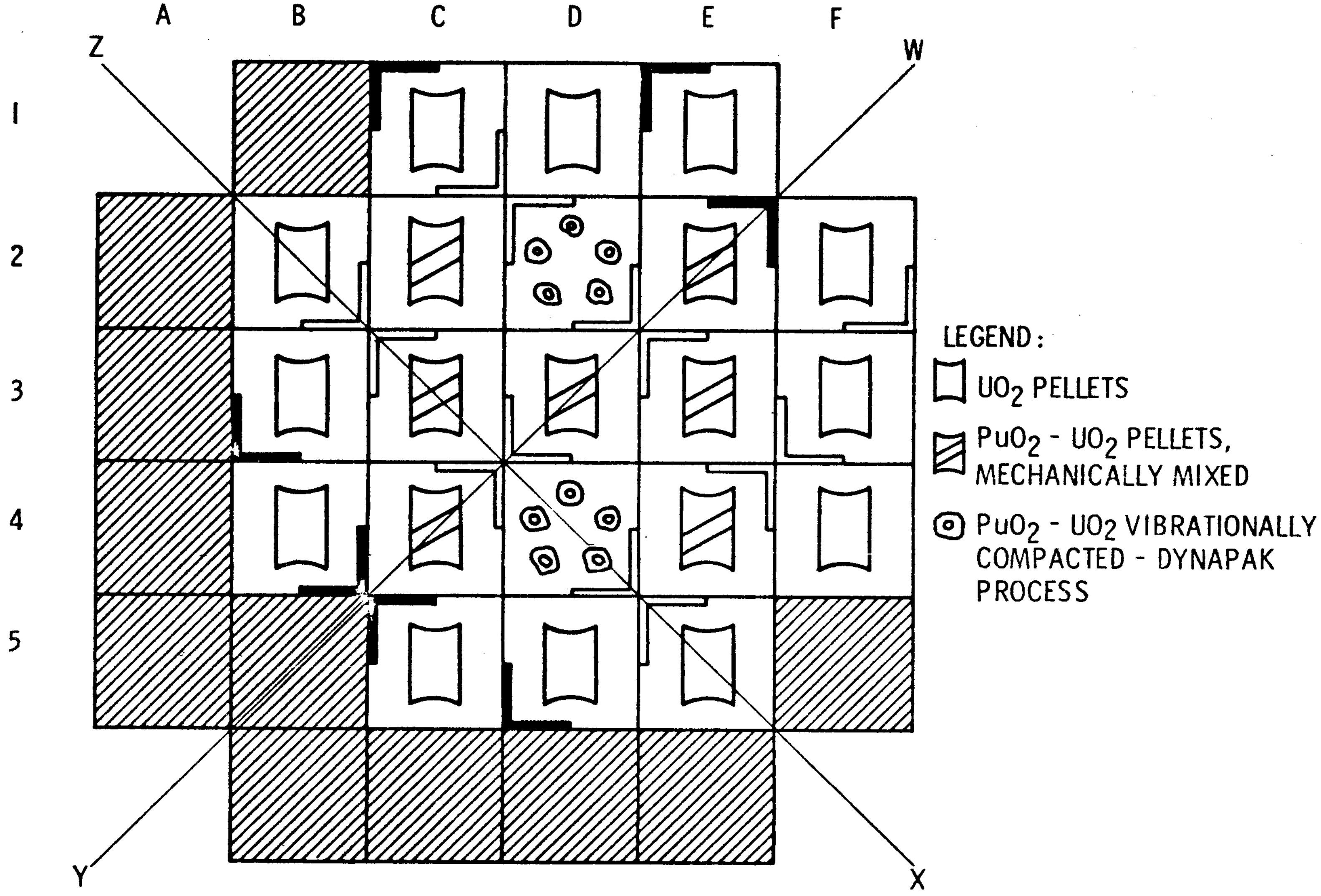


FIGURE 320.11 PLAN VIEW OF SAXTON CORE SHOWING FUEL ASSEMBLY LOCATIONS.

SAX-330 <u>New Fuel Shipping</u>

H. E. Walchli, H. W. Keller

During the quarter, modifications to the fuel shipping containers were completed. Licenses authorizing transport of the fuel and receipt of the fuel at Saxton were issued by the AEC. Fuel assemblies were completed, packaged and shipped to Saxton.

This subtask has been completed. It will not be included in future reports.

SAX-340 **Safeguards Analysis**

R. C. Nichols

The final licensing procedures for the Partial Plutonium Saxton Core II were completed during this quarter. The Saxton Partial Plutonium Core II was reviewed by the Advisory Committee on Reactor Safeguards at its July 8 meeting. The main questions raised by ACRS at this meeting concerned the magnitude of reactivity anomalies which might be expected to occur during operation of the core, and the magnitude of reactivity anomaly whose occurrence would justify a precautionary shutdown.

ACRS was told that a departure of 3 or 4 percent Δk from prediction would not be considered unusual over the lifetime of the Core II because of the uncertainties in the burnup rate of the mixed fuel core. However, based on post-operating experience at Saxton, short-term reactivity losses of significant magnitudes would not be expected in the operation of Core II. A conservative analysis has shown that the Saxton reactor system could accept a sudden insertion of up to 1.25 percent $\Delta k/k$ with the possibility of core damage but without causing failure of the reactor coolant system.

ACRS then recommended that SNEC and the Regulatory Staff select an appropriate limit to reactivity anomalies "beyond those attributable to discrepancies between prediction and observation of long term reactivity effects due to burnup." Accordingly, the following statement was prepared by Westinghouse, approved by SNEC and forwarded to the staff for approval:

"During the operation of the reactor, periodic measurements and predictions of core reactivity shall be made. The core reactivity measurements shall be made at equilibrium conditions and shall take into consideration experimentally determined or analytically determined core characteristics.

"The prediction of core reactivity shall be made based upon extrapolation of all preceding nominal core reactivity measurements and shall be made on a weekly basis. An unexplained reactivity gain or loss shall be defined as the difference between the experimental measurement and the prediction based upon extrapolation. If an unexplained reactivity loss of 1.25 percent $\Delta k/k$ or more should occur, an evaluation shall be instituted and the Commission notified."

The staff felt that this statement was adequate and the proposed Operating License Amendment was published in the August 17 issue of the FEDERAL REGISTER for the required waiting period of thirty (30) days. The Operating License Amendment was officially issued on September 20, 1965.

Work was initiated and completed to re-evaluate the hot startup, rod withdrawal at power and steam break accidents with more conservative values of the moderator temperature coefficient. This re-evaluation was performed so that the Saxton Technical Specifications for the moderator temperature coefficient limits could be made less restrictive if the zero and low power experiments indicate such a requirement.

The values used in the re-evaluation are:

		New	Old
Hot Startup	-	$\alpha_m = -2.0 \times 10^{-4}\ \Delta k/k/^\circ F$	-2.7×10^{-4}
Rod Withdrawal at Power	-	$\alpha_m = -2.0 \times 10^{-4}\ \Delta k/k/^\circ F$	-2.7×10^{-4}
Steam Break	- 2000 ppm	$\alpha_m = -3.4 \times 10^{-4}\ \Delta k/k/^\circ F$	-2.7×10^{-4}
	- 1000 ppm	$\alpha_m = -4.1 \times 10^{-4}\ \Delta k/k/^\circ F$	-3.4×10^{-4}
	- 0 ppm	$\alpha_m = -5.5 \times 10^{-4}\ \Delta k/k/^\circ F$	-4.1×10^{-4}

The results of the re-evaluation do not significantly alter the accident analyses presented in the Safeguards Report for the Saxton Core II. The hot startup accident results are no different at all as the transient is governed by the Doppler coefficient and is not changed by this small variation in moderator temperature coefficient.

The rod withdrawal at power re-analysis shows a change of 0.6°F in the moderator at the peak power conditions which would result in a change in reactivity between the two cases of 0.42×10^{-4} $\Delta k/k$ which is a very small value and does not change the power transient significantly.

The transients of the steam break are not changed by the change in moderator coefficient as reactor scram occurs well before any large moderator temperature changes occur. Changing the moderator coefficient only changes the amount of reactivity required in control rods out of the core prior to the accident to prevent return to critical during the moderator cooldown.

SAX-350 <u>Alpha Protection</u>

J. W. Power

All ten channels of the Alpha Monitoring System (AMS) were delivered, installed, calibrated, and operationally checked-out. Figures 1 to 5 are functional block diagrams of the ten AMS instrumentation channels. Figure 6 is a piping diagram of the detector housing assembly.

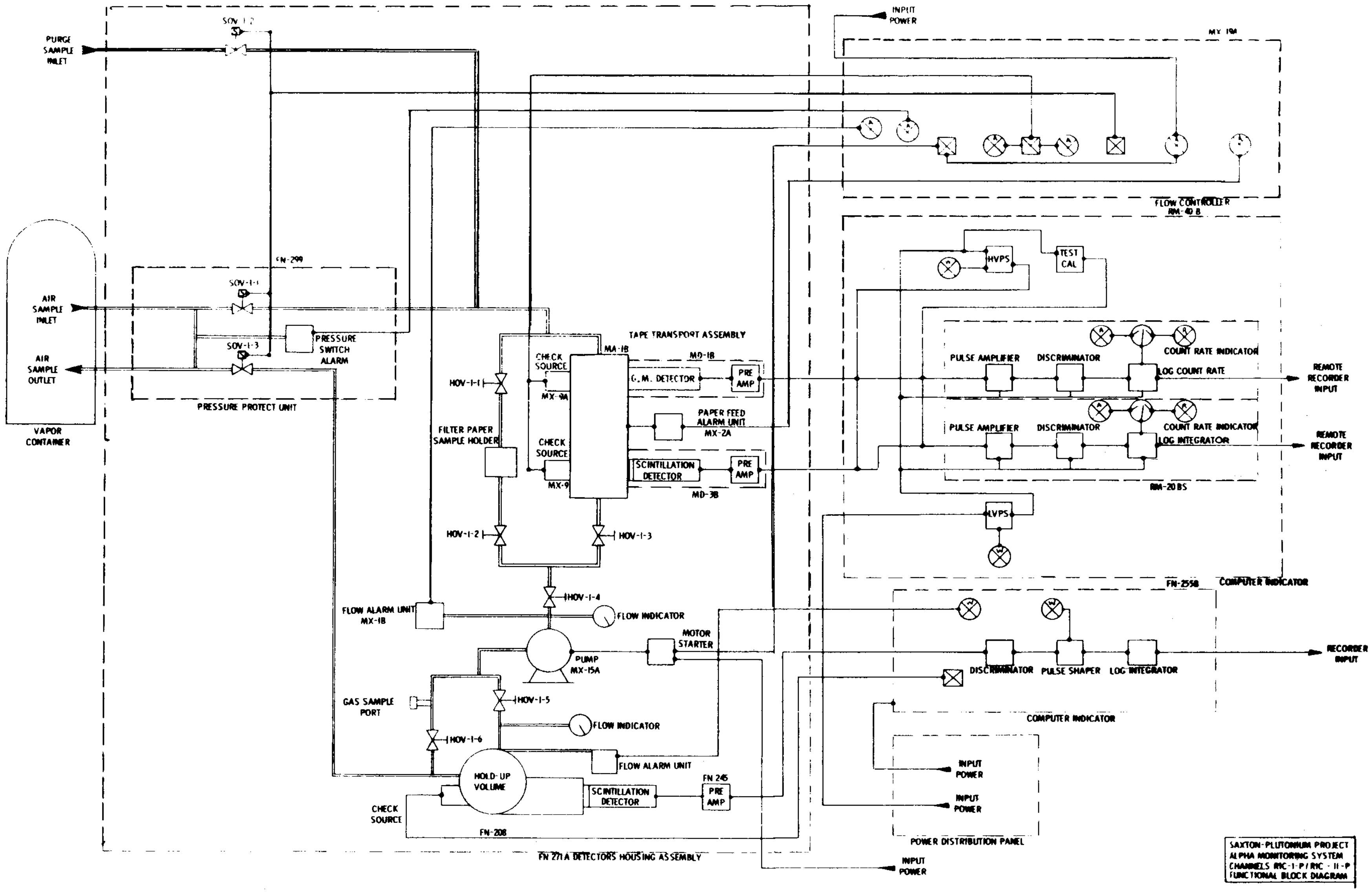
The following programs of instrument operation were initiated in conjunction with SNEC prior to plutonium fuel core loading.

A. Prior to receipt of instrumentation at the site, Radon-Thoron background level studies were conducted on a time basis throughout the plant in order to establish alarm set points.

B. More intensive alpha surface contamination techniques were established as normal plant survey operations.

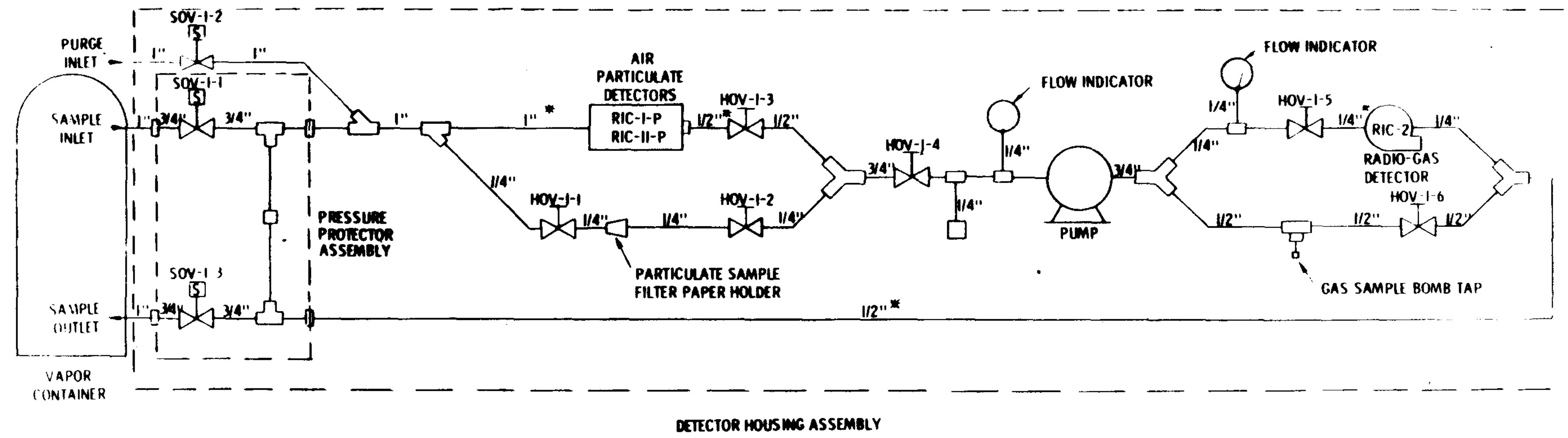
C. Alpha hand and foot monitoring stations were put in operation on a permanent basis.

D. Direct comparisons of the AMS air particulate monitors with the laboratory analysis instrumentation were initiated in order to re-affirm the channel's alpha efficiency and sensitivity.



CHANNELS RIC-1-P, RIC-2, RIC-11-P
VAPOR CONTAINER ENVIRONMENT

FIGURE 350.1



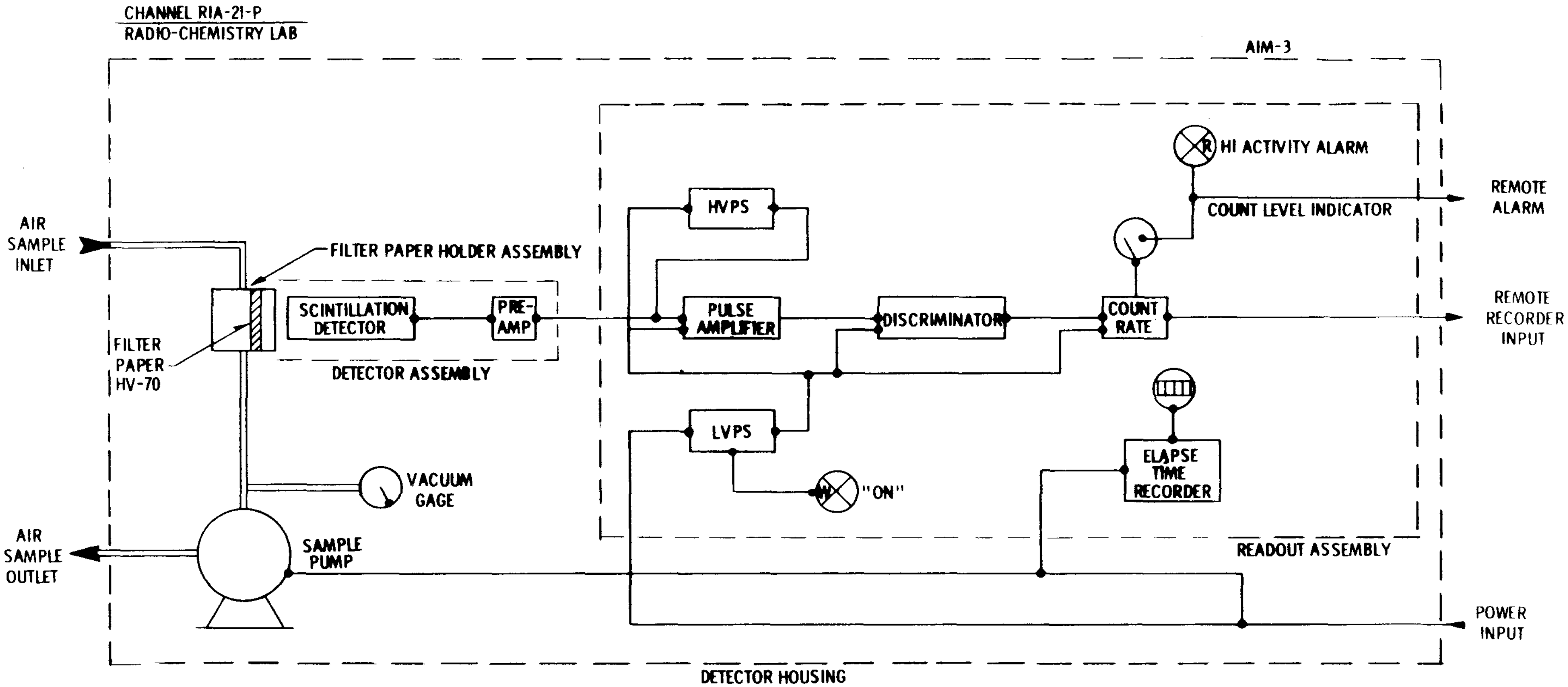
NOTE:
UNLESS OTHERWISE NOTED
ALL CONNECTIONS ARE PIPING

* RUBBER PRESSURE HOSE

SAXTON-PLUTONIUM PROJECT
ALPHA MONITORING SYSTEM
CHANNEL RIC-I-P / RIC-II-P
FLOW DIAGRAM

E.D. SK. 319390-C

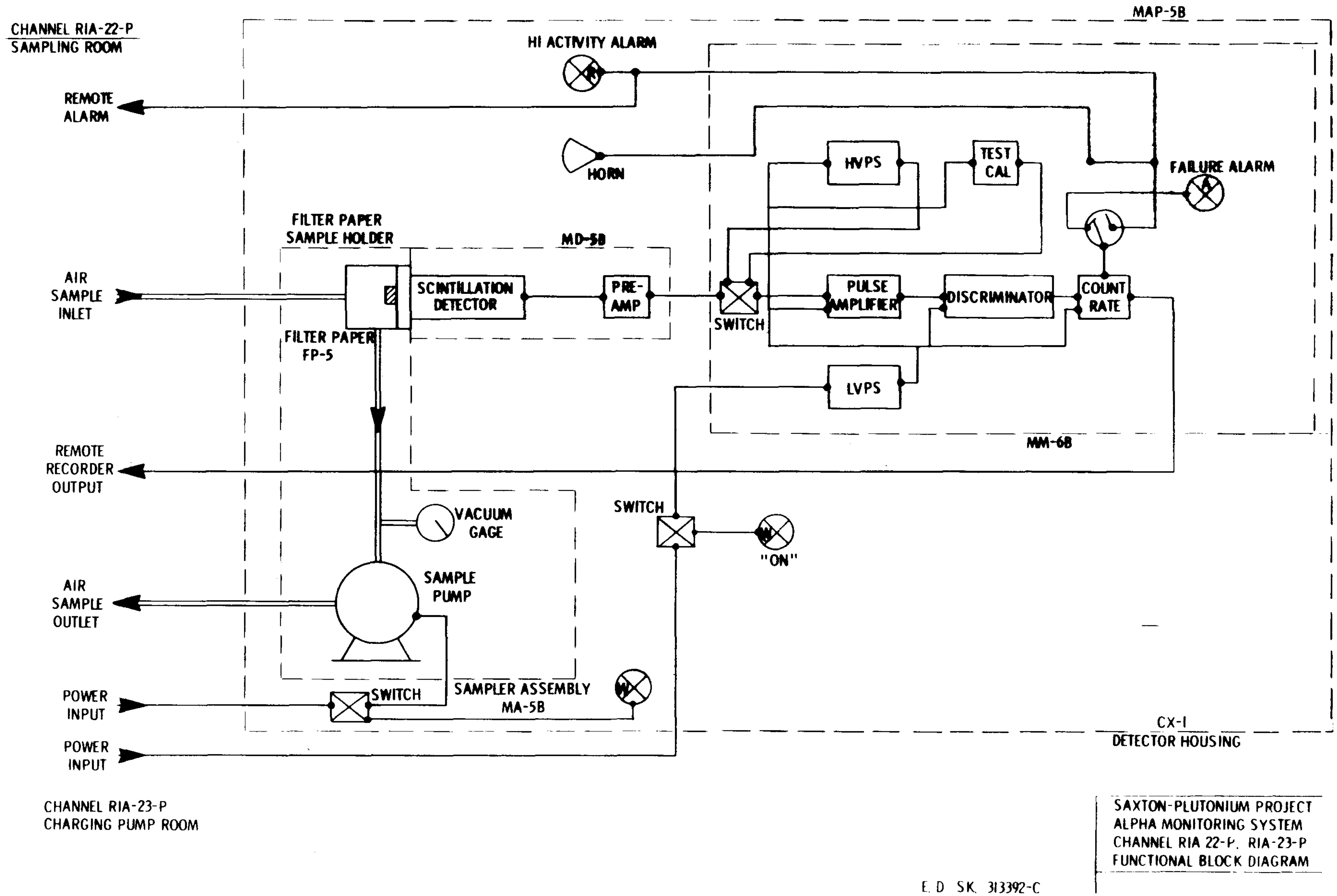
FIGURE 350.2



SAXTON-PLUTONIUM PROJECT
ALPHA MONITORING SYSTEM
CHANNELS RIA-21-P, RIA-24 P
FUNCTIONAL BLOCK DIAGRAM

E D SK 313391-C

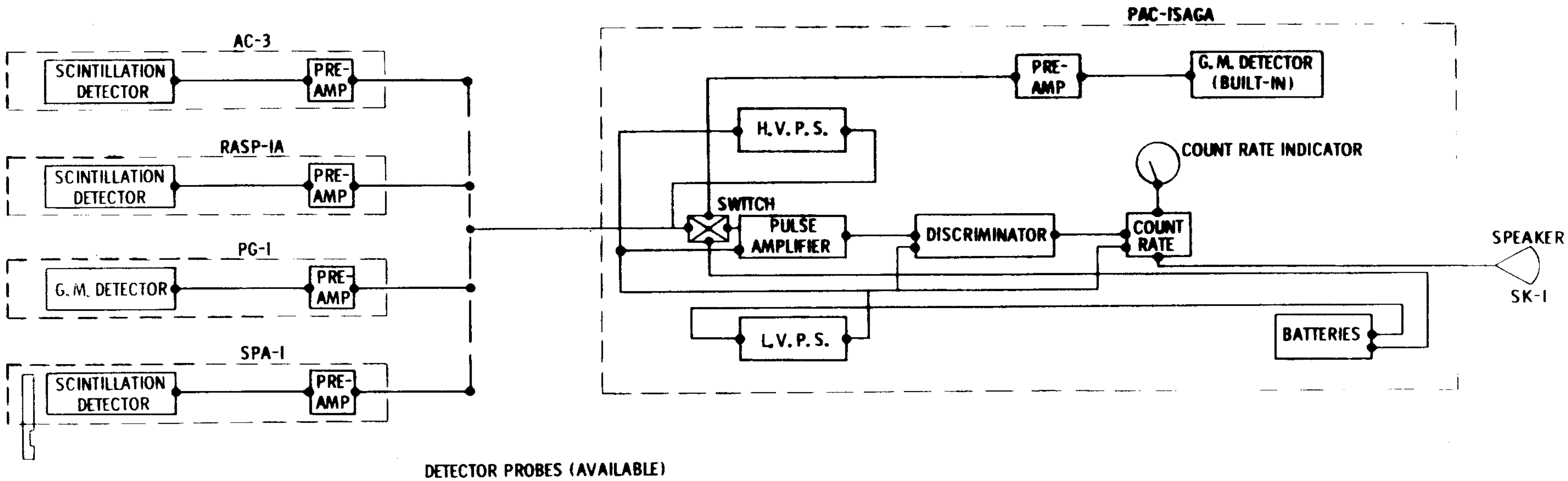
FIGURE 350.3



CHANNEL RIA-22-P
SAMPLING ROOM
MAP-5B
HI ACTIVITY ALARM
REMOTE ALARM
HORN
HVPS
TEST CAL
FAILURE ALARM
FILTER PAPER SAMPLE HOLDER
MD-5B
AIR SAMPLE INLET
SCINTILLATION DETECTOR
PRE-AMP
SWITCH
PULSE AMPLIFIER
DISCRIMINATOR
COUNT RATE
FILTER PAPER FP-5
LVPS
MM-6B
REMOTE RECORDER OUTPUT
SWITCH
VACUUM GAGE
"ON"
AIR SAMPLE OUTLET
SAMPLE PUMP
POWER INPUT
SWITCH
SAMPLER ASSEMBLY MA-5B
CX-1
DETECTOR HOUSING
POWER INPUT
CHANNEL RIA-23-P
CHARGING PUMP ROOM
SAXTON-PLUTONIUM PROJECT
ALPHA MONITORING SYSTEM
CHANNEL RIA 22-P, RIA-23-P
FUNCTIONAL BLOCK DIAGRAM
E. D. SK. 313392-C

FIGURE 350.4

CHANNEL RIA-61-P
GENERAL PLANT SURVEY



CHANNEL RIA-62-P
GENERAL PLANT SURVEY

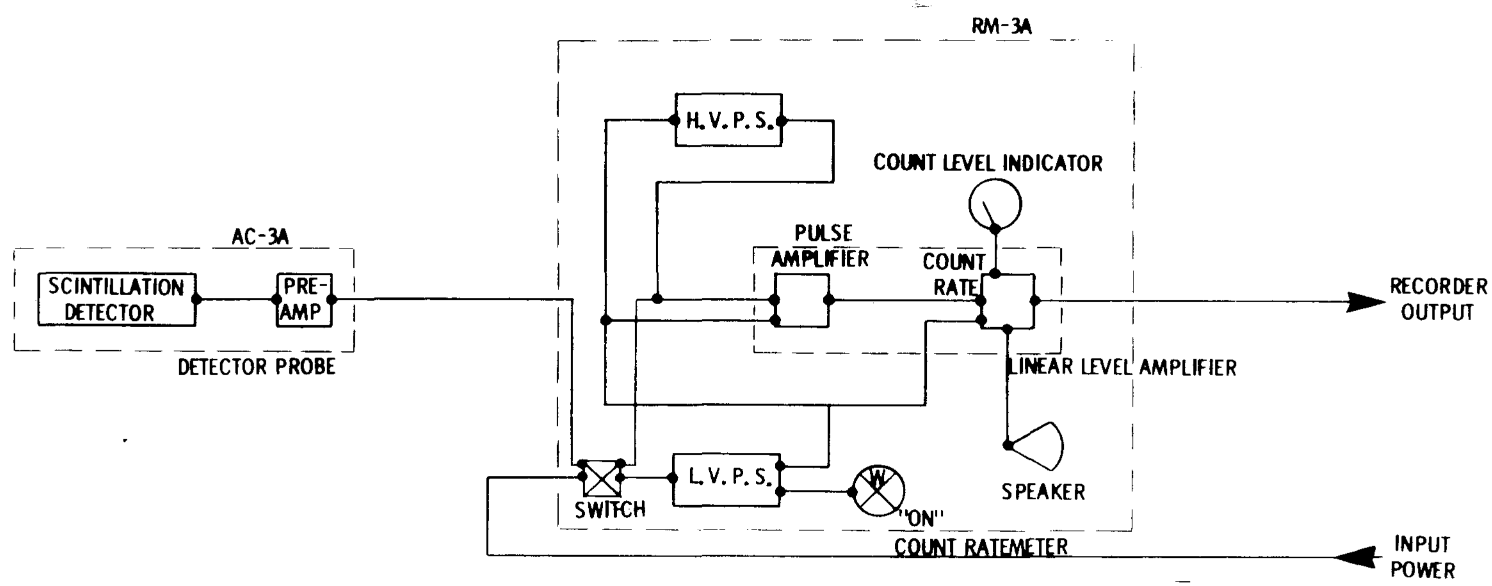
350-6

FIGURE 350

SAXTON-PLUTONIUM PROJECT
ALPHA MONITORING SYSTEM
CHANNELS RIA-61-P RIA-62-P
FUNCTIONAL BLOCK DIAGRAM

E. D. SK 319394-C

CHANNEL RIA-71-P
VAPOR CONTAINER AIR LOCK (DURING SHUTDOWN) MONITORING STATION
RADIO-CHEMISTRY LAB (DURING OPERATION) MONITORING STATION



SAXTON-PLUTONIUM PROJECT
ALPHA MONITORING SYSTEM
CHANNEL RIA-71-P, RIA-72-P
FUNCTIONAL BLOCK DIAGRAM

CHANNEL RIA-72-P
LAUNDRY ROOM MONITORING STATION

E. D. SK. 319393-C

FIGURE 350.6

The following additional equipment, not noted in the last report, was procured for the AMS:

Channel RIC-1-P Vapor Container Air Particulate Monitor
γ, β Monitor for (α/γ, β) Ratio Determination

1 Model MD-1B* G.M. Detector Assembly

1 Model RM-20BS* Count Rate Module Assembly

*Tracerlab/West Model Number

SAX-400 Performance of Critical Experiments

D. F. Hanlen, R. D. Leamer

The experimental work under this sub-task was completed during the previous quarter.

A topical report is being prepared for issue during the next quarter.

SAX-510 Nuclear Analyses of Operation Performance

F. L. Langford, W. L. Orr, A. J. Impink, R. H. Chastain,
G. F. Elletti*, H. I. Sternberg

A. Introduction and Summary

1. Introduction

During the quarter, the work under this task was begun. The objectives of the task are to compare the expected performance of the plutonium fuel in the Saxton reactor with experimental results and to evaluate the differences between the analysis and experiment that are found. A second objective is to provide supporting analysis during the irradiation period. The supporting analysis will include the evaluation of reactivity and power distribution changes with time corresponding to the operating history of the core.

The work to be carried out under this task can be divided into three phases: The first, concerns the planning of the initial test program and the predictions of the reactor performance based on the analysis and the extrapolation of the experimental data from the WREC critical experiment.

*CNEN - Rome, Italy

The second, involves the initial testing in Saxton from zero-power tests to full-power operation. The analytic requirements in this phase include the post-analysis of the startup data. The startup physics data will provide the first test of the nuclear calculation models under power reactor conditions of temperature and pressure and with engineered fuel and control configurations.

The third phase is concerned with the long-term irradiation of the core. During this phase, core conditions will be periodically monitored and analyzed. The measurements will include core power maps using the flux wire system, thermal and hydraulic measurements, and reactivity state point variables. These measurements will indicate the trend in gross power sharing with burnup and provide a measure of reactivity depletion. During this phase, the calculations will be updated to conform with the actual reactor operating history. At least twice during the long-term irradiation period and at the end of Core II life, the zero-power reactivity state will be measured by determining the all-rods out, xenon-free, boron concentration at operating temperature. The moderator temperature coefficient and selected control rod worths will be measured and trends with burnup and boron concentration will be established.

2. Summary

The following statements briefly summarize the work accomplished during the quarter:

a. The measurements program to be followed in the Saxton Core II startup and escalation to full-power was defined.

b. The program of analysis required in support of these initial experiments was begun. In addition, the analytic procedure to be followed throughout Core II operation was defined and the necessary burnup calculations were started.

B. Experimental Program

A detailed sequence of experiments to be carried out from initial criticality to full-power operation has been defined. The planned experimental program is shown in Tables 510.1 and 510.2. The column labeled "Technique" refers to a defined experimental procedure to be followed in the conduct of the experiment.

C. Analytic Program

The analytic program consists of two parts: The first, concerns the analysis that is needed in the conduct of the initial test program. The required analysis includes determining the boron

Table 510.1 - SAXTON CORE II - ZERO POWER TEST SEQUENCE

Step No.	Operation	Core Condition Change: ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	Core Condition Final Value: T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Control Rod Final Position: Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches	Measurement	Technique	Comments
1	All Rods Withdrawn (~ 1% Shutdown)	None*	None*	None*	None	None*	530	2000	*	0	(Li and K) *	40*	40*	40*	40*	1/M, Rod Withdrawl	ZC-1	
2	Boron Dilution (Critical)*	None*	None*		None	None	530	2000		0		40*	40*	40*	~36*	1/M, Boron Dilution	ZC-2	Initial Criticality
3	Endpoint (+ ~0.5 mp)	None*	None*	None*	None*	None*	530*	2000*		0*		40*	40*	40*	40*	B, ρ	ZB-1	
4	Boron Dilution (critical)*	None*	None*		None	None	530	2000		0*		40*	40*	40*	~24*	∂ρ/∂h, periodic B	ZW-1	
5	Instrument Response (~ critical)*	None*	None*	None*	None	None*	530	2000		~0		40*	40*	40*	~24	ρ	ZT-1	
6	Primary System Cool Down (critical)*	-460	-1650	None*	None	None*	Ambient*	350*		~0.2*		40*	40*			Δρ/ T_{avg}; ∂ρ/∂T; ∂ρ/∂h, Reflec. Dens. Maps	ZT-1 ZW-1 I-1	X-1 and C-5 every 20°F
7	Boron Injection (critical)*	None*	None*	+	None	None	Ambient	350		0*		40*	40*	40*	~36*	∂ρ/∂h, periodic B	ZW-1	
8	Temperature Coeff. (critical)*	±5*	None*	Mix.	None	None	~amb	350		0*		40*	40*	40*	~36	∂ρ/∂T	ZT-1	
9	Endpoint (+ ~0.5 mp)	None*	None*	None*	None*	None*	Ambient*	350*		0*		40*	40*	40*	40*	B, ρ	ZB-1	
10	Rod 2 Trip	None	None	None	None	None	Ambient	350		0		40*	40*	40*	0*	Δρ/rod 2	ZW-2	
11	Reactor Noise Measurement	None*	None*	None*	None	None*	Ambient*	350*		0		40*	40*	40*	0*	Noise records for Shutdown Eval.		Subcritical Measurement Test
12	Rod 2 Withdrawl (critical)*	None*	None*	None*	None	None*	Ambient	350		0		40*	40*	40*	~36	1/M, Rod Withdrawl	ZC-1	
13	Boron Dilution (critical)*	None*	None*	-	None	None	Ambient	350		0*		40*	40*	40*	~0*	∂ρ/∂h, periodic B	ZW-1	∂ρ/∂B
14	Temperature Coeff. (critical)*	±5*	None*	Mix.	None	None	~amb	350		0*		40*	40*	40*	~0	∂ρ/∂T	ZT-1	
15	Endpoint (± ~0.5 mp)	None*	None*	None*	None*	None*	Ambient*	350*		0*		40*	40*	40*	0*	B, ρ	ZB-1	

*Controlled condition - This condition is to be approximated as nearly as possible by adjusting as necessary the conditions not designated by asterisks

Table 510.1 - SAXTON CORE II - ZERO POWER TEST SEQUENCE (Cont'd)

Step No.	Operation	Core Condition Change: ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	Core Condition Final Value: T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg (Li & K)	Control Rod Final Position: Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches	Measurement	Technique	Comments
16	Rod 5 Trip	None	None	None	None	None	Ambient	350		0		40*	40*	0*	0*	Δρ/rod 5	ZW-2	Subcritical Measurement Test
17	Reactor Noise Measurement	None*	None*	None*	None	None*	Ambient*	350*		0		40*	40*	0*	0*	Noise records for shutdown evaluation		
18	Rod 5 Withdrawal (critical)*	None*	None*	None*	None	None*	Ambient	350		0		40*	40*	~40*	~0	1/M) rod withdrawal	ZC-1	{∂ρ/∂B
19	Boron Dilution (critical)*	None*	None*	-	None	None	Ambient	350		0*		40*	40*	~0*	0*	∂ρ/∂h, periodic B	ZW-1	
20	Temperature Coeff. (critical)*	± 5*	None*	Mixing	None	None	~Amb.	350		0*		40*	40*	~0	0*	∂ρ/∂T	ZT-1	
21	Endpoint (± 0.5 mp)	None*	None*	None*	None*	None*	Ambient*	350*		0*		40*	40*	0*	0*	B, ρ	ZB-1	∂ρ/∂B
22	Boron Dilution (critical)*	None*	None*	-	None	None	Ambient	350		0*		40*	~18*	0*	0*	∂ρ/∂h, periodic B	ZW-1	
23	Stakepoint. (critical)*	None*	None*	None*	None*	None*	Ambient*	350*		0*		40* r.3 ¦ r.4	~18*	0*	0*	B, h	ZB-3	
24	Configuration Exchange (critical)	None	None	None	None	None	Ambient	350		0		0* ¦	0*	0*	40*	None	~	Stuck rod Shutdown Evaluation
25	Rod 4 Trip	None	None	None	None	None	Ambient	350		0		0* ¦ 0*	0*	0*	40*	Δρ/rod 4	ZW-2	
26	Reactor Noise Meas.	None*	None*	None*	None	None*	Ambient*	350*		0		0*	0*	0*	40*	Noise records for shutdown evaluation		
27	Rod 2 Trip	None	None	None	None	None	Ambient	350		0		0	0	0	0	None	~	
28	Sequenced Rod Withdrawal (critical)*	None*	None*	None*	None	None*	Ambient	350		0		40*	~18	0*	0*	1/M) rod withdrawal	ZC-1	
29	Primary System Heat up (critical)*	+ 180	+ 50	None*	None	None*	250*	400*		~0.2*		40*			0*	$\Delta\rho/T_{avg}$; ∂ρ/∂T; ∂ρ/∂h Reflec. Dens. Maps	ZT-1 ZW-1 I-1	pump heat X-1 & C-5 every 20°F
30	Pressure Coeff. (critical)*	None*	± 100*	None	None	None	250	~400		0*		40*			0*	∂ρ/∂P	ZP-1	

*Controlled Condition

Table 510.1 - SAXTON CORE II - ZERO POWER TEST SEQUENCE (Cont'd)

Step No.	Operation	Core Condition Change					Core Condition Final Value					Control Rod Final Position				Measurement	Technique	Comments
		ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches			
											Li + K							
31	Pri. Sys. Heatup (critical)*	+280	+1600	None*	±< 0.5	None*	530*	2000*		~0.2*		40*	40*		0*	$\Delta\rho/T_{avg}$; $\partial\rho/\partial h$ Ref. Dens. Maps	ZT-1 ZW-1 I-1	Nuclear and pump heat X-1 & C-5 every 20°F
32	Boron Dilution (critical)*	None*	None*	-	None	None	530	2000		0*		40*	~18*	0*	0*	$\partial\rho/\partial h$, periodic B	ZW-1	
33	Temp. Coeff. (critical)*	± 5*	None*	Mixing	None	None	~530	2000		0*		40*	18	0*	0*	$\partial\rho/\partial T$	ZT-1	
34	Press. Coeff. (critical)*	None*	± 100*	None	None	None	530	~2000		0*		40*	~18	0*	0*	$\partial\rho/\partial P$	ZP-1	
35	Stakepoint (critical)*	None*	None*	None*	None*	None*	530*	2000*		0*		40*	18*	0*	0*	B ; h	ZB-3	Stuck rod shutdown Evaluation (steps 35–39)
36	Conf. Exchange (critical)	None	None	None	None	None	530	2000		0		r.3: 0* ¦ r.4	0*	0*	40*	None		
37	Rod 4 Trip	None	None	None	None	None	530	2000		0		0* ¦ 0*	0	0*	40*	$\Delta\rho$/rod 4	ZW-2	
38	Reactor Noise Meas.	None*	None*	None*	None	None*	530*	2000*		0		0*	0*	0*	40*	Noise records for shutdown evaluation		
39	Rod 2 Trip	None	None	None	None	None	530	2000		0		0	0	0	0	None	~	
40	Sequenced Rod Withdrawal (critical)*	None*	None*	None*	None	None*	530	2000		0		40*	~18	0*	0*	1/M) rod withdrawal	ZC-1	
41	Stakepoint (critical)*	None*	None*	None*	None*	None*	530*	2000*		0*		40*	~18*	0*	0*	B ; h	ZB-3	$\partial\rho/\partial B$ (steps 41–45)
42	Boron Injection (critical)*	None*	None*	+	None	None	530	2000		0*		40*	~40*	0*	0*	$\partial\rho/\partial h$, periodic B	ZW-1	
43	Temperature Coeff. (critical)*	± 5*	None*	Mixing	None	None	~530	2000		0*		40*	40	0	0*	$\partial\rho/\partial T$	ZT-1	
44	Pressure Coeff. (critical)*	None*	± 100*	None	None	None	530	~2000		0*		40*	40	0	0*	$\partial\rho/\partial P$	ZP-1	
45	Endpoint (± 0.5 mρ)	None*	None*	None*	None*	None*	530*	2000		0*		40*	40*	0*	0*	B ; ρ	ZB-2	

*Controlled Condition

Table 510.1 - SAXTON CORE II - ZERO POWER TEST SEQUENCE (Cont'd)

Step No.	Operation	Core Condition Change					Core Condition Final Value					Control Rod Final Position				Measurement	Technique	Comments
		ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches			
											Li + K							
46	Boron Injection (critical)*	None*	None*	+	None	None	530	2000		0*		40*	40*	~40*	~0*	∂ρ/∂h, periodic B	ZW-1	{∂ρ/∂B}
47	Temperature Coeff. (critical)*	± 5*	None*	Mixing	None	None	~530	2000		0*		40*	40*	~40	~0	∂ρ/∂T	ZT-1	
48	Endpoint (± 0.5 mρ)	None*	None*	None*	None*	None*	530*	2000*		0*		40*	40*	40*	0*	B ; ρ	ZB-2	
49	Rod 5 Trip	None	None	None	None	None	530	2000		0		40*	40*	0*	0*	Δρ/rod 5	ZW-2	Subcritical Measurement Test
50	Reactor Noise Meas.	None	None	None	None	None	530*	2000*		0		40*	40*	0*	0*	Noise records for shutdown evaluation		
51	Rod 5 Withdrawal (critical)*	None*	None*	None*	None	None*	530	2000		0		40*	40*	~40	~0	1/M) rod withdrawal	ZC-1	
52	Boron Injection (critical)*	None*	None*	+	None	None	530	2000		0*		40*	40*	40*	~30*	∂ρ/∂h, periodic B	ZW-1	∂ρ/∂B
53	Incore Mapping (Incore Detectors) (critical)*	None*	None*	None*	~None	None*	530	2000		~0.2*		40*	40*	40*	~30*	Temp. & Flow Maps Flux Map (Type 2 analysis)	I-Series	
54	Noise & Oscillation Meas. (critical)*	None*	None*	None*	None	None*	530	2000		0*		40*	40*	40*	~30*	Noise & Oscillation Meas.		Basepoint for power measurements
55	Boron Injection (critical)*	None*	None*	+	None	None	530	2000		0*		40*	40*	40*	~36*	∂ρ/∂h, periodic B	ZW-1	
56	Temperature Coeff. (critical)*	± 5*	None*	Mixing	None	None	~530	~2000		0*		40*	40*	40*	~36	∂ρ/∂T	ZT-1	
57	Pressure Coeff. (critical)*	None*	± 100*	None	None	None	530	2000		0*		40*	40*	40*	~36	∂ρ/∂P	ZP-1	
58	Endpoint (± 0.5 mρ)	None*	None*	None*	None*	None*	530*	2000*		0*		40*	40*	40*	40*	B ; ρ	ZB-2	Check against Step 3
59	Rod 2 Trip	None	None	None	None	None	530	2000		0		40*	40*	40*	0*	Δρ/rod 2	ZW-2	Subcritical Measurement Test
60	Reactor Noise Meas.	None*	None*	None*	None	None*	530*	2000*		0*		40*	40*	40*	0*	Noise records for shutdown evaluation		

*Controlled Condition

Table 510.1 - SAXTON CORE II - ZERO POWER TEST SEQUENCE (Cont'd)

Step No.	Operation	Core Condition Change					Core Condition Final Value					Control Rod Final Position				Measurement	Technique	Comments
		ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches			
											Li + K							
61	Rod 2 Withdrawal (critical)*	None*	None*	None*	None	None*	530	2000		0		40*	40*	40*	~36	1/M) rod withdrawal	ZC-1	
62	Rod 3 Trip	None	None	None	None	None	530	2000		0		r.3 r.4 0* 40*	40*	40*	~36*	Δρ/rod 3	ZW-2	
63	Rod 3 Withdrawal (critical)*	None*	None*	None*	None	None*	530	2000		0		40* 40*	40*	40*	~36	1/M) rod withdrawal	ZC-1	
64	Config. Exchange (critical)	None	None	None	None	None	530	2000		0		40*	40*	~36*	40*	None	~	
65	Boron Dilution (critical)*	None*	None*	-	None	None	530	2000		0*		40*	40*	*	40*	∂ρ/∂h, periodic B	ZW-1	
66	Config. Exchange (critical)	None	None	None	None	None	530	2000		0		40*	40*	40*		None		
67	Stakepoint (critical)	None*	None*	None*	None*	None*	530*	2000*		0*		40*	40*	40*		B ; h	ZB-3	

END OF ZERO POWER REACTOR PHYSICS TEST PROGRAM

*Controlled Condition

Table 510.2 - SAXTON CORE II - ELEVATED POWER REACTOR PHYSICS TEST

Step No.	Operation	Core Condition Change: ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	Core Condition Final Value: T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Control Rod Final Position: Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches	Measurement	Technique	Comments
											Li & K							
1	Power Increase (Auxiliary Load)	~None*	None*	None*	+6*	None*	530	2000		6		40*	40*	40*		$\Delta\rho/Q$	QQ-1	
2	Total Loss of Load		None	None*	-6*	None*		2000		0*		40*	40*			System Response	T-Series	
3	Power Increase	~None*	None*	None*	+10*	None*	530	2000		10*		40*	40*	40*		$\Delta\rho/Q$	QQ-1	
4	Incore Instrumen. (Incore Detectors)	-drift	None*	None*	None*	None*	~530*	2000*		10*		40*	40*	40*		Temp. & Flow Maps Flux Maps {Type 1 Analysis}	I-Series	Immediately aft. pow. rise
5 (concurrent)	Incore Instrumen. (Incore Detectors)	-drift	None*	None*	None*	None*	~530*	2000*		10*		40*	40*	40*		Temp. & Flow Maps Flux Maps {Type 2 Analysis}	I-Series	Every 3 in. of rod 2 motion
6 (concurrent)	Noise & Oscil. Meas.	None*	None*	None*	None*	None*	530*	2000*		10*		40*	40*	40*		Noise & Oscil. Recs.	-Series	
7 (concurrent)	Xenon Follow (< 12 hrs)	~None*	None*	None*	None*	None*	530	2000		10*		40*	40*	40*		$\Delta\rho$/xe (t)	QX-1	Continuously
8	Power Increase	~None*	None*	None*	+5*	None*	530	2000		15*		40*	40*	40*		$\Delta\rho/Q$	QQ-1	
9	Incore Instrumen. (Incore Detectors)	-drift	None*	None*	None*	None*	~530*	2000*		15*		40*	40*	40*		Temp. & Flow Maps Flux Maps {Type 1 Analysis}	I-Series	Immediately aft. pow. rise
10 (concurrent)	Incore Instrumen. (Incore Detectors)	-drift	None*	None*	None*	None*	~530*	2000*		15*		40*	40*	40*		Temp. & Flow Maps Flux Maps {Type 2 Analysis}	I-Series	Every 3 in. of rod 2 motion
11 (concurrent)	Noise & Oscil. Meas.	None*	None*	None*	None*	None*	530*	2000*		15*		40*	40*	40*		Noise & Oscil. Recs.	-Series	
12 (concurrent)	Xenon Follow (~72 hrs)	~None*	None*	None*	None*	None*	530	2000		15*		40*	40*	40*		$\Delta\rho$/xe (t) $\partial\rho/\partial h$; $\partial\rho/\partial T$	QX-1	Continuously
13	Incore Instrumen. (Full Core Flux Wires)	-drift	None*	None*	None*	None*	~530*	2000*		15*		40*	40*	40*		Temp. & Flow Maps Flux Maps {Type 3 Analysis}	I-Series	Specify α conditions
14	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		15*		40*	40*	40*		h ; B	QB-3	
15	Power Coefficient	$\mp$ *	None*	None*	$\mp$ 1*	None*	~530*	2000*		15*		40*	40*	40*		$\partial\rho/\partial Q$; $\partial\rho/\partial T$ $\partial\rho/\partial h$	QQ-2	

*Controlled Condition - This condition is to be approximated as nearly as possible by adjusting as necessary the conditions not designated by asterisks.

Table 510.2 - SAXTON CORE II - ELEVATED POWER REACTOR PHYSICS TEST (Cont'd)

Step No.	Operation	Core Condition Change					Core Condition Final Value					Control Rod Final Position				Measurement	Technique	Comments
		ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches			
											Li & K							
16	Total Loss of Load		None	None	-15*	None*		2000		0*		40*	40*	40*		System Response	T-Series	
17	Recovery to Power		None	None	+15	None*	530	2000		15*		40*	40*	40*		None		
18	Boron Dilution	None*	None*	-	None*		530	2000		15*		40*	40*	40*	h α*	$\partial\rho/\partial h$	QW-1	
19	Power Increase	None*	None*	None*	Qx-15*	None*	530	2000		Q_α^*		40*	40*	40*		$\Delta\rho/Q$	QQ-1	
Concurrent 20	Incore Instrumen. (Incore Detectors)	±drift	None*	None*	None*	None*	~530*	2000*		Q_α^*		40*	40*	40*		Temp. & Flow Maps Flux Map{ Type 1 Analysis}	I-Series	Immediately aft. pow. rise to specify β conditions
Concurrent 21	Xenon Follow (6 hrs)	~None*	None*	None*	None*	None*	530	2000		Q_α^*		40*	40*	40*		$\Delta\rho/xe(t)$	QX-1	Continuously
22	Power Adjustment	~None*	None*	None*	$Q_\beta - Q_\alpha$*	None*	530	2000		Q_β^*		40*	40*	40*		$\Delta\rho/Q$	QQ-1	
23	Incore Instrumen. (Incore Detectors)	± drift	None*	None*	None*	None*	~ 530*	2000*		Q_β^*		40*	40*	40*		Temp. & Flow Maps Flux Map {Type 1 Analysis}	I-Series	Immediately aft. pow. rise
Concurrent 24	Incore Instrumen. (Incore Detectors)	- drift	None*	None*	None*	None*	~530*	2000*		Q_β^*		40*	40*	40*		Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	Every 3 in. of rod 2 motion
Concurrent 25	Noise & Oscil. Meas.	None*	None*	None*	None*	None*	530*	2000*		Q_β^*		40*	40*	40*		Noise & Oscil. Recs.	-Series	
Concurrent 26	Xenon Follow (48 hrs)	~None*	None*	None*	None*	None*	530	2000		Q_β^*		40*	40*	40*		$\Delta\rho/xe(t)$	QX-1	
27	Incore Instrumen. (Full core flux wires)	None*	None*	None*	None*	None*	530*	2000*		Q_β^*		40*	40*	40*	T	Temp. & Flow Maps Flux Map {Type 3 Analysis}	I-Series	Specify γ conditions
28	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_β^*		40*	40*	40*		h ; B	QB-3	
29	Power Coefficient	$\mp$ *	None*	None*	$\mp$ 1*	None*	~530*	2000*		~ Q_β^*		40*	40*	40*		$\partial\rho/\partial Q$; $\partial\rho/\partial T$ $\partial\rho/\partial h$	QQ-2	
30	Total Loss of Load		None	None	- Q_β^*	None*		2000		0*		40*	40*	40*		System Response	T-Series	

*Controlled Condition

Table 510.2 - SAXTON CORE II - ELEVATED POWER REACTOR PHYSICS TEST (Cont'd)

Step No.	Operation	Core Condition Change					Core Condition Final Value					Control Rod Final Position				Measurement	Technique	Comments
		ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches			
											Li & K							
31	Recovery to Crit.		None	None*	None*	None*	530*	2000*		0*		40*	40*	40*		None	~	As rapidly as possible
	If recovery to criticality is accomplished in less than 2 hours, omit steps 32 through 34. If recovery to criticality requires more than 2 hours, continue with step 32.																	
32	Power Increase	~None	None	None	$+ Q_{\beta}^{*}$	None*	530	2000		Q_{β}^{*}		40*	40*	40*		None	~	
33	Xenon Stabilization (48 hrs)	None	None	None	None	None*	530*	2000*		Q_{β}^{*}		40*	40*	40*		None	~	
34	Power Decrease	~None*	None*	None*	$-Q_{\beta}^{*}$	None*	530	2000		0*		40*	40*	40*		$\Delta\rho/Q$	QQ-1	As rapidly as possible
35	Xenon Follow (72 hrs) (critical)	None*	None	None	None	None*	~530	2000		0*		40*	40*			$\Delta\rho/xe(t)$	ZX-1	
36	Boron Injection (critical)*	None*	None*	+	None		530	2000		0*		40*	40*	40*		$\partial\rho/\partial h$, periodic B	ZW-1	
37	Temp. Coeff. (critical)*	± 5*	None*	Mixing	None	None*	~530	2000		0*		40*	40*	40*		$\partial\rho/\partial T$	ZT-1	
38	Stakepoint (critical)*	None*	None*	None*	None*	None**	530*	2000*		0*		40*	40*	40*		h ; B	ZB-3	
39	Power Increase (auxiliary Load)	~None*	None*	None*	+ 2*	None**	530	2000		2*		40*	40*	40*		$\Delta\rho/Q$	QQ-1	
40	Power Increase (Min. Generator Load)	~None*	None*	None*	+ ~4*	None*	530	2000		~6*		40*	40*	40*		$\Delta\rho/Q$	QQ-1	Standard startup (steps 39–41)
41	Power Increase	~None*	None*	None*	$+\Sigma(\sim 2)^{*}$	None*	530	2000		Q_{γ}^{*}		40*	40*	40*		$\Delta\rho/Q$	QQ-1	
42	Incore Mapping (Incore Detectors)	- drift	None*	None*	None*	None*	~530*	2000*		Q_{γ}^{*}		40*	40*	40*	30*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	After each 1 4% increase in $\Delta\rho/xe$
43	Xenon Follow (72 hrs) (by xenon boron exchange)	None*	~None*	-	None*	None*	~530*	2000*		Q_{γ}^{*}		40*	40*	40*	30 ± 1*	$\Delta\rho/xe(t)$; periodic B $\partial\rho/\partial h$ 5 30"; $\partial\rho/\partial T$	QX-2	xenon effect on power distribution

*Controlled Condition

Table 510.2 - SAXTON CORE II - ELEVATED POWER REACTOR PHYSICS TEST (Cont'd)

Step No.	Operation	Core Condition Change					Core Condition Final Value					Control Rod Final Position				Measurement	Technique	Comments
		ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches			
44	Incore Mapping (Full Core Flux Wires)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ^*	Li & K	40*	40*	40*	30*	Temp. & Flow Maps Flux Map {Type 3 Analysis}	I-Series	
45	Power Coefficient	±	None*	None*	± 1 MWt*	None*	~530*	2000*		Q_γ^*		40*	40*	40*	~30*	$\partial\rho/\partial Q$	QQ-2	
46	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	30*	B	QB-3	
47	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~24*	$\partial\rho/\partial h$	QW-1	
48	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~24*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	
49	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~24*	B ; h	QB-3	
50	Boron Dilution	None*	None*	- *	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~21*	$\partial\rho/\partial h$	QW-1	
51	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~21*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	
52	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~21*	B ; h	QB-3	rod posit. effect on power distr.
53	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~18*	$\partial\rho/\partial h$	QW-1	
54	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~18*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	
55	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~18*	B ; h	QB-3	
56	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~15*	$\partial\rho/\partial h$	QW-1	
57	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~15*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	
58	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~15*	B ; h	QB-3	
59	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~ 9*	$\partial\rho/\partial h$	QW-1	
60	Incore Mapping (Incore Detectors)	None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~9*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	

*Controlled Condition

Table 510.2 - SAXTON CORE II - ELEVATED POWER REACTOR PHYSICS TEST (Cont'd)

Step No.	Operation	Core Condition Change: ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	Core Condition Final Value: T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Control Rod Final Position: Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches	Measurement	Technique	Comments
											Li & K							
61	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	40*	~9*	B ; h	QB-3	
62	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ*		40*	40*	40*	~0*	$\partial\rho/\partial h$	QW-1	
63	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	~40*	~0*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	
64	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	~40*	~0*	B ; h	QB-3	
65	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ*		40*	40*	30*	0*	$\partial\rho/\partial h$	QW-1	
66	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	30*	0*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	rod posit. effect on power distribution
67	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	30*	0*	B ; h	QB-3	
68	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ*		40*	40*	24*	0*	$\partial\rho/\partial h$	QW-1	
69	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	24*	0*	Temp. & Flow Maps Flux Map Type 2 Analysis	I-Series	
70	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	24*	0*	B ; h	QB-3	
71	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ*		40*	40*	21*	0*	$\partial\rho/\partial h$	QW-1	
72	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	21*	0*	Temp. & Flow Maps Flux Map Type 2 Analysis	I-Series	
73	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	21*	0*	B ; h	QB-3	
74	Boron Dilution	None*	None*	-	None*	None*	530*	2000*		Q_γ*		40*	40*	18*	0*	$\partial\rho/\partial h$	QW-1	
75	Incore Mapping (Incore Detectors)	~None*	None*	None*	None*	None*	530*	2000*		Q_γ*		40*	40*	18*	0*	Temp. & Flow Maps Flux Map {Type 2 Analysis}	I-Series	
76	Power Coefficient	$\mp$	None*	None*	$\mp$ 1*	None*	530*	2000*		Q_γ		40*	40*	18*	0*	$\partial\rho/\partial Q$; $\partial\rho/\partial T$ $\partial\rho/\partial h$	QQ-2	

*Controlled Condition

Table 510.2 - SAXTON CORE II - ELEVATED POWER REACTOR PHYSICS TEST (Cont'd)

Step No.	Operation	Core Condition Change: ΔT_{avg} °F	ΔP psi	ΔB ppm	ΔQ MWt	Δ Total Alkali moles x 104 / kg	Core Condition Final Value: T_{avg} °F	P psi	B ppm	Q MWt	Total Alkali moles x 104 / kg	Control Rod Final Position: Rods 3 and 4 inches	Rods 1 and 6 inches	Rod 5 inches	Rod 2 inches	Measurement	Technique	Comments
											Li & K							
77	Stakepoint	None*	None*	None*	None*	None*	530*	2000*		Q_γ^*		40*	40*	~18*	0*	B ; h	QB-3	
78	Boron Injection	None*	None*	+	None*	None*	530*	2000*		Q_γ^*		40*	40*	~40*	~0*	$\partial\rho/\partial h$, periodic B	QW-1	{$\partial\rho$ ∂B} (steps 77–80)
79	Power Coefficient	$\mp$	None*	None*	$\mp 1^*$	None*	~530*	2000*		$\sim Q_\gamma^*$		40*	40*	~40*	~0*	$\partial\rho/\partial Q$; $\partial\rho$ ∂T $\partial\rho/\partial h$	QQ-2	
80	Endpoint	~None*	None*	None*	None*	None*	~530*	2000*		Q_γ^*		40*	40*	40*	0*	B ; T_{avg}	QB-1	
81	Boron Injection	None*	None*	+	None*	None*	530*	2000*		Q_γ^*		40*	40*	40*	~40*	$\partial\rho/\partial h$, periodic B	QW-1	
82	Power Coefficient	$\mp$	None*	None*	$\mp 1^*$	None*	~530*	2000*		$\sim Q_\gamma^*$		40*	40*	40*	~40*	$\partial\rho/\partial Q$; $\partial\rho/\partial T$ $\partial\rho/\partial h$	QQ-2	{$\partial\rho$ ∂B} (steps 80–83)
83	Endpoint	~None*	None*	None*	None*	None*	~530*	2000*		Q_γ^*		40*	40*	40*	40*	B; T_{avg}	QB-1	
84	Boron Dilution	None	None	-	None	None*	530*	2000*		Q_γ^*		40*	40*	40*	~26*	None	~	
85	Power Increase	~None*	None*	None*	$Q_\beta - Q_\gamma^*$	None*	530*	2000*		Q_β^*		40*	40*	40*	~26*	$\Delta\rho/Q$	QQ-1	
86	Xenon Stabilization (48 hrs)	~None*	None*	None*	Q_β	None*	530*	2000*		Q_β^*		40*	40*	40*	~28*	None	~	
87	Rod/Temperature Exchange	+ 5*	None*	None*	None*	None*	535*	2000*		Q_β^*		40*	40*	40*	30*	$\partial\rho/\partial T$	QT-1	
88	Depletion Run	$\mp$	None*	None*	None*	None*	535*	2000*		Q_β^*		40*	40*	40*		$\Delta\rho$/Depl.(t)	QD-1	
89	Loss of Load		None	None*	$- Q_\beta$	None*	~530	2000		0*		40*	40*	40*		System Response	T-Series	

END OF ELEVATED POWER REACTOR PHYSICS TEST PROGRAM

*Controlled Condition

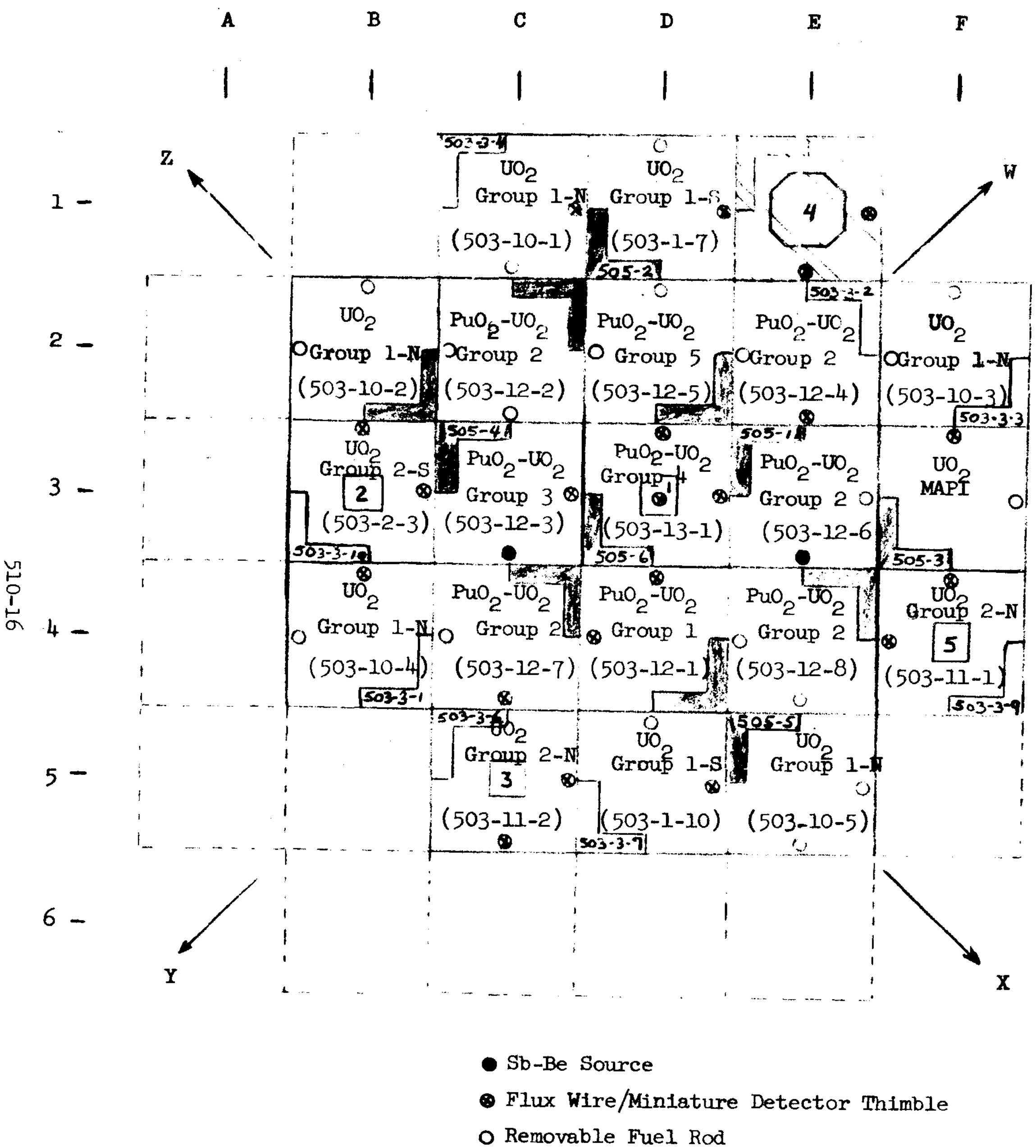
concentration requirements and rod worth for specified core configurations, calculating the two-dimensional power and flux distributions for use in interpreting the in-core flux measurement, and establishing the kinetic characteristics needed to interpret the reactivity measurements. Also included in this work is the extrapolation of the experimental data from the WREC critical experiments and the selection of the methods and cross sections to be used throughout the remainder of the program. The second part concerns the analytic procedure to be followed in tracing the irradiation history of Saxton Core II.

1. Initial Analysis

The Saxton Core II loading diagram showing the location and types of fuel assemblies is included in Figure 510.1. The goal of the initial analysis has been to determine the post-critical, rods out, boron concentration for: (a) the cold, zero-power, (b) hot, zero-power, and (c) hot, full-power conditions for the core shown in Figure 510.1. Rod worths and power distributions are also being calculated for various rod patterns for the three core conditions. The LEOPARD-PDQ-3[1] sequence is being used.

2. Method Selection

During the WREC critical program, three different versions of the LEOPARD[2] code were used. The first of these contained



Saxton Core II
Loading Diagram

PuO_2-UO_2 Assemblies

Clad / Fuel	S.S. Vipac	Zirc. Vipac	S. S. Pellets	Zirc Pellets
Group 1	8	62	-	-
Group 2	-	-	-	70
Group 3	-	-	18	52
Group 4	2	-	2	57
Group 5	-	70	-	-

Conventional UO_2 Assemblies

	Subassembly Space	Grid Design
Group 1-N	No	New
Group 2-N	Yes	New
Group 1-S	No	Old
Group 2-S	Yes	Old
MAPI	No	Old

Subassemblies

N-1	PuO_2-UO_2 3x3 subass'y	503-4-26
N-2	Hollow Tube subass'y	516-2
N-3	Core 1 UO_2 subass'y	503-4-25
N-4	S.T.P. Thimble	503-4-1
N-5	Comb. Eng. 2x2 subass'y	503-9-1

Figure 510.1 - Saxton Core II Loading Diagram

Leonard[3] cross sections. As a result of a detailed criticality study, it was decided to change to a more recent cross section set, those reported by Wescott[4] at the 1964 Geneva Conference. At that time a number of changes were planned for the production code so these changes were also included with the revision in cross-sections. This version, designated the revised LEOPARD, was used throughout the analysis of the WREC critical experiments. The net effect of the changes in the code was small; the major effect was due to the change in cross-section sets.

A new version, LEOPARD-5, is expected to become the production code in the near future. This version contains the changes incorporated in the revised LEOPARD and a still more recent set of cross sections by Sher (1965)[5]. To compare the revised LEOPARD with LEOPARD-5 codes, duplicate calculations were carried out for a number of the WREC critical lattices. The comparison is summarized in Table 510.3 and shows that the two versions are essentially equivalent particularly for the lattice pitch at which most of the experiments were performed, the 0.56-inch lattice. Since LEOPARD-5 is to become the production code and since it is equivalent to that which has been used in the correlation of the WREC experiments, it has been adopted for use in the analysis of Saxton Core II.

Table 510.4

A Comparison of Calculated k_{eff} Using the Revised LEOPARD and LEOPARD-5 Codes for the WREC Mixed-Oxide (PuO_2-UO_2) Critical Experiments*

Lattice Pitch (inches)	LEOPARD-5** [illegible], 1965 Cross Sections	Revised LEOPARD Geneva 1964 Cross Sections
0.52	0.988913	0.988674
0.56	1.00959	1.00981
0.735	1.01093	1.01230
0.792	1.015017	1.01663
1.04	1.013812	1.01620

*k-bias = 1.0 for both sets of calculations and the effect of of the aluminum mid-plate was also included.

**Calculations made by L. Strawbridge.

LEOPARD-5 was selected rather than the LASER code since LEOPARD is a production-oriented code that can be used somewhat more efficiently in the repetitive calculations required in the Saxton Core II follow. (LASER and LEOPARD criticality results for the WREC experiments are compared in the discussion included under the SAX-250 task.)

3. Installed Reactivity

A review was made of the hot, clean, full-power reactivity to be expected in Saxton Core II based on the comparison of analysis with the WREC experimental results and incorporating the changes in core configuration from that initially assumed in the analysis. Table 510.4 summarizes the results. The listed range in the available reactivity value is based on estimates as to the magnitude of the possible error for each item.

The following statements explain the items included in Table 510.4.

a. The calculated reactivity of the system was determined by means of PDQ-3 calculation with group constants determined using LEONARD cross sections. The analysis included the presence of partially depleted fuel followers and L-sections. An exposure equivalent to 18,000 MWD/tonne burnup was assumed for the followers and L-sections.

Table 510.4

Hot, Clean Reactivity for Saxton Core II

		% Δk/k
a.	Calculated reactivity, PDQ-3 analysis, (k-1)/k	13.4
b.	Change in follower locations	+ 0.4 ± 0.3
c.	Analysis-to-experiment discrepancy	- 1.4 ± 0.6
d.	Core configuration changes	- 0.3 ± 0.3
e.	Change in grid material - Stainless Steel to Inconel-X	- 0.3 ± 0.1
f.	Non-uniform moderator temperature distribution	- 0.2 ± 0.2
g.	Change in fuel density from original calculations	- 0.2 ± 0.2
	Available Reactivity	11.4 ± 0.8

b. As shown in Figure 510.1, the two fuel followers in the center of the Saxton Core I will be moved to outer positions in Saxton Core II. The effect of this change is to increase the installed reactivity.

c. The allowance for the discrepancy between analysis and experiment was originally based on a comparison of a number of Hanford approach-to-critical experiments. For these experiments at a lower plutonium fuel loading than that specified for the Saxton reactor, an average discrepancy of $\approx$ 2.6% $\Delta k/k$ was found. To allow for this error in the reactivity predictions, an equivalent full-core error of 3% $\Delta k/k$ was assumed and a calculated weighting factor of $\approx$ 0.7 was applied for a partial core loading. As a result, a correction of 2.0% was used in the original reactivity predictions[7] for the design core. The same type of analysis as that used in the design calculations was carried out for the WREC experiments. A discrepancy of approximately 2% was found for the unborated 0.56-inch lattice which has the same H/Pu ratio as the Saxton design at temperature. Applying the calculated weighting factor of 0.7 results in a revised allowance of 1.4% for the discrepancy.

d. The changes of item (d) include the presence of the supercritical assembly with a steel plug in position E1, the partially burned element in E1, the movement of the vibratory compacted fuel assemblies from the corners of the plutonium region to the flats, and the effect of an increase in Doppler due to a non-uniform fuel temperature distribution.

Items e, f, and g are the same as those included in previous tabulations and correct for the small difference between the actual configuration and that used in the analysis.

4. Operations Follow

Part of the requirement of this task is to follow the operating history of the reactor. Consequently, during this quarter, the analytic procedure to be used was identified and the initial burnup calculations were begun. The procedure will make use of three separate analytic steps. In the first step, LEOPARD calculations will be carried out for a specified burnup sequence with variations made in the boron content according to a planned burnup-boron matrix. The output from the required LEOPARD will then be placed on tape and will be used as a source of group constants to be obtained by a process of interpolation or extrapolation. In the second step, group constants for each region in the reactor will be determined according to the region burnup history and the required boron content. The group constants will then be used in step three, which will consist of a PDQ-3 calculation corresponding to a particular measurement configuration. This procedure was adopted because it will provide a simple yet flexible method for analytically following the operating history of the reactor.

References

1. W. R. Cadwell, et. al., "PDQ-3, A Program for the Solution of the Neutron Diffusion Equation in Two-Dimensions on the IBM-704," WAPD-TM-179 (May 1960).

2. R. F. Barry, "LEOPARD - A Spectrum Dependent Non-Spatial Depletion Code for the IBM-7094," WCAP-3741 (1963).

3. B. R. Leonard, Jr., "Plutonium Physics: Contribution to Plutonium Handbook," WH-72947 (March 1962).

4. C. H. Westcott, "Survey of Nuclear Data for Reactor Calculations," A/Conf. 27/P. 717 (1964).

5. J. R. Stehn, "Thermal-Neutron Cross Sections of Fissile Isotopes," ANS Transactions, Vol. 8, No. 1 (June 1965).

6. C. G. Poncelet, "Burnup Physics of Heterogeneous Reactor Lattices," WCAP-6069 (1965).

7. N. R. Nelson, "Saxton Plutonium Program Quarterly Progress Report for the Period Ending December 31, 1964," WCAP-3385-2 (1964).

SAX-660 Post-Irradiation Materials Evaluation

R. J. Allio, A. Biancheria, R. N. Stanutz

The 3 x 3 removable subassembly containing four vibrationally compacted and four pelletized fuel rods and one flux thimble operated satisfactorily in the Saxton reactor for a period of approximately two months. Exposure accumulated was approximately 1400 MWD per ton (U + Pu). The reactor is presently shut down for refueling. The 3 x 3 assembly will be moved from its present periphery location to the center of the core (the center of Assembly 3D) during the refueling.

A detailed post-irradiation sampling plan was prepared for review by the AEC. It was approved and authority to proceed with the present work program was obtained. Details of the plan are summarized in Table 660.1 and the location of the rods to be examined in Figures 660.1 and 660.2. Additional details of the plan are explained in Attachment I and II.

The plan was based on a review of the Yankee Core Evaluation results and was designed to meet the stated objectives of the work program.

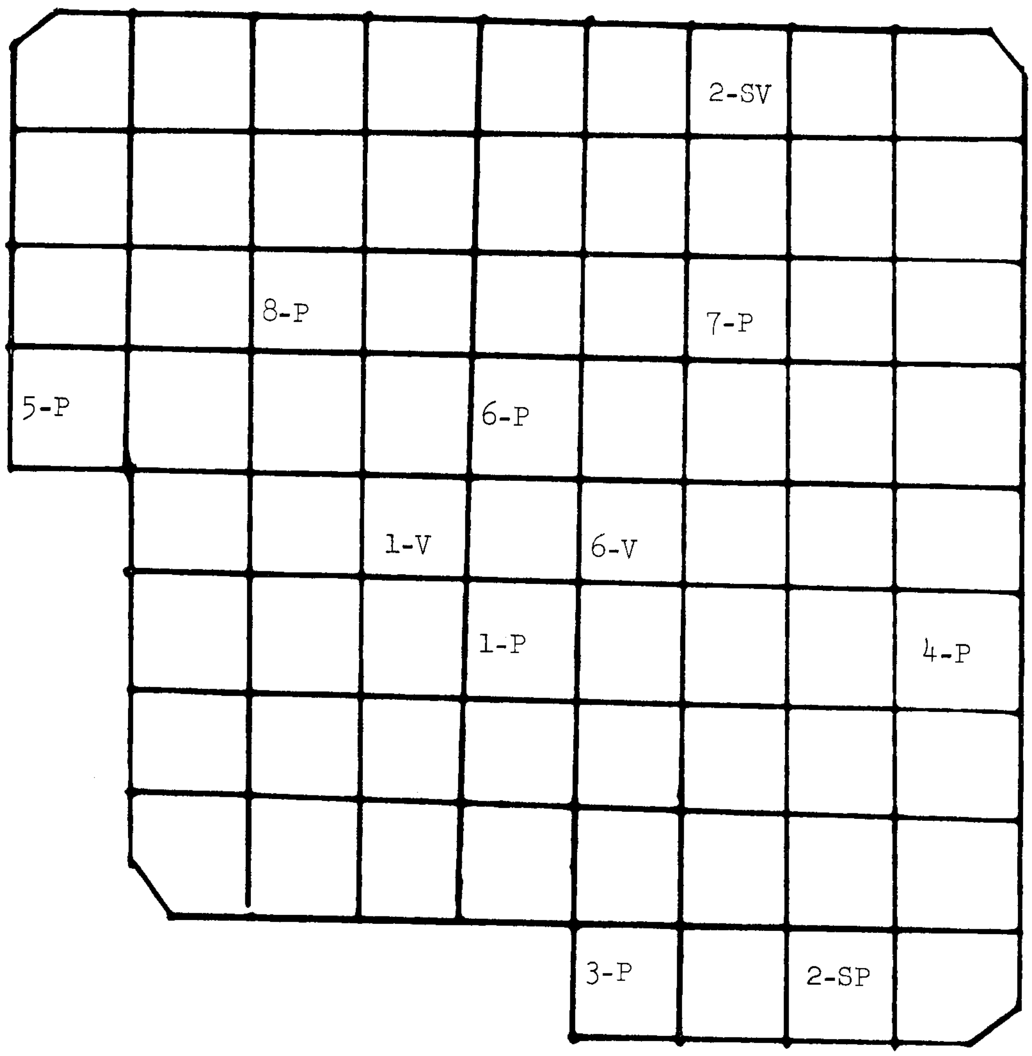
A - Asymptotic Neutron Spectrum
FW - Perturbed Spectrum Near Flux-Wire Location
WS - Perturbed Spectrum Near Water Slot
OP - Perturbed Spectrum, Off Pitch

V - Vipac (Zirc)
P - Pelletized (Zirc)
SP - Pelletized (Stainless)
SV - Vipac (Stainless)

Table 660.1

												Radiochemical								
Assembly	Fuel Rod	Neutron Spectrum	Assembly Exam. On-Site	Visual & Photo. Exam. Intact Assem.	Visual Stereographic Photographic Dimensional	Metallographic	Tensile Test	Burst Test	Single Channel Gross γ-Scan	Multi-Channel γ -Scan	Fission Product. Gas	Mn-54 Clad Sample	Isotopic Analysis	Burnup Cs-137	Sr-90	*Zr-95	X-ray Fluorescence Pu/U	Auto-Radiography	9 cuts, 5 Isotopic 5 Cs, 5 Pu/U 5 Sr-90 Full Radial Analysis	9 cuts, 5 Cs, 5 Pu/U - Partial Radial Analysis
3-D	---	---	X	X																
	1-P	FW			X	3	1	1	1		X	2	2	2			2	1		1
	1-V	FW			X	3	1	1	1		X	2	2	2			2	1		1
	2-SP	OP			X				1	2	X			2			2			
	2-SV	WS			X				1		X			2			2			
	3-P	WS/OP			X	3	1	1	1		X	2	3	3			3			
	4-P	WS/OP			X				1		X			2			2			
	5-P	WS/OP			X				1		X			2			2			
	6-P	FW			X	3	1	1	1		X	2		2			2			
	6-V	FW			X	3	1	1	1		X	2		2			2			
	7-P	A			X				1	2			5	5	5		5	1	1	
	8-P	A			X				1				5	5	5		5			
4-D			X	X																
	3-V	WS/FW			X	3	1	1	1		X	2		2			2			
	4-V	WS/FW			X				1		X			2			2			
	5-V	OP			X				1		X			2			2			
	9-V	A			X				1				3	3	3		3	1	1	
	Sub-Totals		2	2	15	18	6	6	15	4	12	12	18	38	13		38	4	2	2
	Total		2	2	15	18	6	6	15	4	12	12	28	58	23		58	4	2	2

*If techniques improve, may include some Zr-95 analyses.



V - Vipac (Zirc)

P - Pellets (Zirc)

SP - Pellets (Stainless)

SV - Vipac (Stainless)

Figure 660.1 - Location of Rods to be Examined in Assembly 3-D

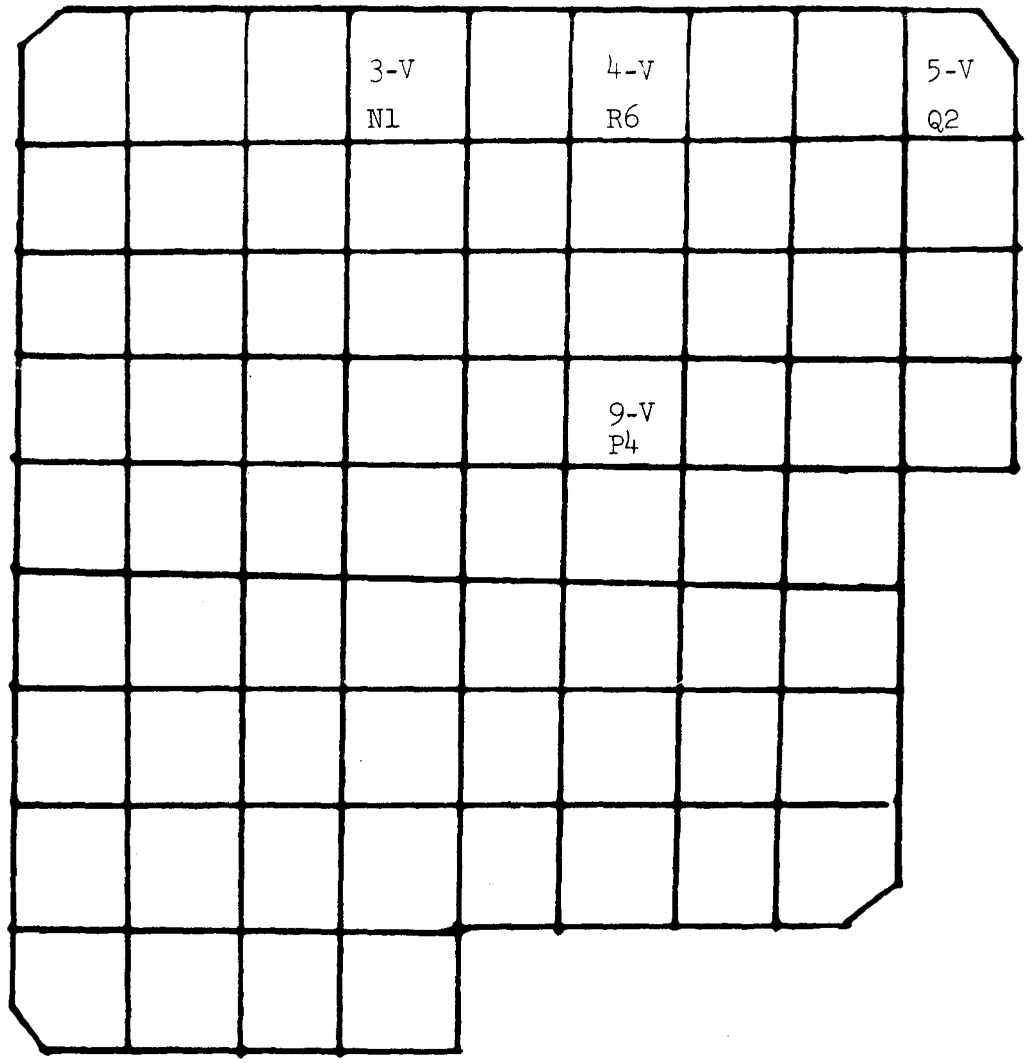


Figure 660.2 - Location of Rod to be Examined in Assembly 4-D

In order to estimate the statistical significance of the results to be obtained, the fission gas diffusion constant results of the Yankee Core Evaluation were analyzed and used as a basis for estimating the required statistics. The variance, σ^2 of the log of the Yankee data was calculated and the unbiased estimate of the variance, S, obtained from the equation.

$$S = \sigma^2 N/(N-1)$$

where N is the number of samples.

The limits of $\bar{X}$, the mean of the log of the data, were then calculated as

$$\bar{X} \pm \frac{ts}{\sqrt{N}}$$

where t is obtained from standard tables of student t distribution. The value of t was taken at the 95% confidence level. For the Saxton Plutonium Program, we have two groups to consider, vibrationally compacted fuel and pelletized fuel; therefore, the number of samples, N, is equal to six (a total of 12 rods will be analyzed). The result of the calculation is:

$$\frac{ts}{\sqrt{N}} = 0.511$$

To interpret the meaning of this result, we may assume that the average diffusion constant for the PuO_2-UO_2 data will be 3.2×10^{-10}, i.e., in the same range as the UO_2 data. The result then says that we will be 95% confident that the true mean, i.e., the mean of the 650 rods being irradiated, will be between 10^{-9} and 10^{-10}. At the 90% confidence level this range is reduced to 1.2×10^{-10} to 8.3×10^{-10}.

The results, therefore, will adequately represent the entire PuO_2-UO_2 core and will be sufficient to compare PuO_2-UO_2 to UO_2, vibrationally compacted fuel to pelletized fuel and most important, will be sufficient to establish reference data for design of future cores. The data will provide a better basis for design of large PuO_2-UO_2 cores than was available for design of the first UO_2 cores.

<u>ATTACHMENT I</u>

Post-Irradiation Examination - Hot Cells
Rev. #3 - 7/29/65

1. Transfer two assemblies from Transfer Building to Hot Cells.

   a. Center 9 x 9, No. 3-D. (Includes 3 x 3 subassembly)

   b. Lower flat 9 x 9, No. 4-D.

2. Perform visual and photographic examination of the two intact assemblies.

   a. Examine each assembly for twist, bow, distortion, broken grid structures and/or wear markings.

   b. Provide overall composite photographs of each assembly.

   c. Photograph and assess extent of irregularities, if any, observed in (a).

3. Remove a total of 15 fuel rods from the two or three assemblies.

   a. Remove rods 1-V, 1-P, 6-V, 6-P, from the 3 x 3.

   b. Remove rods 2-SV, 2-SP, 4-P, 5-P, from Assembly 3-D.

   c. Remove rods 3-V, 4-V, 5-V, from Assembly 4-D.

4. Perform visual, stereomicroscope and photographic examination of each of the 15 fuel rods.

   a. Scan each rod visually in hot cell for possible defects, distortion, excess crud.

   b. Scan each rod with stereomicroscope for possible defects.

   c. Photograph each rod.

   d. Note and photograph any defects under the stereomicroscope.

Perform dimensional measurements of 15 fuel rods.

   a. Take remote measurements of 0° and 90° at six-inch intervals along the rod length with a standard vernier micrometer.

   b. Measure and record length to the nearest mil.

6. Perform single channel gamma scan of the 15 fuel rods.

7. Perform multi-channel gamma scan of the 2 fuel rods.

   a. Use rods 7-P and 2-SV.

   b. Measure gamma activity at frequent intervals over the length of each fuel rod.

   c. Plot activity values.

8. Collect and analyze fission gases released from twelve rods.

   a. Use rods 1-P, 1-V, 2-SP, 2-SV, 3-P, 4-P, 5-P, 6-P, 3-V, 4-V, 5-V, 6-V.

   b. Rods 7-P, 8-P and/or 7-V will be punctured to insure the accurate collection of twelve samples.

   c. Analyze the gasses with a mass spectrograph.

9. Section the 15 fuel rods.

   a. Use the gamma scan of each fuel rod to determine the selection of maximum, intermediate and minimum flux areas.

   b. Section with a water cooled abrasive cut-off wheel.

   c. Number section locations for individual tests.

10. Prepare samples from each rod for burnup and isotopic analysis.

    a. Select .5" long samples from areas of interest on the gamma scan.

    b. Refer to Table 1 for number of samples per rod.

11. Perform metallographic examination of clad and fuel on 6 fuel rods.

    a. Use rods 1-P, 1-V, 6-P, 6-V, 3-P and 3-V.

    b. Cut three .50" sections from each rod and mount.

    c. Select one sample adjacent to a burnup sample.

    d. Select the other two samples from areas representing possible defect clad sections and/or lower flux areas as shown on the gamma scan plot.

12. Perform autoradiography and radial drilling on a total of four selected fuel samples.

    a. Select samples (one each) from rods 1-P, 1-V, 7-P and 9-V.

    b. Drill 9 concentric holes of increasing diameter. Analyze every other ring.

    c. Autoradiograph the sample prior to drilling.

13. Perform clad tensile tests on six selected samples.

    a. Cut six 6-inch tensile specimens from six selected rods.

    b. Use rods 1-V, 1-P, 6-V, and 6-P from the 3 x 3 assembly, and 3-P from assembly 3-D and 3-V from assembly 4-D.

14. Perform burst tests on six selected samples.

    a. Cut six 4-inch burst specimens from the above six selected rods.

    b. Cut these specimens from the area adjacent to the tensile specimens or to metallographic specimen near the burnup samples. This decision shall be dictated by the gamma scan.

15. Prepare twelve samples of cladding for radiochemical determination of Mn-54.

    a. Select two samples from the following rods 1-P, 1-V, 3-P, 3-V, 6-P, and 6-V.

    b. Select cladding samples from the fuel sections dissolved for burnup analysis.

ATTACHMENT II

Post-Irradiation Chemical & Radiochemical Examination

Rev. #3 - 7/29/65

1. Perform chemical analyses of three randomly chosen pre-irradiated Zircaloy samples used as cladding for the fuel rods to determine, among other constituents, the Fe content of the Zircaloy cladding. Later post-irradiation analyses for Mn-54 content will provide a measure of the fast neutron flux received which converted the Fe to Mn-54.

2. Perform radiochemical determination of Mn-54 on twelve samples of irradiated Zircaloy cladding.

   a. Select two vipac Zirc-rod samples and two pelletized Zirc-rod samples.

   b. Employ method of sample choice outlined in Section 15 of Attachment I.

3. Perform burnup and isotopic analyses for 15 fuel rods.

   a. Prepare Pu and U isotopes, Cs-137 and Sr-90 from .5" long sample.

   b. Employ method of sample choice outlined in Section 10 of Attachment I.

4. Perform burnup and isotopic analyses on four radial drilled fuel samples.

   a. Analyze Pu and U isotopes, Cs-137, Sr-90 and Pu/U ratio as listed in Table 660.1.

   b. Employ method of sample choice outlined in Section 12 of Attachment I.

Remaining Sub-Tasks

A. A. Bishop, et. al.

SAX-520 Thermal-Hydraulic Analyses of Operations - A. A. Bishop

This work, which will consist of a minimum effort thermal and hydraulic follow program during startup and operation, is primarily for the purpose of providing flow and heat transfer consultation.

SAX-610 Post Irradiation Storage & Shipments - H. E. Walchli

SAX-620 Post Irradiation Examination - Transfer Building - D. T. Galm

SAX-630 Post Irradiation Examination - Hot Cells - D. T. Galm

SAX-640 Post Irradiation Radiochemical Examination - D. T. Galm

SAX-650 Waste Disposal - D. T. Galm

SAX-660 Material Evaluation - R. J. Allio

A detailed sampling plan is included in this report.

SAX-670 Fuel Reprocessing - H. E. Walchli

Technical work in the preceding 600 series of shop orders will commence in early 1968.

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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