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ORR OPERATIONS FOR PERIOD

APRIL 1958 TO APRIL 1959

J. A. Cox

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ORR OPERATIONS
FOR PERIOD APRIL 1958 TO APRIL 1959

By

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
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CONTENTS

INTRODUCTION.....	1
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PART I

SUMMARY.....	2
REACTOR OPERATIONS	
Oak Ridge Research Reactor.....	3
ORR APPROACH-TO-CRITICAL RUNS	
AND LOW-POWER NEUTRON MEASUREMENTS.....	13
ORR APPROACH-TO-POWER TESTS.....	72

PART II

SUMMARY.....	87
REACTOR OPERATIONS	
Oak Ridge Research Reactor.....	88
ORR Tests	
Neutron Measurements in the ORR.....	109
Flux Trap Tests.....	141

PART III

SUMMARY.....	154
REACTOR OPERATIONS	
Oak Ridge Research Reactor.....	155

PART IV

SUMMARY.....	172
REACTOR OPERATIONS	
Oak Ridge Research Reactor.....	173

INTRODUCTION

It has been the custom to report the operating experience at the ORR along with other activities in the Operations Division at ORNL. A number of requests have been received for information on the operating history of the ORR, and it was decided to combine the appropriate sections of the Operating Division reports covering the year from April 1958 through March 1959.

During the year covered by these reports, the ORR was put into service after a period of preliminary testing. Many of the unique design features have proved to be very useful. For example, the bottom control-rod drives free the top of the reactor tank, making it possible to insert a number of loops and in-pile experiments which do not have to be disturbed during refueling operations. The location of the reactor tank in a pool of water makes it easy to change fuel in a short time. On occasion the fuel has been changed in 5 hours after the reactor was caught by growth of xenon in the fuel following a shutdown. The insertion and removal of in-pile experiments can be done easily, making it possible to achieve a high percentage of operating time. The ease with which the core can be unloaded makes it feasible to remove all fuel before changing experiments in beam holes and, thus, reduce the radiation from hazardous to safe levels. The flat side of the reactor provides a region of high flux in the adjacent pool where experiments can be inserted and removed very readily. The flexibility of the ORR core itself makes it possible to rearrange the fuel, beryllium, and control rods into a number of configurations both for greater usefulness for experiments and for special experiments on the reactor.

The operating time has increased, after initial troubles were overcome, from 48 to 76%.

OPERATIONS DIVISION

Quarterly Report

April - June 1958

SUMMARY

Testing of the ORR was continued under the direction of the ORR Project Group.

The Trane coolers are not giving the rated capacity, and representatives of the Trane Company are working on this problem.

Low-level neutron tests and approach-to-power tests were completed. At the end of the quarter the ORR is being readied for routine operation.

PART I

Taken from OPERATIONS DIVISION QUARTERLY REPORT

April - June, 1958, ORNL CF-58-6-122

1. REACTOR OPERATIONS

W. R. Casto

1.1 Oak Ridge Research Reactor

Operations

The Oak Ridge Research Reactor was operated during this period to perform preoperation tests. These included reactivity measurements, flux measurements, core mapping, and shim rod calibration. Approach-to-power experiments included temperature studies on reactor components at power levels up to 20 Mw. The nuclear tests continued from April 1, through May 19, with power levels up to 200 kw using the operating core and a 4 x 7 array. The power tests continued from May 20, through June 29. Dates on which various power levels were first reached are indicated in Table 1.1.

Table 1.1 Initial ORR Power Levels

<u>Power Level (Mw)</u>	<u>Date</u>
3	5-20
7	5-25
10	5-26
15	5-28
20	5-29

During the quarter 254.08 Mwd of energy were accumulated during a total operating time of 412.137 hr.

Major Shutdowns

Tests were interrupted twice during this period: between June 15 and 16, the fission chamber was repaired and instrumentation installation was continued; on June 24, a second period of shutdown started, extending into the next quarter, to make the reactor ready for routine operation. The cooling water system for the north and south large facilities is to be repiped. The beam hole plugs are to be filled with concrete. Ten 1/2-in. holes are to be drilled in the lattice plate in the reactor vessel in order to obtain a better distribution of cooling water around the large facility thimbles, and the venturi for the reactor water flow is to be calibrated.

Water System

During the quarter the reactor and its associated water systems were operated intermittently. However, sufficient time was available for equilibrium to be reached at several power levels. The water systems were checked closely to ensure that activities were in the expected order of magnitude. Both reactor and pool demineralizers operated satisfactorily. Their performance following four days of continuous operation at 20 Mw is indicated in Table 1.2.

Table 1.2. Demineralizer Performance on June 24

	Flow Rate (gpm)	pH	Specific Resistance (ohm-cm)	Activity (counts/min/ml)
Reactor demineralizer	88			
In		5.7	7×10^5	21,556
Out		6.2	2×10^6	1,659
Pool demineralizer	75			
In		6.04	1.3×10^6	1,209
Out		6.33	2.25×10^6	310

Table 1.3 gives the result of laboratory analyses giving effective capacities of the south reactor demineralizers. It should be pointed out that the units were regenerated last on February 21, and that capacity checks were made on June 5. These units were still in operation at the end of the quarter.

Table 1.3 ORR Demineralizer Resin

Throughput (gal) as of 6-5	Sample Depth	Capacity (meq/ml)							
		Single-Bed Units				Mixed-Bed Units*			
		Cation Residual	Anion Total	Cation Residual	Anion Total	Cation Residual	Anion Total	Cation Residual	Anion Total
6,014,000	Top	3.20	4.75	0.55	2.68			0.77	2.73
	Top					0.34	4.02		
	Bottom							0.17	2.44
	Bottom					3.03	4.79		

*The samples of resin from the mixed bed were taken in the mixed state, with the top sample coming from ~18 in. from top of bed, and the bottom sample coming from ~9 in. from bottom of resin bed.

Analyses of reactor and pool water are indicated in Table 1.4. The reactor was operating at 20 Mw with a flow rate of 12,000 gpm.

Table 1.4 Water Analysis on June 4

Contaminant	Activity (d/min/ml)
Reactor Water (demineralizer flow rate, 60 gpm)	
Na ²⁴	5.25×10^4
Np ²³⁹	~166
A ⁴¹	7.05×10^3
Xe ¹³³	114
Xe ¹³⁵	≥198
I ¹³¹	~28
Sr ⁸⁹	~61
Ba ¹⁴⁰	~20
Te ¹³²	~20
La ¹⁴⁰	~6
Mo ⁹⁹	~25
Ce ¹⁴³	~72
Cd (by activation analysis)	5.3×10^{-9} (g/ml)
U ²³⁸ (by activation analysis)	2.0×10^{-9} (g/ml)
Pool Water (demineralizer flow rate, 75 gpm)	
Na ²⁴	1.32×10^3
Np ²³⁹	48
I ¹³¹	9
Cd (by activation analysis)	2.3×10^{-9} (g/ml)
U ²³⁸ (by activation analysis)	1.1×10^{-9} (g/ml)

The Na^{24} activity in the reactor water system vs flow through the reactor demineralizer is indicated in Table 1.5.

Table 1.5 Sodium-24 Activity

	Date				
	6-2	6-4	6-5	6-23	6-24
Demineralizer flow (gpm)	137	60	60	86	86
Reactor flow (gpm)	12,000	12,000	12,000	15,000	15,000
Power level (Mw)	20	20	20	20	20
Na^{24} activity (d/min/ml)	3.30×10^4	5.25×10^4	5.27×10^4	3.87×10^4	3.89×10^4

The secondary pool cooling loop has required considerable attention during the intermittent and variable power runs. A special chemical treatment to inhibit corrosion and microbiological growth in the redwood tower as recommended by the National Aluminate Corporation is being followed. To maintain the recommended pH and total solids ratio, special equipment was fabricated and installed. An automatic dispenser for dilute H_2SO_4 is used for pH control. An automatic blow-down system maintains the proper total solids ratio.

Corrosion samples have been exposed in the primary pool cooling water. Others are currently installed in the secondary cooling loop. Coupons have been designed and fabricated from metals identical to the reactor core for exposure. Coupons of similar metals will be exposed in the storage pools.

Radiation Level

During this testing period temporary shielding was placed at the north and south facilities to permit operation. As originally designed, a permanent shield is scheduled for installation with the experiments at the north and south facilities. Radiation hazard areas include the sub-pile room, the pipe chase, the reactor demineralizer cells, and the cells at the pump house.

A detailed survey inside the reactor vessel was made following the power tests and after the core pieces and fuel elements had been transferred to the reactor pool. These data and the radiation levels of beam holes and beam hole plugs after their removal are indicated in Tables 1.6 and 1.7.

Table 1.6 Radiation Readings -- ORR Area

Flow Rate: 12,000 gpm

G-M Survey Meter Used for First 2 Readings; Cutie-Pie for Others

<u>Date</u>	<u>Radiation (mr/hr)</u>	<u>Location</u>	<u>Remarks</u>
<u>At a Power Level of 10 Mw</u>			
5-28	80-150	North facility	Reading taken around annulus of large plug
	25-50	North facility	General background through large plug
	50-100	South facility	Reading taken around annulus of large plug
	35-55	South facility	General background through large plug
	150	South facility	Water line exiting from plug
<u>At a Power Level of 20 Mw</u>			
6-2	5	Top of pool	
	1	HB-1, 2, 5, and 6	Holes flooded with H ₂ O
	50	HB-4	Instrumented plug, with H ₂ O
	30	HB-3	Same as above
	19	North facility plug	Same as above
	20	South facility plug	Same as above
	150	South anion unit	South reactor demineralizer in service; reading taken at center
	10	South mixed bed	Same as above
	200	South cation unit	Same as above; through 2 in. of lead
	20	Expansion pit	In pump area
	65	No. 2 pump	Reading taken on discharge line of pump, with pump in service
	30	No. 1 pump	Reading taken on inlet line of pump, with pump not in service
	12	Air cooler	Background at 6-ft level

Table 1.7 Radiation Readings for ORR Area with Reactor
Down and Flow Stopped

Type of Instrument Used: Cutie Pie

<u>Date</u>	<u>Radiation (mr/hr)</u>	<u>Location</u>	<u>Remarks</u>
7-1	30-40	HB holes	Fuel and Be removed from core; beam-hole plug removed
	10 at step of large section; 40 on inner section	HB-3 and 4 plugs	Instrumented full-size plug
	10 at inner end of half plug	HB-1, 2, 5, and 6	Half plugs consisting of outer section

With Fuel Removed and with Cutie Pie at 3 ft Below Reactor Top

6-30	2000	Reactor vessel	With 1 in. H ₂ O over lattice
7-7	42	Reactor vessel	With 4 in. H ₂ O over lattice
	200	Reactor vessel	With 2 in. H ₂ O over lattice; hold- down arms ² in position
	150	Reactor vessel	With 2 in. H ₂ O over lattice; hold- down arms ² on lower grid

The fuel inventory as of June 3 is shown in Table 1.8.

Table 1.8 ORR Fuel Inventory

	U^{235} (g)
Core	
26 fuel elements	2,978.00
4 shim rods	<u>483.47</u>
In pool for temporary storage on 6-29	3,461.47
Pool, 11 fuel elements	1,581.71
Fuel reserve	
Building 3042 vault, 17 fuel elements	2,921.71
Building 3001 storage, 3 shim rods	393.71
Building 3027	
8 elements, 168 of each	1,344.00
21 elements, 200 of each	4,200.00
3 shim rods	<u>390.00</u>
	14,291.97
Three enriched chambers	<u>5.12</u>
Total	14,297.09

General

The following items were dropped into the reactor vessel and not retrieved:

1. A knurled stainless steel nut, about 1 in. in diameter and 1/4 in. thick, fell into core position B-5.
2. Six aluminum discs 1/2 in. in diameter and 1/8 in. thick, which were lost during the drilling of 10 holes in the lattice plate.

The facility assignments as shown in Table 1.9 are also shown in Fig. 1.1 as part of the core loading.

Table 1.9 Facility Assignment

<u>Facility</u>	<u>Access Flange</u>	<u>Nature of Experiment</u>	<u>Division</u>	<u>Individual</u>
A-9	V-1	Thorium oxide slurry studies	Chem. Tech.	J. P. McBride
B-9	V-2	Gas-cooled loop	Solid State	J. G. Morgan
C-8	V-3	HRP irradiation metallurgy	Solid State	R. G. Berggren
F-8	V-4	Hydraulic rabbit	Operations	General Use
F-9	V-5	Vertical fused-salt loop	Solid State	W. E. Browning
F-3	V-6	Creep and stress corrosion	Solid State	J. C. Zukas
F-2	V-7	Gas-cooled fuel studies	Solid State	O. Sisman
F-1	V-8	Solid fuel studies	Metallurgy	J. E. Cunningham
C-1	V-9	Fuel tests	Solid State	J. G. Morgan
B-1	V-10	Air cooled loop	Solid State (G.E.)	E. S. Collins
A-1, A-2	Special	Gas-cooled loop	Reactor Projects	D. B. Trauger
C-3		Fast neutron facility	Solid State	M. C. Wittels
A-7, F-4)				
F-5, F-6) and F-7)		Isotope production	Isotopes	E. E. Beauchamp
Pool		ANP and HRP irradiation metallurgy	Solid State	J. C. Wilson
Pool		He ⁶	Physics	F. Pleasonton
HN-1		HRP solution corrosion loop	REED	R. A. Lorenz
HN-2		HRP autoclave irradiation studies	REED	R. A. Lorenz
HN-3)		Pneumatic rabbit	Chemistry	A. R. Brosi
HN-3)		Activation analysis	Analytical Chem.	G. W. Leddicotte
HN-4		HRP slurry corrosion torroid	REED	D. T. Jones
HS-1, HS-2		PAR slurry loop program	Chem. Tech.	T. A. Arehart
HB-1		Magnetic analysis of fission frag- ments with time of flight	Physics	H. W. Schmitt
HB-2		Neutron spectrometer	Physics	E. O. Wollan
HB-3		Neutron spectrometer	Physics	E. O. Wollan
HB-4		Neutron spectrometer	Chemistry	E. A. Levy
HB-5		Neutron spectrometer	Physics	L. D. Roberts
HB-6		Time-of-flight neutron spectrometer	Physics	J. A. Harvey

Fig. 1.1. ORR Lattice Pattern No. 2.

2. ORR APPROACH-TO-CRITICAL RUNS AND LOW-POWER NEUTRON MEASUREMENTS

C. D. Cagle

The results of the approach-to-critical runs and low-power neutron measurements are being compiled for a special report, ORNL-2559, which will be published sometime during the third quarter of 1958. However, in order to benefit both research and operations personnel in the planning of early experiments, much of the data obtained is given in this report and will be repeated in ORNL-2559 with more attention to the methods used.

Approaches to Critical and Attaining Full-Sized Cores

Criticality was achieved on March 21, at 6:06 p.m., with a test core made up of five 168-g shim rods within a 3-in. minimum thickness of beryllium reflector. The total fuel involved was 1366.16 g, and the rods were withdrawn about 85% of their full travel. This first critical assembly was used for instrument and control performance checks.

A second approach-to-critical run was completed at 3:20 p.m. on March 22 with six 140-g fuel elements and the four 131-g shim rods. The total fuel involved was 1365.46 g, and the rods were withdrawn about 93% of their full travel. The second core was expanded to a 4 x 7 array by the careful addition of 70- and 140-g fuel elements. The 4 x 7 configuration was used to check the design criteria.

In order to supply the desired neutron intensities and spectra to the various research facilities, a T-shaped core is required. This arrangement was built by deforming the 4 x 7 array and using two additional 140-g fuel elements.

The critical assemblies, the 4 x 7 array, and the operating cores are shown in Figs. 2.1 through 2.6. Due to the undesirable neutron flux depression caused by having a radioisotope production facility adjacent to one of the shim rods, a revised operating core was adopted after some of the reactivity calibrations had been made.

Core and Rod Calibrations

The cores and the shim rods in each core assembly were calibrated by the distributed-poison method using boron-carbide-impregnated Plexiglas strips which had been individually calibrated against copper and stainless steel strips in the reflector region of the LITR. The excess reactivity of each core assembly is given in the figure legends. Calibration graphs of the individual rods and the rods as a group in each core are included (Figs. 2.7 through 2.19).

These calibrations were used to measure the reactivity effects of introducing voids around the core, the temperature coefficient of each core, and the reactivity changes resulting from introducing experiments and additional fuel into various regions of the operating core. Since the revised operating core was assembled after the completion of the core and rod calibration runs, it had to be assumed that, although the individual rod calibrations were no longer valid, the gang calibration of the rods was essentially still correct. This was confirmed by fuel additions which caused essentially the same gang rod displacements when done in regions far from the location of the lattice changes.

Reactivity Effects of Voids

The reactivity changes caused by introducing voids were measured for

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POOL
W

A-1	A-2	A-3 Be	A-4 Be	A-5 Be [Ⓢ]	A-6 Be	A-7 Be	A-8 Be	A-9
B-1		Be	SHIM 131.25	FUEL 168.25	SHIM 131.25	Be		
C-1		Be	FUEL 168.44	FUEL 168.25	FUEL 168.23	Be		
D-1		Be	SHIM 131.25	FUEL 167.96	SHIM 131.28	Be		
E-1		Be	Be	Be	Be	Be	Be	
F-1		Be	Be	Be	Be	Be	Be	
G-1		Be	Be	Be	Be	Be	Be	

E

Be --- BERYLLIUM REFLECTOR PIECE

Be[Ⓢ] --- BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON
SOURCE

Fig. 2.1. First Critical Core. Total mass, 1366.16 g.

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POOL
W

A-1	A-2	A-3 Be	A-4 Be	A-5 [Ⓢ] Be	A-6 Be	A-7 Be	A-8 Be	A-9
B-1		Be	SHIM 131.25	FUEL 140.09	SHIM 131.25	Be		
C-1		Be	FUEL 139.65	FUEL 140.09	FUEL 140.12	FUEL 140.36	Be	
D-1		Be	SHIM 131.25	FUEL 140.12	SHIM 131.28	Be		
E-1		Be	Be	Be	Be	Be	Be	
F-1		Be	Be	Be	Be	Be	Be	
G-1		Be	Be	Be	Be	Be	Be	

E

S

N

Be --- BERYLLIUM REFLECTOR PIECE

Be[Ⓢ] --- BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON
SOURCE

Fig. 2.2. Second Critical Core. Total mass, 1365.46 g.

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POOL
W

	A-1 Al	A-2 Be	A-3 Be	A-4 Be	A-5 Be [Ⓢ]	A-6 Be	A-7 Be	A-8 Be	A-9 Al	
	B-1 Be	FUEL 140.12	FUEL 140.09	SHIM 131.25	FUEL 140.09	SHIM 131.25	FUEL 139.87	FUEL 140.12	Be	
	C-1 Be	FUEL 139.65	FUEL 69.96	FUEL 139.65	FUEL 69.96	FUEL 140.12	FUEL 69.87	FUEL 140.36	Be	
S	D-1 Be	FUEL 139.82	FUEL 69.96	SHIM 131.25	FUEL 69.87	SHIM 131.28	FUEL 69.87	FUEL 140.12	Be	N
	E-1 Be	FUEL 139.89	FUEL 139.65	FUEL 70.16	FUEL 139.87	FUEL 70.16	FUEL 140.19	FUEL 139.46	Be	
	F-1 Be	Be	Be	Be	Be	Be	Be	Be	Be	
	G-1 Al	Be	Be	Be	Be	Be	Be	Al	Al	
										E

Al---ALUMINUM REFLECTOR PIECE

Be---BERYLLIUM REFLECTOR PIECE

Be[Ⓢ]---BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON
SOURCE

Fig. 2.3. 4 x 7 Core. Total mass, 3323.83 g; excess reactivity, 13.94% $\Delta k/k$; rods, 52% withdrawn. Individual fuel weights (g) are shown for each fuel element and shim rod.

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POOL
W

A-1 Al	A-2 Be	A-3 Be [Ⓢ]	FUEL 140.10	FUEL 140.09	FUEL 140.11	A-7 Be	A-8 Be	A-9 Al
B-1 Be	Be		SHIM 131.25	FUEL 140.09	SHIM 131.25	FUEL 139.87	Be	Be
C-1 Be	Be	FUEL 69.96	FUEL 139.65	FUEL 69.96	FUEL 140.12	FUEL 69.87	Be	Be
FUEL 140.12	FUEL 139.82	FUEL 69.96	SHIM 131.25	FUEL 69.87	SHIM 131.28	FUEL 69.87	FUEL 140.12	FUEL 140.12
FUEL 139.65	FUEL 139.89	FUEL 139.65	FUEL 70.16	FUEL 139.87	FUEL 70.16	FUEL 140.19	FUEL 139.46	FUEL 140.36
F-1 Be	Be	Be	Be	Be	Be	Be	Be	Be
G-1 Al	Be	Be	Be	Be	Be	Be	Be	Al

S

N

E

Al--- ALUMINUM REFLECTOR PIECE

Be--- BERYLLIUM REFLECTOR PIECE

Be[Ⓢ]---BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON SOURCE

Fig. 2.4. First Operating Core (Clean). Total mass, 3604.12 g; excess reactivity, 13.90% $\Delta k/k$; rods, 54% withdrawn. Individual fuel weights (g) are shown for each fuel element and shim rod.

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POOL
W

A-1 E	A-2 E	A-3 Be [Ⓢ]	FUEL 140.10	FUEL 140.09	FUEL 140.11	A-7 Be	A-8 Be	A-9 E
B-1 E	Be	R	SHIM 131.25	FUEL 140.09	SHIM 131.25	FUEL 139.87	Be	E
C-1 E	E 147.57	FUEL 69.96	FUEL 139.65	FUEL 69.96	FUEL 140.12	FUEL 69.87	E	Be
S FUEL 140.12	FUEL 139.82	FUEL 69.96	SHIM 131.25	FUEL 69.87	SHIM 131.28	FUEL 69.87	FUEL 140.12	N FUEL 140.12
FUEL 139.65	FUEL 139.89	FUEL 139.65	FUEL 70.16	FUEL 139.87	FUEL 70.16	FUEL 140.19	FUEL 139.46	FUEL 140.36
F-1 E	Be	R	Be	R	Be	R	Be	E
G-1 Be	Be	Be	Be	Be	Be	Be	Be	Be
E								

Be --- BERYLLIUM REFLECTOR PIECE

Be[Ⓢ] --- BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON SOURCE

E --- PARTIAL FUEL ELEMENT CONTAINING EXPERIMENT
147.57

R --- RADIOISOTOPE PRODUCTION FACILITY

Fig. 2.5. First Operating Core with Experiments. Total mass, 3751.69 g; excess reactivity, 7.72% $\Delta k/k$ (without experiment in F-9); rods, 65% withdrawn. Individual fuel weights (g) are shown for each fuel element and shim rod.

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POOL
W

A-1 E	A-2 E	A-3 Be [Ⓢ]	FUEL 140.10	FUEL 140.09	FUEL 140.11	A-7 R	A-8 Be	A-9 E
B-1 E	Be	FUEL 69.96	SHIM 131.25	FUEL 140.09	SHIM 131.25	FUEL 139.87	Be	E
C-1 E	Be	E 147.57	FUEL 139.65	FUEL 69.96	FUEL 140.12	FUEL 69.87	E	Be
S FUEL 140.12	FUEL 139.82	FUEL 69.96	SHIM 131.25	FUEL 69.87	SHIM 131.28	FUEL 69.87	FUEL 140.12	FUEL 140.12
FUEL 139.65	FUEL 139.89	FUEL 139.65	FUEL 70.16	FUEL 139.87	FUEL 70.16	FUEL 140.19	FUEL 139.46	FUEL 140.36
F-1 E	Be	R	Be	R	Be	R	Be	E
G-1 Be	Be	Be	Be	Be	Be	Be	Be	Be
E								
N								

Be--- BERYLLIUM REFLECTOR PIECE
Be[Ⓢ]--- BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON SOURCE
E --- EXPERIMENT LOCATION
E --- PARTIAL FUEL ELEMENT CONTAINING EXPERIMENT
147.57
R RADIOISOTOPE PRODUCTION FACILITY

Fig. 2.6. Revised Operating Core with Experiments. Total mass, 3751.69 g; excess reactivity, 8.69% $\Delta k/k$ (without experiment in F-9); rods, 61% withdrawn. Individual fuel weights (g) are shown for each fuel element and shim rod.

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ORNL-LR-DWG 32150

Fig. 2.7. Gang-Rod Calibration in 4 x 7 Test Core. Core worth, 13.94% $\Delta k/k$; central slope, 1.73% $(\Delta k/k)/in.$

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Fig. 2.8. Number 4 Rod Calibration in 4 x 7 Test Core. Total worth, 8.59% $\Delta k/k$; central slope, 0.5% $(\Delta k/k)/\text{in.}$

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Fig. 2.9. Number 6 Rod Calibration in 4 x 7 Test Core. Total worth, 5.95% $\Delta k/k$; central slope, 0.346% $(\Delta k/k)/\text{in.}$

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Fig. 2.10. Gang-Rod Calibration in Clean Operating Core. Core worth, 13.90% $\Delta k/k$; central slope, 1.57% ($\Delta k/k$)/in.

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Fig. 2.11. Number 3 Rod Calibration in Clean Operating Core. Total worth, 10.09% $\Delta k/k$; central slope, 0.675% ($\Delta k/k$)/in.

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Fig. 2.12. Number 4 Rod Calibration in Clean Operating Core. Total worth, 8.97% $\Delta k/k$; central slope, 0.60% $(\Delta k/k)/\text{in.}$

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Fig. 2.13. Number 5 Rod Calibration in Clean Operating Core. Total worth, 7.16% $\Delta k/k$; central slope, 0.47% $(\Delta k/k)/\text{in.}$

Fig. 2.14. Number 6 Rod Calibration in Clean Operating Core. Total worth, 6.14% $\Delta k/k$; central slope, 0.39% $(\Delta k/k)/in.$

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Fig. 2.15. Gang-Rod Calibration in Operating Core with Experiments. Core worth, 7.72% $\Delta k/k$; central slope, 1.30% $(\Delta k/k)/\text{in.}$

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Fig. 2.16. Number 3 Rod Calibration in Operating Core with Experiments. Total worth, 10.35% $\Delta k/k$; central slope, 0.64% $(\Delta k/k)/\text{in.}$

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ORNL-LR-DWG 32160

Fig. 2.17. Number 4 Rod Calibration in Operating Core with Experiments. Total worth, 10.37% $\Delta k/k$; central slope, 0.63% $(\Delta k/k)/in.$

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ORNL-LR-DWG 32161

Fig. 2.18. Number 5 Rod Calibration in Operating Core with Experiments. Total worth, 6.70% $\Delta k/k$; central slope, 0.43% $(\Delta k/k)/\text{in.}$

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ORNL-LR-DWG 32162

Fig. 2.19. Number 6 Rod Calibration in Operating Core with Experiments. Total worth, 5.84% $\Delta k/k$; central slope, 0.35% $(\Delta k/k)/\text{in.}$

the 4 x 7 configuration and for the clean operating core. The results are given in Tables 2.1 and 2.2. During these measurements HB-4 was already a void containing a fission chamber.

Temperature Coefficient

The temperature coefficient was measured with the 4 x 7 core, the clean operating core, and the operating core with experiments. The results are as follows:

<u>Configuration</u>	<u>Temperature Coefficient</u>	
	$\Delta k/k$ (%) per °F	$\Delta k/k$ (%) °C
4 x 7	6.75×10^{-3}	1.22×10^{-2}
Clean operating core	6.43×10^{-3}	1.16×10^{-2}
Operating core with experiments	6.57×10^{-3}	1.18×10^{-2}

It is evident that the experiments in the lattice have no effect upon the temperature coefficient. Heat was supplied to the reactor system by operating the pumps and keeping the heat exchangers turned off.

Reactivity Effects of Experiments

In order to know the reactivity effects which will be caused by replacing beryllium reflector pieces with experiment facilities, the research groups were requested to furnish mocked-up experiments to be used in the lattice for these measurements. Where convenient, measurements were also made of the effect of flooding the facility with water. The measurements are listed in Table 2.3. Due to installation difficulties, a measurement of the reactivity effect of inserting W. Browning's experiment into F-9 was not obtained. The value should be similar to that of J. Zukas' experiment in F-1.

Table 2.1

Summary of Void Worths with 4 x 7 Core

<u>Condition</u>	<u>Reactivity (%)</u>
HB-1 drained	-0.035
HB-1 and HB-2 drained	-0.049
HB-1, HB-2, and HB-3 drained	-0.074
HB-2 and HB-3 drained	-0.054
HB-3 drained	-0.047
HB-1, HB-2, HB-3, HB-5, and HB-6 drained	-0.127
HB-2 drained	-0.017
HN drained	-0.470

On the assumption that the effect of draining HS is the same as for HN and that draining HB-4 is the same as for HB-3, the total effect of draining all holes would be $-1.114\% \Delta k/k$.

Table 2.2

Summary of Void Worths with Clean Operating Core

<u>Condition</u>	<u>Reactivity (%)</u>
HB-1 drained	-0.038
HB-1 and HB-2 drained	-0.042
HB-1, HB-2, and HB-3 drained	-0.113
HB-2 and HB-3 drained	-0.080
HB-3 drained	-0.065
HB-1, HB-2, HB-3, HB-5, and HB-6 drained	-0.201
HN drained	-0.863
Pool side void inserted	-0.97

On the assumption that the effect of draining HS is the same as for HN and that draining HB-4 is the same as HB-3, the total effect of draining all holes is $-1.99\% \Delta k/k$, not including the pool side facility. With the pool side void included, the total is $-2.96\% \Delta k/k$.

Table 2.3

Summary of Reactivity Values of Experiment Insertions and Related Measurements

<u>Core Position</u>	<u>Change</u>	<u>Reactivity (%)</u>
A-1 and A-2	Beryllium replaced by GCRE experiment facility	-0.72
A-1 and A-2	GCRE facility flooded with water	/ 0.024
A-1 and A-2	Fuel test inserted into A-1	/ 0.12
A-1 and A-2	Fuel test inserted into A-2	/ 0.24
A-9	Beryllium insert replaced by J. McBride's experiment	-0.05
B-1	Beryllium replaced by hollow, water-filled aluminum adapter	-0.38
B-1	Hollow, air-filled tube inserted into adapter	-0.27
B-1	Effect of flooding air-filled tube with water	/ 0.11
B-3	Beryllium replaced by radioisotope production facility (later moved to position A-7)	-1.67
A-7	Beryllium replaced by radioisotope production facility	-0.96
B-9	Beryllium insert replaced by G. Morgan's experiment facility	-0.09
C-1	Beryllium insert replaced by H. Morgan's experiment facility	-0.35
C-2	Beryllium replaced by M. Wittel's half fuel element (later moved to C-3)	/ 1.31
C-3	Beryllium replaced by M. Wittel's half fuel element	/ 1.57
C-8	Beryllium replaced by R. Berggren's experiment	-2.26
F-1	Beryllium replaced by J. Zukas' experiment	-0.66
F-3	Beryllium insert replaced by radioisotope production facility	-0.68
F-7	Beryllium insert replaced by radioisotope production facility	-0.35
Pool side	Void chamber installed	-0.98
Pool side	Void chamber filled with water	/ 0.98

Reactivity Effect of Fuel Additions

The gain in reactivity due to fuel additions into various core positions was measured in both the first operating core configuration and the revised operating core configuration with the dummy experiments in place. The measurements were made with both cores in order to check the validity of the assumption that the gang rod calibration for the first core would be correct for the revised core. Agreement was good, particularly in the regions far from the changes of fuel placement. Table 2.4 summarizes the reactivity changes measured.

Table 2.4

Summary of Reactivity Changes Due to Fuel Additions in Old and Revised Operating Cores (Fuel Mass in Core Before Additions = 3751.69 g)

Core Position	Fuel Addition	Reactivity Gain		$\frac{\Delta k/k}{\Delta m/m}$		Reactivity Change Per Gram Added (%)	
		Old Core	Revised Core	Old Core	Revised Core	Old Core	Revised Core
A-5	60.19	0.28		0.174		0.00465	
A-6	60.17	0.27	0.22	0.168	0.137	0.00449	0.00365
B-5	60.19	0.58	0.54	0.352	0.337	0.00964	0.00097
B-7	60.41	0.44	0.33	0.273	0.205	0.00728	0.00546
C-5	130.32	2.06	1.92	0.593	0.553	0.01581	0.01473
C-6	60.16	0.78	0.65	0.487	0.405	0.01297	0.01080
C-7	130.41	1.48	1.18	0.426	0.339	0.01135	0.00904
D-5	130.41	2.05	2.01	0.589	0.578	0.01571	0.01541
E-1	60.63	0.16	0.14	0.0990	0.0867	0.00264	0.00231
E-3	60.63	0.64	0.65	0.396	0.402	0.01056	0.01072
E-5	60.41	0.83	0.75	0.515	0.466	0.01374	0.01242

In order to obtain some idea of the reactivity gain that can be expected from fuel additions in the future, a relationship between the neutron flux and the expected gain in reactivity per amount of fuel added was sought for each core position. Table 2.5 gives the ratios of $(\Delta k/k)/(\Delta m/m)$ to the average relative neutron flux, the square of the

average relative neutron flux, the maximum relative neutron flux, and the square of the maximum relative neutron flux for each position checked in the revised operating core. The best relation, with the exception of position E-1, appears to be the ratio of $(\Delta k/k)/(\Delta m/m)$ to the first power of the average relative thermal neutron flux. Thus, on the average and omitting position E-1,

$$\frac{(\Delta k/k)/(\Delta m/m)}{\bar{\phi} \text{ rel.}} = 1.00,$$

where

$\Delta k/k$ = gain in reactivity,

Δm = weight of fuel added in a certain core position,

m = total weight of fuel in core before the addition,

$\bar{\phi}$ = average thermal neutron flux in the core position relative to the maximum flux in the core.

From this relation the gain in reactivity for any reloading can be estimated if the amount of fuel per position prior to the reloading is known. It must also be recognized that fuel addition to positions E-1, E-9, D-1, and D-9 will be worth only from 50 to 60% of the calculated gain.

Neutron Flux Measurements

Thermal neutron flux measurements were made in the 4 x 7 configuration, the revised clean operating core, and the revised operating core with the mocked-up experiments in place. The spatial distributions, the average flux, the maximum flux, and the maximum-to-average ratios were determined by making vertical traverses with copper wires. Some direct measurements of the thermal flux were made in certain positions by use of Al-Mn and Al-Co alloy foils. No spectrum measurements were made, due to lack of time, but

Table 2.5

Relations of Thermal Neutron Flux in Core Positions to $(\Delta k/k)/(\Delta m/m)$
in Revised Operating Core with Experiments

Core Position	Average Flux, $\bar{\phi}$ (rel. to Maximum)	$\frac{\Delta k/k}{\Delta m/m}$	$\left(\frac{\Delta k/\Delta m}{k/m}\right)/\bar{\phi}$	$\left(\frac{\Delta k/\Delta m}{k/m}\right)/\bar{\phi}^2$	Maximum Flux, ϕ_{max} (neutrons/cm ² ·sec)	$\left(\frac{\Delta k/\Delta m}{k/m}\right)/\phi_{max}$	$\left(\frac{\Delta k/\Delta m}{k/m}\right)/\phi_{max}^2$
A-6	0.127	0.137	1.079	8.496	0.219	0.626	2.858
B-5	0.335	0.337	1.006	3.003	0.555	0.607	1.094
B-7	0.227	0.205	0.903	3.978	0.371	0.553	1.491
C-5	0.606	0.553	0.913	1.507	1.000	0.553	0.553
C-6	0.392	0.405	1.033	2.635	0.643	0.630	0.980
C-7	0.302	0.339	1.123	3.719	0.464	0.731	1.575
D-5	0.604	0.578	0.957	1.584	0.996	0.580	0.582
E-1	0.160	0.0867	0.542	3.388	0.284	0.305	1.074
E-3	0.440	0.402	0.914	2.077	0.642	0.626	0.975
E-5	0.437	0.466	1.066	2.439	0.704	0.662	0.940

cadmium ratios were determined in some cases. ~~Measurements~~

Summaries of the measurements made are given in Tables 2.6, 2.7, and 2.8. Detailed tabulations of the traverses in the three cores are given in Tables 2.9, 2.10, and 2.11. Cadmium ratios are given in Table 2.12.

In order to aid in determining the effects of experiments between the core and the beam holes, vertical flux traverses made in the beryllium reflector adjacent to the inner ends of the beam holes have been plotted with and without the experiments in place. Also, traverses within the beam holes have been plotted for the same cases. These are shown in Figs. 2.20 through 2.30.

Table 2.6

Summary of Thermal Neutron Flux Measurements^(a) in the 4 x 7 Core

<u>Core Position</u>	<u>Flux^(b)</u>	
	<u>Average</u>	<u>Maximum</u>
B-2	0.24	0.37
B-3	0.29	0.46
B-4	0.44	0.91
B-5	0.30	0.53
B-6	0.36	0.71
B-7	0.32	0.54
B-8	0.26	0.38
C-2	0.33	0.51 ^(c)
C-3	0.50	0.77
C-4	0.39	0.64
C-5	0.47	0.81
C-6	0.39	0.69
C-7	0.47	0.74
C-8	0.34	0.51
D-2	0.37	0.53
D-3	0.54	0.84
D-4	0.49	1.04
D-5	0.55	1.00
D-6	0.48	1.03
D-7	0.51	0.87
D-8	0.37	0.55
E-2	0.35	0.52
E-3	0.40	0.60
E-4	0.50	0.82
E-5	0.41	0.64
E-6	0.51	0.83
E-7	0.40	0.63
E-8	0.33	0.49

(a) Average flux relative to maximum in normal core, 0.403; maximum to average ratio, 2.48; maximum flux at 20 Mw (calculated), 3.44×10^{14} neutrons/cm².sec; average flux at 20 Mw (calculated), 1.39×10^{14} neutrons/cm².sec.

(b) Expressed as a fraction of the maximum flux in position D-5.

(c) Obtained by interpolation.

Table 2.7

Summary of Thermal Neutron Flux Measurements^(a)
in the Clean Revised Operating Core

<u>Core Position</u>	<u>Flux</u> ^(b)	
	<u>Average</u>	<u>Maximum</u>
A-4	0.19	0.35
A-5	0.18	0.32
A-6	0.23	0.45
B-3	0.37	0.65
B-4	0.30(c)	
B-5	0.28	0.51
B-6	0.29(c)	
B-7	0.28	0.49
C-3	0.32	0.52
C-4	0.37	0.68
C-5	0.53	0.93
C-6	0.38	0.65
C-7	0.56	0.89
D-1	0.23	0.36
D-2	0.36	0.53
D-3	0.58	0.89
D-4	0.52(c)	
D-5	0.55	1.00
D-6	0.52(c)	
D-7	0.53	0.81
D-8	0.36	0.52
D-9	0.20(c)	
E-1	0.21	0.33
E-2	0.37	0.53
E-3	0.46	0.71
E-4	0.58	0.95
E-5	0.46	0.73
E-6	0.58	0.96
E-7	0.46(c)	
E-8	0.35	0.52
E-9	0.18	0.28

(a) Average flux relative to maximum in normal core, 0.39; maximum to average ratio, 2.56; maximum flux at 20 Mw (calculated), 3.38×10^{14} neutrons/cm².sec; average flux at 20 Mw (calculated), 1.32×10^{14} neutrons/cm².sec.

(b) Expressed as a fraction of the maximum flux in position D-5.

(c) Obtained by interpolation.

Table 2.8

Summary of Thermal Neutron Flux Measurements^(a)
in the Revised Operating Core with Experiments

<u>Core Position</u>	<u>Flux^(b)</u>	
	<u>Average</u>	<u>Maximum</u>
A-4	0.16	0.27
A-5	0.18	0.30
A-6	0.13	0.22
B-3	0.40	0.66
B-4	0.34 ^(c)	
B-5	0.36	0.56
B-6	0.28 ^(c)	
B-7	0.23	0.37
C-3	0.37	0.54
C-4	0.43	0.75
C-5	0.61	1.00
C-6	0.39	0.64
C-7	0.30	0.46
D-1	0.18	0.27
D-2	0.44	0.68
D-3	0.61	0.93
D-4	0.54 ^(c)	
D-5	9.60	1.00
D-6	0.49 ^(c)	
D-7	0.44	0.68
D-8	0.19	0.30
D-9	0.12	0.18
E-1	0.16	0.28
E-2	0.29	0.41
E-3	0.44	0.64
E-4	0.53	0.92
E-5	0.44	0.70
E-6	0.52	0.82
E-7	0.32	0.47
E-8	0.18	0.31
E-9	0.10	0.18

(a) Average flux relative to maximum in normal core, 0.35; maximum to average ratio, 2.85; maximum flux at 20 Mw (calculated), 3.67×10^{14} neutrons/cm².sec; average flux at 20 Mw (calculated), 1.29×10^{14} neutrons/cm².sec.

(b) Expressed as a fraction of the maximum flux in position D-5.

(c) Obtained by interpolation.

Table 2.9

Thermal Neutron Flux Measurements with 4 x 7 Core

Distance From Top (in.)	Flux Measurements*									
	Reflector Positions									
	A-2	A-5	A-6	B-1	B-9	C-1	C-9	D-1	D-9	E-1
0	0.012	0.012	0.002	0.019	0.032	0.063	0.049	0.061	0.054	0.038
1	0.027	0.017	0.031	0.031	0.044	0.078	0.073	0.081	0.067	0.054
2	0.037	0.024	0.029	0.058	0.064	0.11	0.11	0.10	0.98	0.093
3	0.043	0.032	0.035	0.066	0.078	0.12	0.12	0.15	0.13	0.12
4	0.062	0.037	0.060	0.072	0.091	0.16	0.15	0.18	0.16	0.14
5	0.067	0.067	0.069	0.11	0.13	0.18	0.17	0.22	0.19	0.15
6	0.086	0.075	0.089	0.12	0.14	0.20	0.20	0.24	0.21	0.21
7	0.10	0.10	0.10	0.14	0.16	0.25	0.24	0.26	0.26	0.23
8	0.11	0.12	0.13	0.17	0.20	0.28	0.27	0.31	0.28	0.25
9	0.14	0.14	0.15	0.19	0.22	0.32	0.31	0.36	0.31	0.30
10	0.16	0.17	0.17	0.23	0.25	0.35	0.33	0.41	0.37	0.32
11	0.18	0.20	0.20	0.24	0.27	0.38	0.37	0.45	0.40	0.36
12	0.19	0.24	0.24	0.26	0.29	0.42	0.38	0.47	0.43	0.41
13	0.21	0.27	0.29	0.27	0.31	0.45	0.42	0.51	0.45	0.42
14	0.22	0.33	0.35	0.30	0.31	0.48	0.45	0.54	0.49	0.46
15	0.24	0.39	0.41	0.32	0.34	0.49	0.48	0.53	0.52	0.48
16	0.28	0.44	0.47	0.33	0.35	0.50	0.51	0.58	0.51	0.50
17	0.27	0.47	0.52	0.35	0.38	0.51	0.53	0.56	0.51	0.47
18	0.29	0.50	0.53	0.36	0.34	0.50	0.52	0.54	0.54	0.50
19	0.29	0.51	0.54	0.37	0.33	0.48	0.49	0.52	0.53	0.48
20	0.28	0.52	0.56	0.33	0.33	0.47	0.49	0.46	0.50	0.45
21	0.27	0.53	0.55	0.33	0.32	0.45	0.49	0.44	0.49	0.42
22	0.25	0.53	0.52	0.32	0.32	0.43	0.47	0.45	0.49	0.43
23	0.24	0.48	0.49	0.29	0.30	0.39	0.41	0.41	0.42	0.42
24	0.037	0.093	0.046	0.25	0.051	0.053	0.055	0.068	0.12	0.079

*Expressed as a fraction of the maximum flux in position D-5, which, at 20 Mw, was 3.4×10^{14} neutrons/cm²·sec.

Table 2.9 (Continued)

Distance From Top (in.)	Flux Measurements*									
	Reflector Positions					Core Positions				
	E-9	F-2	F-5	F-8	CG-5	BB-2	B-3	B-5	B-7	B-8
0	0.048	0.058	0.075	0.040	0.039	0.11	0.094	0.035	0.092	0.095
1	0.061	0.072	0.11	0.061	0.068	0.087	0.072	0.035	0.081	0.088
2	0.084	0.10	0.15	0.093	0.11	0.083	0.066	0.041	0.067	0.090
3	0.12	0.14	0.17	0.10	0.12	0.087	0.094	0.069	0.088	0.11
4	0.13	0.17	0.21	0.12	0.16	0.12	0.10	0.076	0.10	0.13
5	0.18	0.21	0.28	0.14	0.21	0.14	0.13	0.10	0.13	0.15
6	0.21	0.23	0.32	0.13	0.25	0.17	0.17	0.11	0.15	0.18
7	0.23	0.28	0.38	0.20	0.29	0.20	0.19	0.13	0.19	0.21
8	0.28	0.31	0.44	0.23	0.31	0.21	0.22	0.14	0.23	0.24
9	0.31	0.35	0.47	0.26	0.36	0.24	0.26	0.17	0.23	0.26
10	0.39	0.40	0.54	0.29	0.40	0.27	0.29	0.22	0.29	0.29
11	0.37	0.43	0.61	0.33	0.44	0.28	0.32	0.27	0.33	0.30
12	0.42	0.47	0.66	0.34	0.47	0.31	0.36	0.34	0.37	0.34
13	0.43	0.50	0.73	0.37	0.53	0.33	0.38	0.40	0.42	0.36
14	0.46	0.53	0.76	0.41	0.54	0.34	0.41	0.47	0.48	0.37
15	0.46	0.56	0.80	0.43	0.58	0.35	0.44	0.49	0.50	0.38
16	0.48	0.57	0.86	0.43	0.60	0.37	0.46	0.51	0.53	0.38
17	0.46	0.57	0.87	0.44	0.61	0.35	0.45	0.52	0.54	0.38
18	0.45	0.54	0.84	0.45	0.61	0.33	0.46	0.53	0.53	0.37
19	0.42	0.55	0.85	0.46	0.59	0.30	0.42	0.50	0.48	0.34
20	0.42	0.53	0.86	0.43	0.58	0.29	0.38	0.45	0.43	0.31
21	0.41	0.54	0.81	0.42	0.55	0.26	0.36	0.45	0.42	0.27
22	0.40	0.49	0.79	0.39	0.53	0.23	0.34	0.41	0.37	0.25
23	0.375	0.43	0.72	0.365	0.50	0.24	0.34	0.45	0.41	0.26
24	0.095	0.14	0.15	0.085	0.12	0.28	0.39	0.58	0.55	0.34

Table 2.9 (Continued)

Distance From Top (in.)	Flux Measurements*										
	Core Positions										
	C-3	C-4	C-5	C-6	C-7	C-8	D-2	D-3	D-5	D-7	D-8
0	0.14	0.080	0.073	0.071	0.12	0.14	0.14	0.16	0.053	0.086	0.18
1	0.13	0.059	0.074	0.064	0.12	0.10	0.12	0.14	0.057	0.083	0.16
2	0.14	0.068	0.078	0.064	0.13	0.11	0.14	0.17	0.057	0.11	0.14
3	0.19	0.085	0.11	0.075	0.15	0.14	0.18	0.20	0.088	0.13	0.17
4	0.22	0.11	0.14	0.089	0.20	0.18	0.22	0.25	0.13	0.17	0.19
5	0.26	0.15	0.18	0.12	0.24	0.23	0.26	0.28	0.16	0.20	0.23
6	0.32	0.19	0.22	0.16	0.26	0.25	0.29	0.33	0.22	0.24	0.27
7	0.36	0.22	0.24	0.19	0.30	0.29	0.31	0.38	0.23	0.31	0.31
8	0.39	0.24	0.28	0.21	0.34	0.31	0.37	0.44	0.31	0.34	0.32
9	0.46	0.29	0.34	0.25	0.39	0.36	0.38	0.49	0.35	0.38	0.36
10	0.51	0.36	0.38	0.28	0.45	0.37	0.41	0.54	0.41	0.47	0.42
11	0.58	0.43	0.45	0.36	0.51	0.41	0.45	0.60	0.53	0.55	0.42
12	0.64	0.48	0.54	0.40	0.55	0.43	0.50	0.66	0.61	0.66	0.47
13	0.68	0.57	0.64	0.48	0.63	0.46	0.50	0.72	0.79	0.72	0.49
14	0.73	0.63	0.71	0.57	0.68	0.48	0.51	0.75	0.84	0.82	0.51
15	0.76	0.64	0.76	0.59	0.70	0.49	0.52	0.82	0.95	0.84	0.51
16	0.77	0.64	0.78	0.65	0.72	0.49	0.53	0.82	0.95	0.87	0.55
17	0.77	0.63	0.81	0.67	0.74	0.51	0.51	0.84	0.97	0.82	0.52
18	0.72	0.62	0.79	0.69	0.71	0.46	0.48	0.81	1.00	0.81	0.51
19	0.69	0.60	0.76	0.67	0.68	0.42	0.45	0.77	0.95	0.76	0.49
20	0.63	0.57	0.72	0.64	0.64	0.38	0.40	0.69	0.82	0.65	0.43
21	0.56	0.51	0.68	0.60	0.57	0.35	0.36	0.63	0.82	0.65	0.42
22	0.51	0.48	0.63	0.58	0.53	0.31	0.36	0.58	0.74	0.57	0.38
23	0.52	0.51	0.66	0.63	0.58	0.32	0.35	0.61	0.76	0.55	0.37
24	0.58	0.64	0.70	0.68	0.64	0.39	0.36	0.62	0.68	0.63	0.39

Table 2.9 (Continued)

Distance From Top (in.)	Flux Measurements*									
	Core Positions							Shim Rods		
	E-2	E-3	E-4	E-5	E-6	E-7	E-8	B-4	B-6	D-4 D-6
0	0.17	0.14	0.13	0.14	0.12	0.12	0.15			
1	0.14	0.13	0.13	0.13	0.11	0.091	0.12			
2	0.14	0.11	0.16	0.10	0.14	0.12	0.12			
3	0.16	0.13	0.18	0.13	0.17	0.13	0.14			
4	0.20	0.17	0.22	0.15	0.21	0.17	0.17			
5	0.23	0.21	0.17	0.18	0.24	0.20	0.22			
6	0.27	0.23	0.30	0.21	0.29	0.24	0.26			
7	0.30	0.28	0.33	0.24	0.31	0.27	0.17			
8	0.34	0.32	0.36	0.27	0.37	0.32	0.31			
9	0.37	0.34	0.41	0.32	0.41	0.34	0.33			
10	0.38	0.39	0.50	0.38	0.47	0.39	0.36			
11	0.43	0.44	0.57	0.42	0.56	0.43	0.40			
12	0.46	0.49	0.64	0.47	0.65	0.50	0.43			
13	0.49	0.52	0.71	0.56	0.73	0.55	0.45			
14	0.52	0.55	0.76	0.59	0.78	0.58	0.46	0.85	0.56	1.04 1.00
15	0.52	0.60	0.76	0.59	0.81	0.61	0.47	0.91	0.71	1.04 1.03
16	0.52	0.60	0.78	0.62	0.82	0.62	0.49	0.84	0.59	0.68 0.69
17	0.48	0.60	0.82	0.64	0.83	0.63	0.47	0.52	0.50	0.63 0.67
18	0.48	0.58	0.73	0.64	0.77	0.60	0.47	0.49	0.51	0.63 0.66
19	0.44	0.59	0.73	0.61	0.74	0.54	0.40	0.48	0.51	0.60 0.65
20	0.38	0.58	0.67	0.57	0.68	0.54	0.39	0.52	0.48	0.59 0.56
21	0.36	0.54	0.61	0.54	0.60	0.49	0.33	0.49	0.44	0.59 0.56
22	0.30	0.49	0.56	0.47	0.59	0.42	0.31	0.45	0.41	0.53 0.52
23	0.33	0.49	0.56	0.51	0.60	0.45	0.33	0.42	0.38	0.48 0.42
24	0.43	0.59	0.57	0.69	0.68	0.52	0.40	0.37	0.30	0.42 0.38
25								0.32	0.25	0.37 0.33
26								0.29	0.20	0.30 0.27
27								0.19	0.13	0.23 0.18
28								0.15	0.080	0.15 0.11
29								0.068	0.040	0.10 0.046
30								0.034	0.003	0.038
31								0.003		

Table 2.10

Thermal Neutron Flux Measurements in Clean Operating Core

Distance From Top (in.)	Flux Measurements*									
	Core Positions									
	A-4	A-5	A-6	B-3	B-5	B-7	C-3	C-4	C-5	C-6
0		0.003		0.048		0.039	0.095	0.036	0.049	0.057
1	0.006	0.003		0.051		0.033	0.079	0.027	0.039	0.037
2	0.013	0.012	0.003	0.061	0.012	0.039	0.052	0.019	0.072	0.044
3	0.019	0.022	0.026	0.077	0.026	0.067	0.059	0.049	0.10	0.066
4	0.032	0.022	0.035	0.12	0.045	0.078	0.10	0.065	0.14	0.087
5	0.063	0.048	0.054	0.13	0.054	0.11	0.12	0.12	0.16	0.12
6	0.076	0.074	0.077	0.18	0.081	0.14	0.17	0.13	0.22	0.14
7	0.069	0.10	0.080	0.23	0.081	0.17	0.18	0.16	0.29	0.17
8	0.12	0.11	0.13	0.28	0.13	0.20	0.23	0.18	0.33	0.21
9	0.15	0.13	0.14	0.31	0.14	0.23	0.24	0.25	0.39	0.27
10	0.17	0.17	0.19	0.38	0.21	0.25	0.30	0.30	0.47	0.31
11	0.21	0.19	0.23	0.42	0.28	0.31	0.36	0.36	0.55	0.32
12	0.26	0.24	0.26	0.47	0.38	0.32	0.39	0.48	0.65	0.44
13	0.29	0.25	0.30	0.52	0.46	0.39	0.43	0.54	0.75	0.52
14	0.29	0.25	0.37	0.57	0.50	0.41	0.47	0.57	0.84	0.63
15	0.31	0.32	0.40	0.63	0.47	0.44	0.49	0.63	0.87	0.62
16	0.33	0.32	0.42	0.61	0.51	0.49	0.51	0.66	0.89	0.63
17	0.35	0.31	0.45	0.60	0.51	0.45	0.52	0.68	0.93	0.63
18	0.29	0.31	0.40	0.65	0.64	0.46	0.49	0.67	0.92	0.64
19	0.28	0.27	0.39	0.59	0.44	0.43	0.50	0.66	0.85	0.65
20	0.26	0.27	0.42	0.55	0.45	0.41	0.47	0.60	0.82	0.59
21	0.24	0.24	0.37	0.47	0.38	0.39	0.39	0.56	0.77	0.57
22	0.23	0.23	0.32	0.45	0.37	0.36	0.39	0.48	0.68	0.49
23	0.29	0.26	0.32	0.39	0.45	0.33	0.42	0.50	0.68	0.59
24	0.27	0.29	0.32	0.37	0.50	0.41	0.58	0.55	0.72	0.71

*Expressed as a fraction of the maximum flux in position D-5, which, at 20 Mw, was

3.4×10^{14} neutrons/cm².sec.

Table 2.10 (Continued)

Distance From Top (in.)	Flux Measurements*									
	Core Positions									
	C-7	D-1	D-2	D-3	D-5	E-7	D-8	E-1	E-2	E-3
0	0.13	0.054	0.10	0.15	0.062	0.13	0.14	0.056	0.16	0.13
1	0.13	0.064	0.071	0.10	0.062	0.16	0.13	0.066	0.12	0.13
2	0.14	0.091	0.13	0.17	0.075	0.17	0.12	0.066	0.10	0.13
3	0.19	0.11	0.14	0.22	0.071	0.22	0.13	0.091	0.13	0.17
4	0.25	0.13	0.18	0.26	0.15	0.26	0.16	0.11	0.17	0.21
5	0.30	0.18	0.26	0.32	0.19	0.31	0.23	0.16	0.21	0.25
6	0.37	0.19	0.26	0.35	0.21	0.35	0.25	0.19	0.28	0.31
7	0.40	0.23	0.32	0.42	0.27	0.44	0.27	0.20	0.31	0.37
8	0.44	0.24	0.36	0.47	0.31	0.46	0.37	0.23	0.36	0.39
9	0.50	0.27	0.41	0.61	0.38	0.54	0.37	0.25	0.38	0.43
10	0.56	0.29	0.45	0.76	0.45	0.59	0.43	0.26	0.38	0.50
11	0.65	0.31	0.46	0.88	0.54	0.62	0.48	0.27	0.42	0.52
12	0.71	0.33	0.50	0.73	0.64	0.65	0.48	0.30	0.49	0.57
13	0.77	0.32	0.53	0.82	0.73	0.72	0.49	0.31	0.49	0.63
14	0.86	0.34	0.50	0.81	0.92	0.77	0.52	0.32	0.48	0.63
15	0.89	0.36	0.52	0.84	1.00	0.81	0.55	0.33	0.48	0.71
16	0.89	0.33	0.53	0.88	0.96	0.80	0.50	0.29	0.49	0.68
17	0.87	0.34	0.50	0.82	0.96	0.79	0.51	0.30	0.53	0.66
18	0.82	0.31	0.46	0.81	0.99	0.81	0.47	0.26	0.51	0.61
19	0.76	0.26	0.41	0.76	0.93	0.73	0.43	0.25	0.48	0.61
20	0.74	0.23	0.40	0.69	0.83	0.64	0.41	0.22	0.48	0.58
21	0.61	0.20	0.35	0.61	0.81	0.56	0.34	0.20	0.42	0.55
22	0.56	0.20	0.31	0.53	0.74	0.55	0.34	0.15	0.41	0.52
23	0.64	0.20	0.38	0.54	0.65	0.59	0.43	0.15	0.44	0.63
24	0.66	0.041	0.35	0.54	0.68	0.35	0.41	0.095	0.48	0.56

Table 2.10 (Continued)

Distance From Top (in.)	Flux Measurements*									
	Core Positions					Reflector Positions				
	E-4	E-5	E-6	E-8	E-9	A-2	A-8	C-1	C-2	F-2
0	0.17	0.13	0.13	0.11	0.065				0.19	0.027
1	0.16	0.096	0.15	0.11	0.047			0.051	0.066	0.056
2	0.19	0.11	0.15	0.13	0.044		0.018	0.063	0.093	0.12
3	0.22	0.12	0.22	0.16	0.095	0.011	0.030	0.081	0.13	0.15
4	0.25	0.18	0.24	0.20	0.11	0.026	0.037	0.11	0.14	0.16
5	0.34	0.23	0.30	0.22	0.10	0.044	0.045	0.16	0.20	0.21
6	0.36	0.29	0.35	0.26	0.14	0.048	0.096	0.16	0.23	0.25
7	0.43	0.33	0.41	0.31	0.17	0.084	0.11	0.22	0.28	0.28
8	0.50	0.37	0.47	0.33	0.18	0.11	0.12	0.26	0.32	0.32
9	0.55	0.40	0.49	0.40	0.22	0.18	0.14	0.33	0.32	0.36
10	0.50	0.44	0.55	0.39	0.24	0.14	0.19	0.35	0.41	0.41
11	0.70	0.50	0.63	0.45	0.24	0.15	0.20	0.39	0.47	0.45
12	0.75	0.56	0.76	0.46	0.27	0.19	0.21	0.45	0.55	0.48
13	0.85	0.64	0.79	0.49	0.26	0.23	0.26	0.49	0.58	0.58
14	0.84	0.71	0.91	0.51	0.27	0.24	0.28	0.50	0.62	0.59
15	0.88	0.71	0.96	0.52	0.28	0.23	0.28	0.52	0.67	0.62
16	0.95	0.72	0.95	0.52	0.24	0.30	0.31	0.57	0.73	0.65
17	0.88	0.73	0.93	0.48	0.25	0.31	0.33	0.57	0.75	0.65
18	0.83	0.69	0.87	0.56	0.23	0.35	0.27	0.58	0.73	0.65
19	0.82	0.61	0.84	0.45	0.22	0.34	0.33	0.56	0.76	0.65
20	0.69	0.57	0.79	0.39	0.20	0.35	0.36	0.56	0.71	0.65
21	0.63	0.50	0.73	0.33	0.18	0.31	0.30	0.52	0.73	0.60
22	0.60	0.49	0.65	0.30	0.12	0.30	0.33	0.65	0.69	0.53
23	0.81	0.53	0.61	0.33	0.13	0.27	0.28	0.63	0.66	0.50
24		0.68	0.67	0.30		0.19	0.19	0.30	0.26	0.23

Table 2.10 (Continued)

Distance From Top (in.)	Flux Measurements*									
	Reflector Positions									
	F-3	F-5	F-8	G-2	G-3	G-4	G-5	G-6	G-7	G-8
0	0.060	0.057	0.031	--	0.035	0.015	0.015	0.032	0.015	
1	0.083	0.076	0.061	0.015	0.042	0.066	0.058	0.063	0.040	0.012
2	0.11	0.12	0.077	0.053	0.074	0.10	0.094	0.095	0.058	0.016
3	0.16	0.17	0.092	0.065	0.12	0.14	0.12	0.13	0.099	0.036
4	0.21	0.21	0.17	0.085	0.15	0.16	0.15	0.16	0.12	0.048
5	0.29	0.28	0.20	0.12	0.18	0.21	0.19	0.21	0.18	0.096
6	0.34	0.34	0.26	0.16	0.20	0.22	0.26	0.27	0.21	0.12
7	0.38	0.39	0.27	0.16	0.25	0.26	0.32	0.32	0.25	0.14
8	0.44	0.45	0.31	0.20	0.32	0.36	0.33	0.32	0.32	0.17
9	0.51	0.48	0.36	0.23	0.39	0.37	0.41	0.43	0.36	0.24
10	0.56	0.55	0.38	0.26	0.42	0.37	0.46	0.45	0.39	0.25
11	0.62	0.63	0.46	0.34	0.44	0.49	0.52	0.50	0.41	0.29
12	0.70	0.73	0.50	0.32	0.48	0.52	0.64	0.51	0.45	0.32
13	0.71	0.76	0.50	0.35	0.53	0.59	0.63	0.52	0.48	0.31
14	0.77	0.88	0.57	0.36	0.58	0.61	0.67	0.62	0.51	0.34
15	0.83	0.71	0.58	0.36	0.60	0.63	0.65	0.65	0.55	0.39
16	0.89	0.93	0.55	0.38	0.60	0.64	0.68	0.65	0.54	0.36
17	0.93	0.96	0.61	0.38	0.59	0.69	0.70	0.65	0.54	0.35
18	0.86	0.98	0.61	0.38	0.63	0.69	0.70	0.73	0.57	0.35
19	0.89	1.01	0.65	0.38	0.62	0.66	0.69	0.68	0.54	0.36
20	0.86	1.02	0.61	0.41	0.60	0.66	0.65	0.69	0.55	0.37
21	0.78	0.98	0.58	0.35	0.57	0.66	0.65	0.70	0.53	0.31
22	0.74	0.86	0.54	0.33	0.55	0.60	0.65	0.66	0.52	0.25
23	0.72	0.86	0.47	0.27	0.46	0.57	0.58	0.55	0.51	0.22
24	0.23	0.35	0.20	0.085	0.30	0.28	0.20	0.21	0.20	0.084

Table 2.10 (Continued)

Distance from Inner End (in.)	Flux Measurements*	
	Beam Holes	
	HB-3	HB-4
0		
1		
2	0.14	0.17
3	0.13	0.15
4	0.11	0.14
5	0.10	0.12
6	0.088	0.11
7	0.079	0.098
8	0.069	0.084
9	0.062	0.072
10	0.049	0.064
11	0.044	0.055
12	0.037	0.045
13	0.032	0.036
14	0.026	0.029
15	0.023	0.026
16	0.019	0.019
17	0.016	0.016
18	0.013	0.012
19	0.011	0.010
20	0.008	0.006
21	0.006	0.005
22	0.004	
23	0.003	
24	0.002	

Table 2.11

Thermal Neutron Flux Measurements in Operating Core with Experiments

Distance from Top (in.)	Flux Measurements*								
	Core Positions								
	A-4	A-5	A-6	B-3	B-5	B-7	C-3	C-4	C-5
0	0.008	0.032	0.008	0.076	0.031	0.035	0.13	0.084	0.091
1	0.017	0.017	0.008	0.085	0.027	0.043	0.12	0.064	0.081
2	0.026	0.026	0.008	0.11	0.035	0.039	0.095	0.074	0.11
3	0.028	0.028	0.008	0.12	0.047	0.057	0.12	0.12	0.15
4	0.045	0.055	0.026	0.13	0.086	0.067	0.16	0.13	0.22
5	0.074	0.068	0.036	0.18	0.12	0.11	0.21	0.19	0.24
6	0.074	0.091	0.074	0.23	0.15	0.13	0.21	0.24	0.32
7	0.10	0.10	0.083	0.30	0.22	0.16	0.26	0.29	0.44
8	0.14	0.14	0.12	0.32	0.33	0.19	0.32	0.39	0.47
9	0.15	0.16	0.12	0.37	0.38	0.24	0.35	0.45	0.59
10	0.18	0.19	0.13	0.43	0.43	0.25	0.44	0.56	0.68
11	0.21	0.23	0.15	0.52	0.48	0.30	0.47	0.58	0.75
12	0.23	0.25	0.19	0.53	0.51	0.31	0.50	0.64	0.84
13	0.23	0.26	0.19	0.57	0.52	0.33	0.51	0.72	0.88
14	0.25	0.27	0.19	0.59	0.54	0.37	0.53	0.72	0.96
15	0.27	0.30	0.22	0.63	0.56	0.37	0.54	0.75	0.97
16	0.26	0.29	0.21	0.66	0.56	0.34	0.54	0.69	1.00
17	0.24	0.26	0.20	0.59	0.55	0.34	0.53	0.66	0.94
18	0.24	0.26	0.18	0.59	0.56	0.35	0.51	0.62	0.92
19	0.23	0.24	0.19	0.55	0.49	0.31	0.47	0.56	0.87
20	0.21	0.24	0.17	0.51	0.43	0.29	0.43	0.53	0.80
21	0.21	0.22	0.16	0.45	0.39	0.27	0.38	0.52	0.74
22	0.20	0.20	0.16	0.43	0.38	0.24	0.39	0.41	0.68
23	0.18	0.22	0.15	0.36	0.49	0.21	0.47	0.46	0.62
24	0.26	0.29	0.16	0.41	0.54	0.23	0.53	0.61	0.70

*Expressed as a fraction of the maximum flux in position D-5, which, at 20 Mw, was

3.2×10^{14} neutrons/cm²·sec.

Table 2.11 (Continued)

Distance from Top (in.)	Flux Measurements*								
	Core Positions								
	C-6	C-7	D-1	D-2	D-3	D-5	D-7	D-8	D-9
0	0.062	0.062	0.088	0.18	0.14	0.083	0.094	0.084	0.043
1	0.051	0.066	0.067	0.13	0.14	0.089	0.084	0.052	0.032
2	0.045	0.072	0.058	0.16	0.16	0.093	0.11	0.056	0.022
3	0.059	0.093	0.094	0.15	0.023	0.14	0.13	0.058	0.028
4	0.094	0.13	0.10	0.20	0.25	0.19	0.20	0.099	0.054
5	0.14	0.16	0.13	0.25	0.34	0.026	0.20	0.10	0.076
6	0.18	0.22	0.16	0.31	0.41	0.31	0.28	0.14	0.98
7	0.23	0.22	0.19	0.35	0.47	0.36	0.33	0.17	0.095
8	0.29	0.30	0.23	0.40	0.56	0.52	0.40	0.19	0.11
9	0.35	0.35	0.24	0.45	0.69	0.67	0.44	0.21	0.13
10	0.43	0.37	0.25	0.46	0.70	0.78	0.47	0.24	0.16
11	0.50	0.39	0.24	0.54	0.80	0.85	0.56	0.24	0.15
12	0.54	0.41	0.27	0.62	0.83	0.87	0.59	0.28	0.17
13	0.58	0.43	0.27	0.60	0.93	0.88	0.65	0.29	0.18
14	0.64	0.46	0.24	0.63	0.90	0.92	0.63	0.30	0.18
15	0.63	0.46	0.25	0.68	0.88	1.00	0.68	0.30	0.17
16	0.62	0.44	0.23	0.67	0.90	0.98	0.65	0.28	0.17
17	0.63	0.45	0.22	0.65	0.85	0.95	0.64	0.28	0.17
18	0.61	0.44	0.20	0.58	0.85	0.91	0.65	0.27	0.16
19	0.58	0.39	0.18	0.60	0.77	0.79	0.58	0.22	0.15
20	0.51	0.36	0.18	0.53	0.74	0.74	0.56	0.21	0.13
21	0.46	0.34	0.15	0.48	0.67	0.67	0.48	0.20	0.12
22	0.44	0.27	0.13	0.44	0.56	0.61	0.44	0.15	0.067
23	0.48	0.25	0.14	0.44	0.52	0.57	0.42	0.16	0.067
24	0.54	0.26	0.22	0.48	0.40	0.57	0.49	0.22	0.12

Table 2.11 (Continued)

Distance from Top (in.)	Flux Measurements*								
	Core Positions								
	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9
0	0.081	0.13	0.17	0.024	0.14	0.11	0.074	0.070	0.034
1	0.033	0.10	0.13	0.069	0.13	0.11	0.067	0.058	0.017
2	0.059	0.099	0.12	0.014	0.093	0.13	0.053	0.053	0.017
3	0.066	0.13	0.17	0.17	0.11	0.15	0.11	0.068	0.036
4	0.094	0.14	0.21	0.15	0.16	0.22	0.14	0.092	0.066
5	0.12	0.19	0.25	0.21	0.19	0.26	0.17	0.11	0.058
6	0.13	0.22	0.31	0.25	0.27	0.31	0.20	0.12	0.095
7	0.15	0.26	0.36	0.31	0.27	0.38	0.26	0.18	0.092
8	0.19	0.32	0.40	0.37	0.31	0.43	0.26	0.16	0.11
9	0.21	0.33	0.44	0.41	0.39	0.55	0.32	0.21	0.13
10	0.21	0.34	0.51	0.46	0.46	0.62	0.41	0.24	0.15
11	0.24	0.38	0.56	0.54	0.53	0.65	0.39	0.26	0.13
12	0.24	0.40	0.57	0.58	0.60	0.73	0.44	0.27	0.16
13	0.28	0.38	0.60	0.72	0.63	0.78	0.43	0.28	0.16
14	0.25	0.38	0.61	0.75	0.63	0.79	0.47	0.29	0.18
15	0.24	0.40	0.64	0.81	0.68	0.78	0.47	0.31	0.17
16	0.22	0.41	0.62	0.88	0.70	0.82	0.45	0.31	0.14
17	0.20	0.38	0.62	0.92	0.68	0.77	0.46	0.28	0.16
18	0.19	0.35	0.61	0.86	0.64	0.77	0.42	0.26	0.15
19	0.14	0.34	0.56	0.87	0.63	0.71	0.42	0.23	0.11
20	0.13	0.29	0.55	0.77	0.59	0.66	0.39	0.18	0.11
21	0.12	0.28	0.47	0.68	0.50	0.63	0.35	0.15	0.080
22	0.098	0.25	0.42	0.73	0.46	0.55	0.30	0.036	0.058
23	0.11	0.26	0.46	0.60	0.45	0.45	0.27	0.058	0.070
24	0.15	0.34	0.54	0.61	0.55	0.50	0.43	0.18	0.078

Table 2.11 (Continued)

Distance from Top (in.)	Flux Measurements								
	Reflector Positions								
	A-8	B-2	C-2	C-9	F-4	F-6	G-1	G-2	G-3
0			0.032		0.029	0.029			
1		0.023	0.051	0.002	0.066	0.047		0.010	
2		0.046	0.087	0.010	0.091	0.084	0.002	0.035	0.015
3		0.060	0.12	0.021	0.15	0.12	0.007	0.057	0.038
4	0.008	0.075	0.15	0.029	0.20	0.19	0.025	0.077	0.068
5	0.019	0.11	0.19	0.037	0.27	0.20	0.049	0.072	0.10
6	0.036	0.12	0.21	0.052	0.31	0.24	0.084	0.16	0.15
7	0.057	0.14	0.26	0.083	0.36	0.33	0.089	0.17	0.16
8	0.076	0.17	0.31	0.083	0.45	0.37	0.13	0.22	0.20
9	0.089	0.22	0.35	0.10	0.51	0.43	0.13	0.26	0.25
10	0.094	0.27	0.37	0.14	0.59	0.48	0.16	0.28	0.31
11	0.12	0.28	0.43	0.15	0.63	0.56	0.15	0.28	0.35
12	0.14	0.30	0.48	0.19	0.71	0.60	0.19	0.28	0.42
13	0.16	0.34	0.49	0.20	0.74	0.75	0.21	0.35	0.42
14	0.19	0.37	0.54	0.20	0.84	0.77	0.22	0.34	0.47
15	0.19	0.39	0.58	0.22	0.89	0.76	0.24	0.32	0.53
16	0.21	0.41	0.60	0.23	0.92	0.81	0.27	0.31	0.54
17	0.22	0.43	0.63	0.23	0.93	0.84	0.26	0.35	0.53
18	0.21	0.43	0.64	0.25	0.94	0.87	0.23	0.27	0.54
19	0.21	0.41	0.61	0.22	0.94	0.82	0.24	0.25	0.51
20	0.21	0.41	0.62	0.23	0.92	0.85	0.22	0.29	0.50
21	0.21	0.41	0.57	0.21	0.82	0.80	0.22	0.27	0.49
22	0.20	0.39	0.53	0.18	0.77	0.74	0.19	0.25	0.45
23	0.17	0.36	0.49	0.20	0.71	0.69	0.19	0.20	0.41
24	0.17	0.37	0.47	0.17	0.65	0.63	0.17	0.16	0.41

Table 2.11 (Continued)

Distance from Top (in.)	Flux Measurements*									
	Reflector Positions						Experiments			
	G-4	G-5	G-6	G-7	G-8	G-9	B-1	B-9	C-1	F-9
0							0.011		0.033	
1	0.022	0.018	0.003	0.010			0.022		0.055	
2	0.056	0.048	0.008	0.018			0.022		0.055	
3	0.076	0.063	0.031	0.046	0.010		0.044	0.016	0.093	0.005
4	0.13	0.12	0.067	0.066	0.064		0.044	0.022	0.10	0.026
5	0.13	0.16	0.078	0.094	0.062		0.071	0.022	0.10	0.032
6	0.21	0.21	0.11	0.13	0.090	0.021	0.11	0.071	0.22	0.047
7	0.25	0.28	0.17	0.18	0.095	0.036	0.13	0.10	0.21	0.063
8	0.28	0.28	0.20	0.20	0.13	0.064	0.14	0.12	0.25	0.076
9	0.33	0.45	0.24	0.21	0.15	0.059	0.14	0.12	0.28	0.084
10	0.37	0.39	0.34	0.26	0.16	0.059	0.14	0.14	0.31	0.084
11	0.41	0.48	0.37	0.30	0.19	0.082	0.14	0.15	0.30	0.084
12	0.45	0.49	0.41	0.35	0.20	0.11	0.15	0.15	0.34	0.076
13	0.50	0.49	0.43	0.36	0.24	0.093	0.20	0.18	0.31	0.097
14	0.51	0.52	0.48	0.40	0.25	0.095	0.18	0.17	0.32	0.076
15	0.55	0.56	0.48	0.37	0.27	0.11	0.15	0.20	0.32	0.068
16	0.57	0.60	0.49	0.43	0.30	0.11	0.15	0.21	0.31	0.060
17	0.62	0.58	0.51	0.40	0.31	0.13	0.14	0.16	0.31	0.058
18	0.56	0.58	0.54	0.37	0.32	0.11	0.16	0.15	0.26	0.052
19	0.57	0.59	0.48	0.39	0.27	0.11	0.15	0.15	0.24	0.047
20	0.59	0.54	0.47	0.38	0.30	0.10	0.15	0.076	0.20	0.047
21	0.53	0.57	0.46	0.38	0.25	0.11	0.082	0.060	0.20	0.032
22	0.48	0.47	0.43	0.29	0.24	0.10	0.016	0.055	0.20	0.024
23	0.44	0.46	0.43	0.25	0.23	0.098		0.011	0.19	0.021
24	0.43	0.45	0.43	0.17	0.18	0.069		0.005	0.038	0.021

Table 2.11 (Continued)

Distance from Inner End (in.)	Flux Measurements*	
	Beam Holes	
	HB-3	HB-4
0		
1		
2	0.15	
3	0.12	0.17
4	0.11	0.14
5	0.087	0.12
6	0.081	0.096
7	0.68	0.074
8	0.051	0.072
9	0.043	0.055
10	0.038	0.052
11	0.032	0.039
12	0.031	0.029
13	0.024	0.021
14	0.019	0.019
15	0.013	0.012
16	0.011	0.006
17	0.007	0.006
18	0.007	

Table 2.12Cadmium Ratios in Revised Operating Core with Experiments

<u>Position</u>	<u>Cadmium Ratio</u>		
	<u>For Mn</u>	<u>For Co</u>	<u>For Cu</u>
A-5			
6 in. above center	2.61	1.72	9.15
Center	3.63	7.20	11.30
6 in. below center	7.36	4.00	9.89
C-5			
6 in. above Center		5.90	13.60
Center		7.30	14.18
6 in. below center		5.24	14.19
D-1			
6 in. above center	1.23	4.09	15.27
Center	1.85	8.69	15.03
6 in below center	2.70	5.33	13.26
E-5			
6 in above center	2.11	5.24	11.43
Center		5.06	14.55
6 in. below center		7.20	11.60
HB-4			
2 in. from inner end		7.69	
14 in. from inner end		>2.30

Fig. 2.20. Thermal Neutron Flux Traverses for Position G-1.

Fig. 2.21. Thermal Neutron Flux Traverses for Position G-2.

Fig. 2.22. Thermal Neutron Flux Traverses for Position G-3.

Fig. 2.23. Thermal Neutron Flux Traverses for Position G-4.

Fig. 2.24. Thermal Neutron Flux Traverses for Position G-5.

Fig. 2.25. Thermal Neutron Flux Traverses for Position G-6.

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Fig. 2.26. Thermal Neutron Flux Traverses for Position G-7.

Fig. 2.27. Thermal Neutron Flux Traverses for Position G-8.

Fig. 2.28. Thermal Neutron Flux Traverses for Position G-9.

Fig. 2.29. Thermal Neutron Flux Traverses for Position HB-4.

Fig. 2.30. Thermal Neutron Flux Traverses for Position HB-3.

3. ORR APPROACH-TO-POWER TESTS

F. T. Binford

Testing of the ORR to demonstrate operation at full power was started on May 29, and continued through June. The object of these tests was threefold:

1. to demonstrate the adequacy of the structural cooling at elevated powers,
2. to determine the upper limit of power with respect to heat removal in the core,
3. to observe the behavior of the system at design power and gain operating experience.

With the exception of the main heat exchangers, the performance of the system was shown to exceed design requirements with regard to heat removal.

In order to determine the temperature distribution in the reactor structure 155 thermocouples were placed at various locations throughout the system. Of these, 105 had been embedded in the concrete biological shield during the construction period. The remaining 50 were placed in various locations where high temperatures were expected. Forty of the latter and twelve of the concrete-embedded couples, representing typical positions, were connected to recording instruments for constant observations. The remaining thermocouples were connected to potentiometers and read periodically. The thermocouple locations are shown in Figs. 3.1 through 3.3.

In addition to the thermocouples a probe device for measuring the temperature at the front face of the beam holes was constructed. The device consists of a long tube, with a pair of sharply pointed thermocouple wires which can be forced into the lattice plate, thus forming a thermocouple for measuring the plate temperatures. Figure 3.4 is a schematic diagram of this device.

The highest temperatures were expected to occur at the lattice plate inside the beam holes, at the ends of the beam hole plugs during dry operation, at the thick edges of the tank near the poolside face, and in the internal ion chamber shield. High temperatures in the internal ion chamber shield was of concern because of experience at Los Alamos Omega West reactor in which the aluminum-canned lead shield became overheated because of inadequate bonding between the lead and the aluminum. This resulted in loss of heat transfer at the surface and subsequent overheating of the lead.

Fig. 3.1. Thermocouple Location - Pool Structure.

Fig. 3.2. Horizontal Section Through the Reactor Showing Thermocouple Location.

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Fig. 3.3. Horizontal Section Through the Reactor Showing Thermocouple Location.

E-32087

Fig. 3.4. Diagram of Probe Device for Measuring Plate Temperatures.

Measurements were made with two different core configurations. The first configuration, designated core No. 1, was a 7 x 4 lattice containing 24 fuel elements, 4 control rods, and 35 reflector pieces. The second configuration, designated core No. 2, was the triangular-shaped operating core containing 26 fuel elements, 4 control rods, and 33 reflector pieces. These cores are shown in Figs. 3.5 and 3.6.

Observations were made of the temperatures at various flows and power levels up to 20 Mw. The highest temperatures recorded at 20 Mw and 12,000 gpm flow with 120°F reactor coolant inlet are listed in Table 3.1. The pool temperature varied between 85°F and 98°F.

Table 3.1 Maximum Temperatures Observed at 20 Mw and 12,000 gpm

<u>Location</u>	<u>Temperature °F</u>	
	<u>Core No. 1</u>	<u>Core No. 2</u>
Concrete-embedded thermocouples	118	110
Tank wall	133	136
Beam hole plugs (full)	112	105
Beam hole plugs (empty)	120	
Beam hole core plate (full)	127	
Beam hole core plate (empty)	127	
Beam hole surface (full)	99	
Beam hole surface (empty)	97	
North facility plug (full)	122	122
North thermal shield	96	95
External ion chamber shield	112	114
Internal ion chamber shield	124	124

Temperatures indicated by two thermocouples pressed against the wall of the nose of the north facility were observed to rise quite rapidly when this facility was operated empty. These thermocouples are held against the wall by a scissors arrangement. At 4 Mw the temperature of the two thermocouples rose to 171 and 178°F, respectively. The power was increased to 10 Mw but was reduced to 5 Mw when the temperatures reached 212 and 227°F. At 5 Mw the temperatures leveled off at 181 and 189°F. The increase above reactor inlet temperature of 120°F appears to be approximately proportional to the power level.

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POOL
W

A-1 Al	A-2 Be	A-3 Be	A-4 Be	A-5 Be	A-6 Be	A-7 Be	A-8 Be	A-9 Al
B-1 Be	140	140	S 131	140	S 131	140	140	Be
C-1 Be	70	140	140	70	140	140	70	Be
D-1 Be	140	70	S 131	70	S 131	70	140	Be
E-1 Be	140	140	70	140	70	140	140	Be
F-1 Be	Be	Be	Be	Be	Be	Be	Be	Be
G-1 Al	Be	Be	Be	Be	Be	Be	Al	Al

S

N

E

(NUMBERS REFER TO GRAMS OF ENRICHED URANIUM)

Fig. 3.5. Core Configuration No. 1.

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POOL
W

A-1 Al	A-2 Be	A-3 Be	A-4 140	A-5 140	A-6 140	A-7 Be	A-8 Be	A-9 Al
B-1 Be	Be	Be	S 131	140	S 131	140	Be	Be
C-1 Be	Be	70	140	70	140	70	Be	Be
D-1 140	140	70	S 131	70	S 131	70	140	140
E-1 140	140	140	70	140	70	140	140	140
F-1 Be	Be	Be	Be	Be	Be	Be	Be	Be
G-1 Al	Be	Be	Be	Be	Be	Be	Be	Al

E

(NUMBERS REFER TO GRAMS OF ENRICHED URANIUM)

Fig. 3.6. Core Configuration No. 2.

It was suspected that the thermocouples were not in good contact with the wall. Therefore they were removed from contact by retracting the scissors, and the power was again increased to 5 Mw. The temperatures reached were 179 and 218°F. Further attempts to reposition the thermocouples led to the conclusion that they were indeed in poor contact with the wall and the temperature resulting from gamma heating in the couples themselves rather than the temperatures of the cooled walls was being recorded. It is planned to construct another positioning device to obtain more reliable information.

With the above exception all the temperatures observed fall well below the design maxima, and it appears that the structural cooling is more than adequate for operation at design power level.

In order to determine the upper operating limit with respect to cooling the lattice itself, a series of boiling tests were performed with core configuration No. 2. The coolant flow was established at some low level with the reactor operating at a few kilowatts. The reactor power was then increased until boiling was observed. A Brush recorder connected to one of the reactor safety channels was used to give a rapid indication of the onset of boiling. One of the traces attained is shown in Fig. 3.7.

It was expected that the power level at boiling would be proportional to the 0.8 power of the flow once turbulent conditions were established. Because it was not desired to boil the reactor at high heat fluxes, only two points were obtained in the turbulent region. Both these points may be fitted by an 0.8 power relation. The results are shown in Fig. 3.8.

In order to obtain independently the heat fluxes obtained in the hottest fuel element, two elements and two reflector pieces were equipped with three thermocouples each (Fig. 3.9). These instrumented elements were placed in the

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Fig. 3.7. Tracing from Brush Recorder Showing
Typical Onset of Boiling.

Fig. 3.8. Power Level vs Flow at Boiling.

Fig. 3.9. Instrumented ORR Temperature Test Fuel Element.

highest heat flux regions as estimated from previous neutron flux measurements. At 20 Mw and the nominal flow of 12,000 gpm, the average water temperature rise observed in the hottest element was 14.5°F , which exceeded the core average by a factor of 1.26. The original figure based on neutron flux measurements was 1.29. The heat flux at the hottest point on this element exceeded the average by a factor of 1.6 based on neutron flux measurements. Thus the ratio of maximum to average flux was 2.02, and since the average heat flux at 20 Mw is 128,000 Btu/ft²hr for the No. 1 core and 120,000 Btu/ft²hr for the No. 2 core, the maximum heat fluxes were 260,000 and 242,000 Btu/hr, respectively. This compares with the design maximum of 400,000 Btu/ft²hr.

On this basis it appears that, provided the ratio of maximum to average heat flux is kept below 3, the reactor could operate at 47 Mw and 17,000 gpm flow through the core without exceeding plate temperatures of 210°F . It is assumed here, of course, that the external cooling could be maintained at a level sufficient to supply inlet water at 120°F or less.

A second set of boiling tests was undertaken to determine the maximum power level at which the reactor could be shut down concurrent with complete flow failure and still have sufficient cooling capacity due to natural convection to prevent damage to the core. Tests were conducted by blocking out the emergency cooling circuits and shutting off the main pumps, thus causing the reactor to scram through the action of the 80% flow interlock. These tests were performed at power levels of 9.7, 12.5, 15.0, and 17.5 Mw. Boiling was observed at 17.5 Mw, but not at lower powers. It was decided to halt these tests at this point until an estimate of the results of flow failure at higher power can be made. The highest temperature observed after the 17.5-Mw test was 208°F in one of the aluminum reflector pieces. In all cases the maximum

was reached approximately 5 min after shutdown. Fig. 3.10 is the temperature recorder trace of the 17.5-Mw test.

Interspersed with these tests were periods of sustained power operation at various levels up to 20 Mw. It was not possible to operate at powers above 20 Mw because of insufficient cooling capacity in the external heat exchangers supplied by the Trane Company.

During one such period of operation a G-M tube was suspended just above the pool directly over the core tank. The reactor was operated at a steady power of 20 Mw, and the inlet temperature was allowed to increase slowly from 87°F to 97°F. A constant increase in radiation intensity was observed, indicating increased thermal convection of N^{16} -bearing water to the pool surface. The maximum reading of only 7 mr/hr indicates that N^{16} activity above the pool will probably not be a serious problem.

The Na^{24} concentration in the core effluent due to $Al^{27}(\eta, \alpha)Na^{24}$ reaction was also investigated. As a first approximation the concentration of Na^{24} in the core effluent can be expressed as

$$C \approx \frac{\eta NP}{F(\alpha + \lambda t)}$$

where C is the Na^{24} concentration in d/min/ml, P is the power level in Mw, N is the number of fuel elements, F is the total flow in gpm $\times 10^3$, α is the fraction of flow bypassed to the demineralizer, λ is the decay constant and η is a constant of proportionality. Since λ is constant, it is possible to find η by measuring C under known conditions of flow and power level. Three different measurements gave values of 10.0, 9.8, and 8.6 for η . Thus the Na^{24} concentration can be estimated to be

$$C \approx \frac{9.5NP}{F(\alpha + \lambda t)}$$

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Fig. 3.10. Temperature Recorder Tracing During 17.5-Mw Test.

PART II

Taken from OPERATIONS DIVISION QUARTERLY REPORT

July - September, 1958, ORNL CF-58-9-88

OPERATIONS DIVISION

Quarterly Report

July - September 1958

SUMMARY

A considerable number of scrams occurred at the ORR, and changes to correct this are being made in the reactor instrumentation and mechanical controls. Basically, the trouble appears to be insufficient magnet holding force coupled with trouble in the electronic controls which occasionally causes the magnet current to be reduced.

Corrosion was discovered in aluminum pipe embedded in the concrete. To dry the pipes and reduce corrosion, a vacuum is being pumped on the annular space around the most important pipes. A corrosion test simulating various conditions existing in the reactor is being built.

The Trane coolers are still short of capacity. A decision has not yet been reached about the corrective measures necessary. In addition, it was discovered that two tubes have begun to leak apparently due to turbulator wear.

Flux traverses were made to determine operating characteristics of the ORR, and a series of flux trap experiments were done. In these experiments, an enhancement of almost 4 over the average flux in the fuel is found in the center of the 3 x 3 trap.

1. REACTOR OPERATIONS

W. R. Casto

1.1 Oak Ridge Research Reactor

The operating data for the ORR are given in Table 1.1.

Table 1.1 ORR Operations

Period July 1, 1958, to September 30, 1958

	This Quarter	Last Quarter	Year to Date*
Total energy, Mwd	797.8	245.8	1043.6
Average power, Mw/operating hour	18.0		
Time operating, %	48.2		
Unscheduled shutdowns, hr	82.99		
Regular shutdowns, hr	1058.78		
Research shutdowns, hr	1.23		
Reactor inlet water temperature (av), °F	114.6		
Reactor exit water temperature (av), °F	122.0		
Pool inlet water temperature (av), °F	86.5		
Pool exit water temperature (av), °F	92.3		
Reactor water radioactivity, c/m/ml	22,087		
Pool water radioactivity, c/m/ml	712		
Reactor water resistivity, ohm-cm	844,200		
Pool water resistivity, ohm-cm	968,600		

*Continuous operation was not established until the present quarter.

Operations

The Oak Ridge Research Reactor was operated during this period for experiments. Nuclear experiments were also done during the major shutdowns and included reactivity effects of experiment and fuel elements in various lattice positions, flux determinations, effects of inverting fuel

elements, recalibration of shim rods, and flux trap experiments. The first three-weeks' cycle of power operation began on July 20. A schedule of three-weeks' operation and one-week shutdown was established as a standard cycle to give maximum time at power and still provide time for experiment installation. Dates on which various cycles of operation began are indicated in Table 1.2.

Table 1.2 Cycles of Operation

<u>Cycle No.</u>	<u>Date Began</u>	<u>Date Ended</u>	<u>Energy in Mwd</u>
1	July 20	August 8	315.936
2	August 15	September 7	254.423
3	September 18	In progress	

During a total operating time of 926.329 hrs, 797.771 Mwd of energy were accumulated this quarter.

Shutdowns

Three major shutdowns occurred during the quarter.

July 1 through July 20 -- The reactor was at zero or low power to permit the repiping of the north and south facilities, the filling of the horizontal beam hole plugs with concrete for shielding, the calibration of the venturi, and the performance of critical tests and flux runs.

August 8 through August 15 -- During this shutdown, the piping to the horizontal beam holes was reworked. A tie-in to the pool primary cooling system for water supply to the horizontal beam holes and hydraulic tubes was completed. The plug at HN-1 was installed. Harvey's collimator plug was installed in HB-6. Routine shutdown work was completed. Prior to taking the reactor up to power, a series of nuclear experiments were performed.

September 7 through September 18 -- During this period the following jobs were done; experiment installation work including Pleasonton's pool side facility, hydraulic tube installation work, piping at HN-1 facility, nuclear experiments, and routine operational work.

A summary of all shutdowns occurring this quarter is presented in Table 1.3.

Table 1.3 Shutdown Summary

Scheduled Shutdowns

<u>Date</u>	<u>Duration, hr</u>	<u>Remarks</u>
7-1 to 7-20	461.200	For critical tests prior to cycle 1 operation
7-29 to 7-31	53.117	To permit core drilling on concrete sheilding around reactor water lines
8-8 to 8-15	182.083	End of cycle 1 operation
8-18	.267	For maintenance to repair leak at south facility
9-2	7.233	Testing shim rods to determine cause of scrams
9-3	7.100	Investigating scrams
9-4	12.225	Investigating scrams
9-5	22.417	Investigating scrams
9-6	20.500	Investigating scrams
9-7 to 9-18	280.917	End of cycle 2, extended for performance of flux trap experiment
9-22	9.917	To permit repair work in the pipe chase
9-23	.483	To permit work at HN-1
9-25	.483	To increase working time in basement south of pipe chase
9-27	.533	Operator training
9-28		

Table 1.3 Shutdown Summary (Continued)

<u>Date</u>	<u>Duration, hr</u>	<u>Remarks</u>
9-28	.183	Operator training
9-29	<u>1.350</u>	Operator training
Total	1060.008	
<u>Unscheduled Shutdowns</u>		
7-20	.300	Dropped No. 4 rod, reason unknown
7-21	.433	Dropped No. 6 rod then No. 4, reason unknown
7-24	.283	Dropped No. 4 and No. 5 rod, " "
7-24	.267	Dropped No. 3 rod, reason unknown
7-24	.183	Dropped No. 5 rod, " "
7-24	.233	Dropped No. 3 rod, " "
7-24	.300	Dropped No. 4 rod, " "
7-24	.317	Dropped No. 4 rod, " "
7-24	.200	Dropped No. 3 rod, " "
7-25	.350	Dropped No. 3 rod, " "
7-26	.117	Dropped No. 6 rod, " "
7-26	.283	Dropped No. 4 rod, " "
7-27	2.367	Reverse caused by high reactor H ₂ O temperature followed by a scram of unknown origin; caught by Xenon. Made an emergency core change.
7-27	8.000	
7-28	6.250	
7-28	.267	Dropped No. 5 rod, reason unknown
8-2	.383	Dropped No. 6 rod, " "
8-6	.367	Dropped No. 4 rod, " "

Table 1.3 Shutdown Summary (Continued)

Unscheduled Shutdowns

<u>Date</u>	<u>Duration, hr</u>	<u>Remarks</u>
8-16	.400	Dropped No. 3 rod then No. 4, reason unknown
8-16	.250	Dropped No. 3 rod, reason unknown
8-25	.433	Dropped No. 4 rod, " "
8-27	.283	Dropped No. 6 rod, " "
8-27	.350	Dropped No. 3 rod, " "
8-27 } to 8-28 }	31.664	Dropped No. 3 rod caught by Xenon; made emergency core change Completion of core change
8-29	.383	Dropped No. 3 rod then No. 4, reason unknown
8-29	.417	Dropped No. 3 rod then No. 4, " "
8-29	.467	Dropped No. 3 then No. 4, reason unknown
8-29	.283	Dropped No. 4 rod, reason unknown
8-29	23.500	Dropped No. 4 rod caught by Xenon; made an emergency core change
8-30	6.830	Dropped No. 3 rod then No. 4, reason unknown
8-31	.383	Dropped No. 3 rod then No. 4, " "
8-31	.617	When changing main flow pumps flow dropped below 80%
9-1	.483	Slow scram from ΔT
9-1	.817	Dropped No. 4 then No. 3 rod, reason unknown
9-22	.367	Dropped No. 3 rod, reason unknown
9-29	.317	Dropped No. 3 rod and then No. 4 rod, reason unknown
Total	82.997	

Total downtime, scheduled and unscheduled 1,143.005

Water System

During cycles 1, 2, and 3, the reactor and its associated water systems were operated at designed flow rates. The flow rate in the reactor system was increased from 12,000 gpm to about 15,500 gpm to permit the motorized valves, located on the discharge side of the pump, to be operated in the fully open position. This minimized vibration of the valve gates.

The accuracy of the ORR venturi was questioned by the Trane Company after heat balance calculations on the air coolers indicated that their heat removal capacity was over 25% below specifications. Calibration of the venturi was performed on July 15, and results indicate the factory calibration is correct.

During the first week of July aluminum corrosion products were discovered on the concrete around the primary pool cooling line No. 201. Investigations revealed that this line (six-inch diameter, and of 6061-T6 aluminum) had pit penetrations from the outside, some completely through the wall, causing the pool water leakage. The Laboratory Corrosion Group was consulted regarding cause and prevention of corrosion of aluminum embedded in concrete. No definite cause has been established for this particular case.

The line which failed had approximately one-inch of glass-wool insulation surrounded by a paper fiber shell. Water from the grout apparently soaked the glass wool at the time the concrete was poured, approximately 18 months previously. It seems likely that the wet glass-wool was a major factor in increasing the corrosion rate. Other lines, which were directly in the concrete, are believed to be in much better condition since the concrete is dry adjacent to the aluminum. In a third method of placing the aluminum in the concrete, the aluminum was covered by a plastic tape. This type also appears

to be in good condition from the cursory examinations which are possible.

A program of drilling holes through the pool concrete shielding to the annular glass wool filled spaces around the major water lines to and from the reactor was started July 28. Core holes were drilled on the inlet and exit lines at the north and south side. A solution flowed from the core holes which indicated that water surrounded the aluminum pipes. A vacuum pumping, cold-trap system was installed to dry out the space surrounding the aluminum lines.

Table 1.4 gives the analysis of the first solution which came from the north shield wall.

Table 1.4 Analysis of Initial Liquid

<u>Date</u>	<u>Constituent</u>	<u>Amount, ppm</u>
7-31-58	Al	71
	Cl	70
	Fe	7
	Mg	465
	Na	544
	OH	0.02 <u>N</u>
	pH	8.55

After pumping on the same space for 15 days, a total of 75,200 ML of liquid was collected. Analysis of liquid collected in the cold traps on 8-15 is indicated in Table 1.5.

Table 1.5 Analysis of Condensate

<u>Constituent</u>	<u>Amount, ppm</u>
Al	Less than 0.5
Cl	Less than 0.005
Fe	Less than 0.5
TS	Less than 10
OH	Less than 0.005 <u>N</u>
pH	7.20

A vacuum pump system has been

A vacuum varying between 10 and 25 inches of mercury has been kept on the core holes continuously since drilling was completed. Condensate collections have been made daily. Although the data are scattered, they indicate that the volume of condensate has decreased by as much as a factor of five. Variations in volumes collected resulted because the program was hurriedly placed in operation and the number of core holes attached to a single cold trap varied. The vacuum on each hole changed as the number of holes increased, and the pumps occasionally gave trouble. A permanent pumping system has been designed and is scheduled for installation as soon as possible.

A corrosion test stand has been designed and built whereby aluminum piping can be subjected to environments similar to that of the aluminum piping located in the concrete shielding. Studies will be made with this facility, and it is hoped that predictions of corrosion rates on reactor piping embedded in the concrete can be made. Various corrosion inhibitors will also be studied to determine what reduction in corrosion rate is possible under the different present, and possible future, conditions of the aluminum in the system.

Demineralizers

Demineralizer performance has been extremely satisfactory. During the quarter regenerations were performed on the pool anion unit and the south mixed-bed of the reactor demineralizer. On August 17 the south reactor demineralizer was taken out of service because of a depleted mixed-bed unit. Total throughput was 11,027,080 gal. The north reactor demineralizer was placed in service on August 17, and the throughput was 7,098,790 gal on September 30. The pool demineralizer was taken out of service on July 26 when the anion unit became depleted. Total throughput was 14,612,616 gal. Following the regeneration of the anion unit, the demineralizer was placed back in service. On September 30 the total throughput was 5,468,462 gal for the anion unit and 20,081,178 gal for the cation unit. Performance data for all of the ORR demineralizers since initial operation is given in Table 1.6.

Results of capacity checks on the resins before and after regeneration are given in Table 1.7.

Reactor Water Heat Exchangers

On September 28 a leak was discovered in No. 6 unit of the air-cooled heat exchanger. The unit was taken out of service on September 29 when it was found the leak rate was increasing. An inspection indicated the leak was in one or more of the tubes. At the end of cycle 3 a detailed inspection and repair will be made.

Table 1.6 ORR Demineralizer Data

Column	Run No.	Initiation Date	Termination Date	Throughput (gal)	Specific Resistance ohm/cm		Average c/m/ml	
					Influent	Effluent	In	Out
Pool Anion	1	2-5-58	7-26-58	14,612,616		1,750,000		124
Pool Anion	2	7-24-58	In service	6,353,120		1,400,000		78
Pool Cation	1	2-5-58	In service	20,965,736	985,000		700	
S. Cation	1	2-21-58	Stand-by	11,027,080	900,000		22,863	
S. Anion	1	2-21-58	Stand-by	11,027,080				
S. Mixed-Bed	1	2-21-58	8-17-58	11,027,080		1,431,000		1506
N. Cation	1	1-13-58	In service	6,150,715	716,000		22,501	
N. Anion	1	1-13-58	In service	6,150,715				
N. Mixed-Bed	1	1-13-58	In service	6,150,715		1,242,000		1591

97

Table 1.7 Resin Capacities

Date	Unit	Demineralizer	Residual Capacity meq/g			
			Before		After	
			Anion	Cation	Anion	Cation
8-4	Anion	Pool	0.51		0.57	
8-21	Mixed-bed	South Reactor	0.18	0.76		
8-24	Mixed-bed	South Reactor			0.44	1.03

Pool Secondary Water System

The pool secondary cooling loop was in normal operation during cycles 1, 2, and 3. Treatment to minimize corrosion, algae formation, and microbiological growth, as recommended by National Aluminate Corporation, is being followed. Results thus far are satisfactory as indicated in Table 1.8.

Some difficulty has been encountered in the automatic control system. This difficulty has been analyzed by the Instrument Department and the controls are being redesigned.

Corrosion Samples

Corrosion specimens representing the various types of metals involved in the ORR water system have been fabricated and exposed. Eight samples were removed from the core area on August 11, 1958. However, due to the high level of radioactivity and other high priority work, no inspection has been made at this time. Coupons of the four aluminum alloys used in the secondary cooling loop were exposed for 190 hours in the tower sump. The results are indicated in Table 1.8.

Table 1.8 Corrosion Rates

<u>Alloy</u>	<u>Rate at 190 hrs</u>
1100-H14	0.7 mpy
3003-H14	0.8 mpy
5054-F	1.2 mpy
6061-T6	1.0 mpy

A second set of samples, identical to those mentioned above, was exposed in the same location for a period of 1970 hours. An evaluation indicated the corrosion rate to be 1-mpy or less. A corrosion rate of 1-mpy is considered acceptable.

Radiation and Radioactivity

On September 19, shortly after the beginning of cycle 3 operation, air activity was discovered throughout the building. Investigations indicated that the source was the pipe chase from which a blower was exhausting the air-borne activity into the basement. It was then being distributed throughout the building via the roof fans. As a temporary measure, until the leak could be repaired, all openings in the pipe chase were closed except the blower which was attached to the building off-gas system. The reactor was shut down on September 22 to permit entry into the pipe chase where it was found that a swage-lock fitting on a line from an orifice flange to a dp cell was leaking. This was repaired immediately, and a larger, semi-permanent, off-gas line was installed to exhaust the pipe chase air to the off-gas system. A decay study by the Health Physics counting group indicated the activity to be mostly Cesium 138 with a half-life of 32 minutes.

During the week of September 22 and September 25, the activity of the reactor pool was considerably higher than normal. The source was found to be reactor water leaking into the pool around the access cover; after tightening the cover the activity returned to normal. The background level at the surface of the pool water increased from a normal 5 to 8 mr/hr to around 20 mr/hr, while the activity of the water increased from a normal 800 to 1000 c/m/ml to around 2500 c/m/ml.

Reactor Control System

Repeated troubles with accidental shim rod drops necessitated an investigation of the magnets and magnet amplifiers by members of the Reactor Controls Department. As a result of this investigation, the following proposals were made:

1. The response of the electromechanical system should be made less sensitive to short electronic noise spikes by using suitable filters in the sigma amplifiers and the magnet amplifiers. Instead of the 16 ms. release time, the rods dropped in ~ 1 ms under certain conditions.
2. The magnet current should be raised to give a larger magnet holding force to reduce the sensitivity of the mechanical system to vibration and shock.

In order to accomplish the first objective above the following changes in the electronic circuits were made:

1. A .11 mfd, 600-volt Vitamin Q capacitor was inserted between the common grid connection of the two 6BG6 tubes and ground in each magnet amplifier.

2. A .047 mfd, 600-volt Vitamin Q capacitor was inserted between the grid of the sigma amplifier tube (tube driving sigma bus) and ground in each sigma amplifier.

(The capacitors inserted in these amplifiers introduce RC time constants totaling approximately 20 milliseconds into the circuits. It should be pointed out that, in normal drop tests using a pulse technique, delays of this order may contribute to the observed drop time. It is the opinion of the Reactor Controls Department that the delays introduced do not make the effectiveness of the safety system unacceptable.)

3. The Jordan button circuit in each sigma amplifier was modified to simulate a power level of approximately $1.7 N_F$ when the button is pressed.

Facility Changes

Facility changes which have been made during the quarter are listed in Table 1.9.

Table 1.9 Facility Changes

<u>Facility</u>	<u>Date In</u>	<u>Date Out</u>	<u>Nature of Experiment</u>	<u>Sponsor</u>
C-3	8-18		Fast neutron facility	Wittels
B-9	7-18		Experimental tube with thermocouples	Morgan and Baumann
HB-6	8-11		Collimator plug	Harvey
HN-1	8-11		HRP beam hole plug and equipment chamber	Lorenz
A-9	8-27		Capsule irradiation	Fredricks
Pool side	9-11		He ⁶ recoil study	Pleasanton
B-1	9-17		Experimental tube and thermocouple	Collins (G.E.)
Pool side	9-25	9-25	Flux monitoring	McQuilkin
Pool side	9-19	9-22	Na ₂ CO ₃ isotope	Isotope

Fuel Inventory

The fuel inventory as of September 30 is shown in Table 1.10.

Table 1.10 ORR Fuel Inventory

ORR Reactor and Storage Pool

	<u>Number</u>	<u>Weight Range (g)</u>
Used elements	8	55-60
	28	100-129
	20	149-167
	<u>6</u>	196-199
Total	62	
New elements	none	
Used shim rods	5	95-131
New shim rods	none	

SS Vault

New elements	8	168
	33	200
New shim rods	3	131

In Shops (fabrication)

Elements	10	150
Shim rods	3	131

Total Number on Inventory

Fuel elements	113
Shim rods	<u>11</u>
Grand Total	124

Facility Assignment

As of September 30 the assignments of facilities were as shown in Table 1.11 and Figure 1.1.

Table 1.11 Facility Assignment

<u>Facility</u>	<u>Access Flange</u>	<u>Nature of Experiment</u>	<u>Division</u>	<u>Individual</u>
A-9	V-1	Thorium oxide slurry studies	Chem.Tech.	J. P. McBride
B-9	V-2	Gas-cooled loop	Solid State	J. G. Morgan
C-8	V-3	Unassigned		
F-8	V-4	Hydraulic rabbit	Operations	General Use
F-9	V-5	Vertical fused-salt loop	Solid State	W. E. Browning
F-3	V-6	Creep and stress corrosion	Solid State	J. C. Zukas
F-2	V-7	Air-cooled loop	Solid State(G.E.)	E. S. Collins
F-1	V-8	Solid fuel studies	Metallurgy	J. E. Cunningham
C-1	V-9	Fuel tests	Solid State	J. G. Morgan
B-1,B-2	V-10	Gas-cooled loop	Reactor Projects	D. B. Trauger
A-1,A-2	Special	MSR H ₂ O loop		Ira Dudley
C-3		Fast neutron facility	Solid State	M. C. Wittels
A-7, F-4, F-5, F-6, and F-7)		Isotope production	Isotopes	E. E. Beauchamp
Pool		GCPR capsule tests	Reactor Projects	F. R. McQuilkin
Pool		ANP and HRP irradiation metallurgy	Solid State	J. C. Wilson
Pool	He	He ⁶	Physics	F. Pleasonton
HN-1		HRP solution corrosion loop	REED	R. A. Lorenz
HN-2	Una	Unassigned		
HN-3		Pneumatic rabbit	Chemistry	A. R. Brosi
HN-3		Activation analysis	Analytical Chem.	G. W. Leddicotte
HN-4		Unassigned		
HS-1		PAR slurry loop program	Chem. Tech.	T. A. Arehart

LEGEND

BERGGREN - C-8
BROWNING - F-9
CUNNINGHAM - F-1
GENERAL ELECTRIC - F-2
HYDRAULIC TUBE - F-8
ISOTOPE - A-7, F-4, F-5, F-6, F-7
McBRIDE - A-9
MORGAN - B-9, C-1
TRAUGER - A-1, A-2, B-1, B-2
WITTELS - C-3
ZUKAS - F-3

O.R.N.L. RESEARCH REACTOR
LATTICE PATTERN AND EXPERIMENT LOCATIONS

FIGURE I.1
RESEARCH ASSIGNMENTS AND
FUEL LOADING ON 9-30-58

Table 1.11 Facility Assignment (Continued)

<u>Facility</u>	<u>Access Flange</u>	<u>Nature of Experiment</u>	<u>Division</u>	<u>Individual</u>
HS-2		Unassigned		
HB-1		Magnetic analysis of fission fragments with time of flight	Physics	H. W. Schmitt
HB-2		Unassigned		
HB-3		Neutron spectrometer	Physics	E. O. Wollan
HB-4		Neutron spectrometer	Chemistry	E. A. Levy
HB-5		Neutron spectrometer	Physics	L. D. Roberts
HB-6		Time-of-flight neutron spectrometer	Physics	J. A. Harvey

Chamber Inventory

The chamber inventory on September 30 is given in Table 1.12.

Table 1.12 Chamber Inventory

<u>Type</u>	<u>Quantity</u>	<u>Size</u>	<u>Location</u>	<u>Usage</u>
PCP	1	3 in.	Reactor Pool	No. 1 safety
PCP	1	3 in.	Reactor Pool	No. 2 safety
PCP	1	3 in.	Reactor Pool	No. 3 safety
Compensated	1	4 in.	Reactor Pool	Log N
Compensated	1	4 in.	Reactor Pool	Servo
Fission	1	2 in.	Reactor Tank	CRM
Fission	1	2 in.	Reactor Pool	Auxillary CRM

ORR Water Analysis

Ionic analyses of reactor and pool water are given in Table 1.13. At the time of sampling, the reactor was operating at 20 Mw with a flow rate of 15,500 gpm. The pool flow rate was 775 gpm.

Table 1.13 Water Analysis of ORR Water

Impurities	Quantity, ppm	
	Reactor	Pool
Al	<.05	.10
Fe	<.05	<.05
Ni	<.05	<.05
Cd	<.05	<.05
Pd	<.05	<.05
Si	5	4
H ⁺	$4 \times 10^{-5} \text{N}$	$4 \times 10^{-5} \text{N}$
T. S.	11.8	10.4
Cr	<.05	<.05
Ca	.008	.09
Cl	<.05	.05
pH	5.95	5.95
Spec. Res.	$1.16 \times 10^6 \text{ ohm-cm}$	$1.11 \times 10^6 \text{ ohm-cm}$

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2. ORR Tests

2.1 Neutron Measurements in the ORR

C. D. Cagle and R. A. Costner

Thermal neutron measurements were made in the ORR Cycle I core and the Cycle III core. The core configurations at the time measurements were made are shown in Figs. 2.1.1 through 2.1.3. The spatial distributions, the average fluxes, the maximum fluxes, and the maximum-to-average ratios were determined. The method was essentially the same as used in the previous measurements^{(1),(2)} in that vertical traverses were made by irradiating wires; however, cobalt wires were substituted for copper and the wires were cut into one-inch increments and the activity measured by the Activation Analysis Group.

In order to observe the effect of the equilibrium xenon in the core and the effect of control rod withdrawal for compensation, two measurements were made on the Cycle I core. A flux traverse was made previous to start-up and another after completion of the cycle. The second measurement was made 40.3 hours after shutdown when xenon-135 had grown to its shutdown maximum and decayed to about one and one-half times the equilibrium operating xenon concentration. Due to a shutdown during the cycle, it had been necessary to replace some of the elements in order to remove enough xenon to allow start-up, but an attempt was made to replace fuel elements with elements of approximately the same weight. During the first flux measurement, the shim rods were withdrawn 15.65-in. or 53% and in the second 23.89-in. or 81%.

- (1) Cagle, C. D., Costner, R. A., Initial Nuclear Measurements in the ORR, ORNL-2559.
- (2) Cagle, C. D., "ORR Approach-To-Critical Runs and Low-Power Neutron Measurements", Operations Division Quarterly Report, April-June 1958, ORNL CF-58-6-122.

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ORNL-LR-DWG 34022

POOL
W

	1	2	3	4	5	6	7	8	9	
A	A	Be	Be [Ⓢ]	FUEL 168.25	FUEL 137.86	FUEL 167.31	R	Be	A	
B	Be	Be	FUEL 135.33	SHIM 121.13	FUEL 129.08	SHIM 123.17	FUEL 129.08	Be	E	
C	Be	Be	E 147.57	FUEL 126.09	FUEL 137.87	FUEL 126.46	FUEL 130.04	Be	Be	
S D	FUEL 167.96	FUEL 126.97	FUEL 131.83	SHIM 119.34	FUEL 137.25	SHIM 119.54	FUEL 130.23	FUEL 127.27	FUEL 168.44	N
E	FUEL 130.90	FUEL 127.32	FUEL 124.92	FUEL 60.73	FUEL 125.13	FUEL 60.84	FUEL 133.97	FUEL 127.74	FUEL 138.12	
F	Be	Be	R	Be	R	Be	R	Be	Be	
G	Be	Be	Be	Be	Be	Be	Be	Be	Be	

E

Be ---- BERYLLIUM REFLECTOR PIECE

Be[Ⓢ] ---- BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON SOURCE

E ---- EXPERIMENT

E_{147.57} ---- PARTIAL FUEL ELEMENT CONTAINING EXPERIMENT

R ---- RADIOISOTOPE PRODUCTION FACILITY

A ---- ALUMINUM PIECE

TOTAL MASS --- 4038.67 g U²³⁵

RODS AT CRITICAL --- 15.65 in. (53 %) WITHDRAWN

Fig. 2.1.1 . Core at Start-up of Cycle I on July 19, 1958.

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ORNL-LR-DWG 34023

POOL									
W									
	1	2	3	4	5	6	7	8	9
A	A	Be	Be [Ⓢ]	FUEL 162.30	FUEL 129.29	FUEL 163.16	R	Be	A
B	Be	Be	FUEL 121.15	SHIM 111.36	FUEL 132.60	SHIM 114.19	FUEL 118.29	Be	E
C	Be	Be	E 132.01	FUEL 130.76	FUEL 129.71	FUEL 130.95	FUEL 115.46	Be	Be
S D	FUEL 159.86	FUEL 113.61	FUEL 122.61	SHIM 107.94	FUEL 130.43	SHIM 108.16	FUEL 130.84	FUEL 114.30	FUEL 161.96
E	FUEL 120.73	FUEL 114.34	FUEL 110.56	FUEL 55.44	FUEL 122.42	FUEL 55.26	FUEL 119.38	FUEL 114.37	FUEL 129.36
F	Be	Be	R	Be	R	Be	R	Be	Be
G	Be	Be	Be	Be	Be	Be	Be	Be	Be

Be----BERYLLIUM REFLECTOR PIECE

Be[Ⓢ]----BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON SOURCE

E----- EXPERIMENT

E_{132.01}----- PARTIAL FUEL ELEMENT CONTAINING EXPERIMENT

R----- RADIOISOTOPE PRODUCTION FACILITY

A----- ALUMINUM PIECE

TOTAL MASS --- 3782.80 g U²³⁵

ROD POSITIONS DURING FLUX MAPPING --- 23.89 in. (81%) WITHDRAWN

Fig. 2.1.2 . Core after Shutdown of Cycle I on August 9, 1958.

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ORNL-LR-DWG 34024

POOL									
W									
	1	2	3	4	5	6	7	8	9
A	Be	Be	Be [Ⓢ]	FUEL 199.95	FUEL 167.40	FUEL 199.80	R	Be	E
B	E	Be	FUEL 166.62	SHIM 103.12	FUEL 121.82	SHIM 106.30	FUEL 166.88	Be	E
C	Be	Be	E 119.24	FUEL 112.34	FUEL 115.68	FUEL 109.53	FUEL 167.10	Be	Be
S D	FUEL 199.95	FUEL 102.86	FUEL 122.21	SHIM 98.39	FUEL 116.47	SHIM 131.15	FUEL 122.09	FUEL 103.62	FUEL 200.29
E	FUEL 199.63	FUEL 103.32	FUEL 109.87	FUEL 107.56	FUEL 109.66	FUEL 111.31	FUEL 107.36	FUEL 103.63	FUEL 200.28
F	Be	Be	R	Be	R	Be	R	Be	Be
G	Be	Be	Be	Be	Be	Be	Be	Be	Be

Be ---- BERYLLIUM REFLECTOR PIECE

Be[Ⓢ] ---- BERYLLIUM REFLECTOR PIECE CONTAINING NEUTRON SOURCE

E ---- EXPERIMENT.

E^{119.24} ---- PARTIAL FUEL ELEMENT CONTAINING EXPERIMENT

R ---- RADIOISOTOPE PRODUCTION FACILITY

TOTAL MASS --- 4205.43 g U²³⁵

ROD POSITIONS DURING FLUX MAPPING --- 15.73 in. (53 %) WITHDRAWN

Fig. 2.1.3. Core Before Start-up of Cycle III on September 17, 1958.

Flux traverses illustrating the effects observed have been plotted and are shown in Figs. 2.1.4 through 2.1.6. The variation in the relative shapes of the vertical neutron flux distributions in the core containing xenon is illustrated by Figure 2.1.7. Since significant changes had been made in the fuel distribution as well as the addition of experiments, a flux traverse was made in the Cycle III core prior to start-up.

Summaries of the measurements made are given in Tables 2.1.1, 2.1.2, and 2.1.3. Detailed tabulations of the traverses are given in Tables 2.1.4, 2.1.5, and 2.1.6. Vertical flux traverses are plotted in reflector positions for the benefit of research personnel assigned these positions. These are shown in Figs. 2.1.8 through 2.1.15.

Fig. 2.1.4. Flux Traverse E-row.

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Fig. 2.1.5. Thermal Neutron Flux Traverse for Position D-2.

Fig. 2.16. Thermal Neutron Flux Traverse for Position D-5.

Fig. 2.1.7. Thermal Neutron Flux Traverse with Xenon in Core (Shim Rods Withdrawn 23.89 in. or 81%) .

Table 2.1.1

Summary of Thermal Neutron Flux Measurements^(a) in ORR
Core 7-19-58. Prior to Startup of Cycle I

Core Position	Flux ^(b)	
	Average	Maximum
A-4	0.61	0.93
A-5	0.59	0.92
A-6	0.52	0.81
B-3	1.03	1.51
B-4	0.94	1.75
B-5	0.92	1.54
B-6	0.88	1.46
B-7	0.80	1.22
C-3	1.04	1.66
C-4	1.18	1.95
C-5	1.21	1.94
C-6	1.10	1.78
C-7	1.09	1.62
D-1	0.82	1.15
D-2	1.04	1.40
D-3	1.22	1.75
D-4	1.18	1.97
D-5	1.20	1.97
D-6	1.18	1.97
D-7	1.13	1.67
D-8	1.01	1.40
D-9	0.61	0.81
E-1	0.75	1.04
E-2	1.01	1.39
E-3	1.14	1.56
E-4	1.51	2.20
E-5	1.18	1.72
E-6	1.46	2.13
E-7	1.05	1.47
E-8	1.02	1.42
E-9	0.59	0.78

(a) Average flux in core taken as 1.00; maximum-to-average ratio, 2.2; Average flux at 20 Mw (calculated) 1.16×10^{14} neutrons/cm².sec; maximum flux at 20 Mw (calculated), 2.55×10^{14} neutrons/cm². sec.

(b) Expressed as ratio to average flux in core.

Table 2.1.2

Summary of Thermal Neutron Flux Measurements^(a) in ORR
Core 8-9-58, after Cycle I Shutdown with Xenon in Core

Core Position	Flux ^(b)	
	Average	Maximum
A-4	0.66	0.86
A-5	0.73	0.98
A-6	0.66	0.88
BB-3	1.04	1.38
B-4	0.87	1.32
B-5	1.07	1.44
B-6	0.93	1.33
B-7	0.95	1.27
C-3	1.22	1.57
C-4	1.24	1.64
C-5	1.30	1.69
C-6	1.22	1.62
C-7	1.18	1.58
D-1	0.56	0.73
D-2	0.91	1.17
D-3	1.12	1.44
D-4	1.18	1.69
D-5	1.24	1.62
D-6	1.08	1.50
D-7	1.13	1.48
D-8	0.85	1.12
D-9	0.71	0.90
E-1	0.55	0.71
E-2	0.85	1.10
E-3	1.03	1.36
E-4	1.43	1.90
E-5	1.17	1.50
E-6	1.43(c)	1.90(c)
E-7	1.07	1.42
E-8	1.06	1.37
E-9	0.55	0.73

(a) Average flux in core taken as 1.00; maximum-to-average ratio, 1.9; average flux at 20 Mw (calculated), 1.24×10^{14} neutrons/cm².sec; maximum flux at 20 Mw (calculated), 2.36×10^{14} neutrons/cm². sec.

(b) Expressed as ratio to average flux in core.

(c) Assumed to be the same as E-4 due to similar weights and previous measurements.

Table 2.1.3

Summary of Thermal Neutron Flux Measurements^(a)
in ORR Core 9-17-58

<u>Core Position</u>	<u>Flux^(b)</u>	
	<u>Average</u>	<u>Maximum</u>
A-4	0.62	1.09
A-5	0.60	1.03
A-6	0.53	0.85
B-3	0.88	1.31
B-4	1.06	1.77
B-5	1.06	1.71
B-6	0.99	1.97
B-7	0.81	1.25
C-3	1.22	1.89
C-4	1.24	2.02
C-5	1.30	2.12
C-6	1.27	2.11
C-7	1.19	1.87
D-1	0.54	0.74
D-2	1.05	1.47
D-3	1.15	1.84
D-4	1.41	2.42
D-5	1.28	2.19
D-6	1.21	2.14
D-7	1.27	1.09
D-8	1.93	1.49
D-9	0.56	0.75
E-1	0.47	0.62
E-2	1.09	1.59
E-3	1.13	1.63
E-4	1.22	1.87
E-5	1.10	1.66
E-6	1.24	1.89
E-7	1.09	1.55
E-8	1.03	1.47
E-9	0.54	0.71

(a) Average flux in core taken as 1.00; maximum to average ratio, 2.19;
 average flux at 20 Mw (calculated), 1.12×10^{14} neutrons/cm².sec;
 maximum flux at 20 Mw (calculated), 2.45×10^{14} neutrons/cm².sec;
 (Shim rods were excluded in determination of maximum to average ratio).

(b) Expressed as ratio to average flux in core.

Table 2.1.4

Thermal Neutron Flux Measurements in Cycle I Core (without Xenon) 8-9-58

Distance From Top (in.)	Flux Measurements*								
	Core Positions						Reflector Position		Core Position
	A-4	A-5	A-6	B-3	B-5	B-7	C-1	C-2	C-3
1	0.17	0.18	0.15	0.28	0.22	0.29	0.24	0.30	0.42
2	0.17	0.16	0.15	0.34	0.19	0.23	0.31	0.38	0.32
3	0.20	0.18	0.17	0.39	0.22	0.24	0.36	0.47	0.34
4	0.24	0.21	0.20	0.46	0.26	0.29	0.45	0.55	0.41
5	0.28	0.25	0.24	0.53	0.32	0.38	0.51	0.61	0.48
6	0.33	0.30	0.28	0.62	0.38	0.40	0.59	0.71	0.52
7	0.37	0.35	0.32	0.71	0.44	0.48	0.69	0.84	0.63
8	0.42	0.42	0.37	0.80	0.51	0.54	0.78	0.96	0.73
9	0.46	0.44	0.42	0.90	0.60	0.63	0.90	1.10	0.82
10	0.55	0.51	0.47	1.03	0.72	0.69	1.01	1.24	0.89
11	0.63	0.57	0.52	1.09	0.87	0.79	1.13	1.36	1.02
12	0.72	0.64	0.60	1.28	0.96	0.91	1.21	1.46	1.24
13	0.78	0.76	0.66	1.38	1.16	1.02	1.29	1.59	1.31
14	0.83	0.78	0.71	1.41	1.41	1.09	1.39	1.69	1.43
15	0.86	0.83	0.74	1.48	1.44	1.16	1.40	1.78	1.46
16	0.89	0.89	0.78	1.51	1.54	1.22	1.46	1.91	1.56
17	0.90	0.92	0.81	1.51	1.54	1.22	1.46	1.97	1.53
18	0.93	0.92	0.79	1.48	1.51	1.22	1.50	2.04	1.53
19	0.91	0.91	0.77	1.44	1.51	1.16	1.56	2.07	1.43
20	0.86	0.90	0.72	1.35	1.44	1.12	1.46	2.10	1.37
21	0.77	0.85	0.66	1.19	1.28	1.09	1.46	2.01	1.27
22	0.70	0.79	0.59	1.12	1.16	1.03	1.45	1.94	1.24
23	0.68	0.74	0.57	1.16	1.09	0.90	1.32	1.78	1.31
24	0.94	0.73	0.80	1.41	1.44	1.16	1.26	1.66	1.66

*Expressed as the ratio of the flux to the average flux in the core, which at 20 Mw was 1.16×10^{14} neutrons/cm².sec.

Table 2.1.4 (Continued)

Distance From Top (in.)	Reflector Position	Flux Measurements*							
		Core Positions							
		C-4	C-5	C-6	C-7	D-1	D-2	D-3	D-5
1	0.28	0.32	0.32	0.37	0.38	0.51	0.53	0.27	0.43
2	0.27	0.28	0.27	0.34	0.32	0.43	0.44	0.27	0.38
3	0.32	0.32	0.29	0.38	0.38	0.49	0.48	0.32	0.43
4	0.39	0.38	0.35	0.46	0.45	0.57	0.56	0.38	0.53
5	0.45	0.46	0.42	0.55	0.51	0.68	0.66	0.44	0.62
6	0.54	0.55	0.48	0.63	0.60	0.78	0.77	0.52	0.71
7	0.62	0.64	0.57	0.73	0.66	0.88	0.89	0.61	0.75
8	0.73	0.73	0.66	0.88	0.75	0.96	0.96	0.70	0.89
9	0.86	0.89	0.75	0.92	0.81	1.02	1.08	0.83	1.02
10	0.99	1.08	0.89	1.02	0.87	1.11	1.27	0.99	1.08
11	1.15	1.21	1.02	1.15	0.94	1.24	1.34	1.11	1.21
12	1.34	1.40	1.21	1.27	0.99	1.31	1.46	1.37	1.40
13	1.59	1.59	1.40	1.40	1.05	1.34	1.59	1.59	1.46
14	1.75	1.69	1.59	1.53	1.10	1.37	1.69	1.75	1.56
15	1.82	1.78	1.66	1.59	1.10	1.40	1.72	1.82	1.59
16	1.91	1.82	1.75	1.62	1.15	1.37	1.75	1.85	1.66
17	1.94	1.88	1.78	1.62	1.11	1.37	1.75	1.88	1.67
18	1.85	1.91	1.75	1.59	1.08	1.37	1.69	1.91	1.62
19	1.78	1.94	1.72	1.50	1.03	1.31	1.66	1.97	1.53
20	1.72	1.78	1.59	1.40	0.96	1.27	1.50	1.82	1.43
21	1.53	1.69	1.46	1.34	0.83	1.11	1.43	1.62	1.40
22	1.37	1.53	1.37	1.15	0.76	1.04	1.24	1.53	1.27
23	1.34	1.45	1.37	1.15	0.75	0.97	1.21	1.46	1.15
24	1.75	1.75	1.78	1.53	1.04	1.10	1.50	1.78	1.43

*Expressed as the ratio of the flux to average flux in the core, which at 20 Mw was 1.16×10^{14} neutrons/cm² . sec.

Table 2.1.4 (Continued)

Distance From Top (in.)	Flux Measurements*								
	Core Positions								
	D-8	D-9	E-1	E-2	E-3	E-4	E-5	E-6	E-7
1	0.54	0.32	0.38	0.50	0.45	0.45	0.38	0.45	0.39
2	0.44	0.28	0.31	0.43	0.41	0.47	0.37	0.46	0.38
3	0.45	0.31	0.34	0.46	0.47	0.57	0.43	0.55	0.44
4	0.53	0.37	0.40	0.57	0.55	0.66	0.50	0.64	0.53
5	0.62	0.41	0.46	0.65	0.64	0.78	0.58	0.76	0.62
6	0.71	0.46	0.53	0.75	0.75	0.96	0.68	0.89	0.70
7	0.80	0.52	0.61	0.85	0.88	1.05	0.78	0.96	0.81
8	0.86	0.57	0.68	0.94	0.97	1.18	0.91	1.11	0.90
9	0.96	0.62	0.74	1.03	1.07	1.39	1.03	1.34	0.99
10	1.08	0.67	0.80	1.12	1.22	1.46	1.18	1.40	1.08
11	1.11	0.69	0.84	1.19	1.34	1.69	1.31	1.59	1.20
12	1.18	0.75	0.92	1.26	1.39	1.91	1.45	1.75	1.27
13	1.27	0.77	0.97	1.27	1.46	2.01	1.50	1.97	1.34
14	1.34	0.79	1.02	1.37	1.46	2.10	1.59	2.01	1.45
15	1.40	0.80	1.04	1.39	1.56	2.10	1.66	2.04	1.45
16	1.40	0.81	1.04	1.39	1.56	2.13	1.72	2.07	1.46
17	1.37	0.80	1.03	1.38	1.53	2.13	1.72	2.10	1.47
18	1.34	0.79	1.00	1.33	1.53	2.17	1.66	2.13	1.46
19	1.27	0.75	0.94	1.25	1.46	2.20	1.62	2.13	1.41
20	1.21	0.71	0.87	1.17	1.46	1.97	1.46	1.97	1.31
21	1.08	0.65	0.78	1.04	1.34	1.82	1.43	1.85	1.20
22	0.99	0.59	0.69	0.92	1.17	1.66	1.30	1.69	1.04
23	1.02	0.55	0.66	0.88	1.11	1.59	1.13	1.53	1.02
24	1.40	0.57	0.89	1.13	1.52	1.75	1.94	1.72	1.24

*Expressed as the ratio of the flux to average flux in the core, which at 20 Mw was 1.16×10^{14} neutrons/cm².sec.

Table 2.1.4 (Continued)

Distance From Top (in.)	Flux Measurements*								
	Core Position		Reflector Positions			Shim Rods			
	E-8	E-9	F-2	F-4	F-8	B-4	B-6	D-4	D-6
1	0.42	0.25	0.27	0.19	0.24				
2	0.40	0.28	0.34	0.24	0.31				
3	0.47	0.32	0.43	0.29	0.38				
4	0.57	0.38	0.50	0.34	0.46				
5	0.65	0.43	0.58	0.39	0.52				
6	0.73	0.48	0.68	0.45	0.61				
7	0.85	0.54	0.78	0.52	0.70				
8	0.92	0.59	0.86	0.60	0.79				
9	1.01	0.63	0.99	0.68	0.89				
10	1.12	0.67	1.02	0.75	1.02				
11	1.18	0.71	1.18	0.82	1.11				
12	1.24	0.75	1.21	0.90	1.21				
13	1.29	0.78	1.37	0.95	1.27				
14	1.38	0.78	1.46	1.01	1.31				
15	1.41	0.77	1.50	1.06	1.40	1.75	1.46	1.97	1.97
16	1.42	0.78	1.53	1.08	1.43	1.43	1.24	1.69	1.69
17	1.41	0.76	1.62	1.10	1.46	1.40	1.24	1.69	1.69
18	1.35	0.73	1.66	1.10	1.46	1.40	1.27	1.69	1.69
19	1.29	0.69	1.56	1.11	1.53	1.37	1.21	1.69	1.69
20	1.17	0.64	1.59	1.09	1.50	1.27	1.21	1.69	1.69
21	1.05	0.57	1.53	1.04	1.46	1.15	1.11	1.46	1.46
22	0.94	0.51	1.46	1.01	1.40	1.10	1.02	1.40	1.40
23	0.94	0.49	1.37	0.92	1.27	0.96	0.90	1.34	1.34
24	1.21	0.61	1.34	0.83	0.21	0.85	0.85	1.11	1.11
25						0.72	0.78	0.94	0.94
26						0.57	0.64	0.76	0.76
27						0.43	0.51	0.57	0.57
28						0.30	0.29	0.42	0.42
29						0.20	0.22	0.29	0.29
30						0.13	0.13	0.19	0.19

Table 2.1.5

Thermal Neutron Flux Measurements in Cycle II Core (with Xenon 7-19-58)

Distance From Top (in.)	Flux Measurements**								
	Core Positions								
	A-4	A-5	A-6	B-3	B-5	B-7	C-3	C-4	C-5
1	0.33	0.35	0.34	0.57	0.46	0.39	0.77	0.58	0.59
2	0.31	0.32	0.28	0.53	0.41	0.36	0.63	0.54	0.57
3	0.36	0.38	0.29	0.61	0.53	0.43	0.71	0.65	0.69
4	0.44	0.48	0.36	0.72	0.70	0.61	0.84	0.81	0.86
5	0.53	0.55	0.44	0.83	0.87	0.80	0.96	0.98	1.02
6	0.61	0.64	0.53	0.93	1.00	0.93	1.08	1.12	1.15
7	0.65	0.72	0.62	1.03	1.09	0.98	1.20	1.26	1.30
8	0.73	0.80	0.69	1.15	1.16	1.07	1.28	1.37	1.42
9	0.77	0.85	0.75	1.20	1.25	1.15	1.36	1.43	1.51
10	0.81	0.91	0.78	1.28	1.30	1.20	1.45	1.50	1.59
11	0.84	0.94	0.83	0.33	1.37	1.23	1.48	1.57	1.68
12	0.86	0.95	0.84	1.35	1.40	1.25	1.54	1.59	1.67
13	0.86	0.97	0.83	1.38	1.44	1.27	1.57	1.62	1.69
14	0.86	0.98	0.86	1.38	1.40	1.23	1.55	1.64	1.68
15	0.85	0.97	0.87	1.34	1.41	1.22	1.55	1.60	1.68
16	0.81	0.94	0.88	1.31	1.39	1.19	1.52	1.55	1.65
17	0.79	0.91	0.85	1.26	1.35	1.16	1.50	1.57	1.59
18	0.75	0.86	0.85	1.18	1.26	1.08	1.42	1.43	1.51
19	0.69	0.80	0.79	1.10	1.17	1.00	1.35	1.37	1.40
20	0.64	0.74	0.74	1.00	1.09	0.93	1.25	1.23	1.29
21	0.58	0.66	0.68	0.91	0.97	0.81	1.15	1.15	1.19
22	0.52	0.58	0.63	0.83	0.88	0.73	1.05	1.03	1.07
23	0.53	0.55	0.58	0.80	0.90	0.77	1.05	1.04	1.09
24	0.75	0.70	0.60	0.90	0.97	0.97	1.08	1.19	1.30

**Expressed as the ratio of the flux to the average flux in core which at 20 Mw was

1.24×10^{14} neutrons/cm² .sec.

Table 2.1.5 (Continued)

Distance From Top (in.)	Flux Measurements**								
	Core Positions								
	C-6	C-7	D-1	D-2	D-3	D-5	D-7	D-8	D-9
1	0.50	0.68	0.36	0.66	0.58	0.45	0.56	0.60	0.49
2	0.48	0.57	0.31	0.55	0.53	0.53	0.49	0.51	0.44
3	0.58	0.63	0.36	0.61	0.66	0.70	0.61	0.59	0.49
4	0.76	0.76	0.41	0.71	0.81	0.92	0.78	0.68	0.55
5	0.94	0.91	0.47	0.78	0.95	1.10	0.95	0.75	0.61
6	1.11	1.06	0.51	0.88	1.07	1.24	1.07	0.85	0.68
7	1.24	1.18	0.56	0.96	1.16	1.33	1.17	0.93	0.73
8	1.33	1.27	0.79	1.01	1.23	1.42	1.26	1.00	0.78
9	1.43	1.37	0.65	1.09	1.33	1.47	1.33	1.04	0.83
10	1.51	1.47	0.68	1.10	1.38	1.55	1.40	1.07	0.86
11	1.55	1.51	0.70	1.13	1.40	1.60	1.45	1.10	0.87
12	1.60	1.55	0.70	1.14	1.44	1.61	1.47	1.12	0.87
13	1.60	1.58	0.73	1.17	1.43	1.62	1.48	1.11	0.90
14	1.62	1.55	0.72	1.17	1.43	1.61	1.47	1.07	0.88
15	1.60	1.54	0.71	1.13	1.42	1.59	1.45	1.05	0.86
16	1.55	1.51	0.68	1.10	1.40	1.54	1.41	1.01	0.85
17	1.50	1.47	0.66	1.08	1.32	1.48	1.35	0.98	0.80
18	1.42	1.37	0.64	0.92	1.25	1.36	1.30	0.91	0.76
19	1.37	1.28	0.59	0.91	1.17	1.28	1.21	0.84	0.71
20	1.22	1.16	0.55	0.86	1.06	1.16	1.12	0.75	0.66
21	1.15	1.06	0.51	0.77	0.95	1.04	1.03	0.66	0.59
22	1.02	0.91	0.46	0.70	0.83	0.94	0.93	0.59	0.53
23	0.94	0.88	0.41	0.65	0.86	0.93	0.90	0.57	0.54
24	1.12	1.08	0.41	0.71	1.05	1.27	0.95	0.65	0.68

Table 2.1.5 (Continued)

Distance From Top (in.)	Flux Measurements**								
	Core Positions								
	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9
1	0.44	0.60	0.66	0.73	0.68	0.73	0.60	0.76	0.40
2	0.34	0.51	0.55	0.73	0.68	0.73	0.53	0.60	0.36
3	0.36	0.58	0.64	0.86	0.80	0.86	0.61	0.64	0.40
4	0.41	0.66	0.75	1.05	0.95	1.05	0.74	0.75	0.46
5	0.46	0.76	0.84	1.23	1.06	1.23	0.86	0.86	0.52
6	0.52	0.84	0.95	1.38	1.07	1.38	0.99	0.96	0.56
7	0.57	0.91	1.05	1.52	1.17	1.52	1.09	1.07	0.63
8	0.60	0.98	1.11	1.64	1.26	1.64	1.18	1.15	0.65
9	0.64	1.03	1.22	1.72	1.32	1.72	1.25	1.23	0.68
10	0.66	1.05	1.28	1.83	1.40	1.83	1.34	1.27	0.70
11	0.69	1.07	1.33	1.85	1.46	1.85	1.35	1.32	0.71
12	0.70	1.08	1.36	1.90	1.50	1.90	1.40	1.36	0.73
13	0.70	1.10	1.34	1.87	1.46	1.87	1.42	1.37	0.71
14	0.71	1.08	1.35	1.87	1.48	1.87	1.40	1.33	0.70
15	0.70	1.05	1.33	1.87	1.44	1.87	1.42	1.33	0.69
16	0.68	1.03	1.27	1.78	1.43	1.78	1.36	1.30	0.64
17	0.66	0.97	1.22	1.70	1.36	1.70	1.32	1.23	0.63
18	0.63	0.92	1.15	1.60	1.27	1.60	1.26	1.16	0.58
19	0.59	0.83	1.07	1.50	1.17	1.50	1.17	1.10	0.53
20	0.54	0.73	0.96	1.36	1.08	1.36	1.05	1.00	0.48
21	0.48	0.66	0.87	1.19	0.96	1.19	0.94	0.89	0.42
22	0.43	0.58	0.78	1.07	0.88	1.07	0.83	0.82	0.37
23	0.39	0.62	0.78	1.05	0.93	1.05	0.76	0.87	0.34
24	0.37	0.75	0.93	1.08	1.23	1.08	0.90	1.09	0.40

Table 2.1.5 (Continued)

Distance From Top (in.)	Flux Measurements**			
	Shim Rods			
	B-4	B-6	D-4	D-6
1				
2				
3				
4				
5				
6				
7	1.32	1.30	1.50	1.47
8	1.11	1.09	1.31	1.28
9	1.13	1.12	1.41	1.32
10	1.18	1.18	1.45	1.40
11	1.24	1.27	1.52	1.43
12	1.26	1.32	1.61	1.49
13	1.26	1.32	1.63	1.50
14	1.25	1.33	1.69	1.50
15	1.24	1.30	1.67	1.48
16	1.20	1.28	1.64	1.44
17	1.16	1.24	1.56	1.40
18	1.08	1.18	1.50	1.37
19	1.02	1.11	1.42	1.31
20	0.92	1.01	1.31	1.18
21	0.83	0.91	1.18	1.10
22	0.75	0.81	1.08	0.96
23	0.65	0.74	0.95	0.85
24	0.56	0.67	0.86	0.78
25	0.48	0.60	0.78	0.72
26	0.39	0.49	0.70	0.61
27	0.31	0.39	0.56	0.48
28	0.23	0.28	0.44	0.35
29	0.16	0.18	0.31	0.23
30	0.14	0.16	0.25	0.18

Table 2.1.6

Thermal Neutron Flux Measurements in Cycle III Core (9-17-58)

Distance From Top (in.)	Flux Measurements***								
	Core Positions								
	A-4	A-5	A-6	B-3	B-5	B-7	C-3	C-4	C-5
1	0.19	0.21	0.19	0.31	0.24	0.28	0.43	0.29	0.29
2	0.16	0.15	0.15	0.24	0.21	0.22	0.38	0.27	0.28
3	0.19	0.18	0.16	0.28	0.22	0.24	0.40	0.31	0.34
4	0.22	0.19	0.19	0.32	0.28	0.28	0.47	0.35	0.41
5	0.25	0.24	0.24	0.40	0.32	0.34	0.57	0.44	0.52
6	0.31	0.29	0.22	0.47	0.41	0.40	0.68	0.52	0.59
7	0.37	0.34	0.25	0.54	0.47	0.47	0.78	0.62	0.68
8	0.41	0.40	0.31	0.62	0.54	0.54	0.90	0.72	0.82
9	0.46	0.47	0.34	0.71	0.66	0.62	1.05	0.82	0.96
10	0.54	0.53	0.44	0.81	0.81	0.71	1.16	1.00	1.10
11	0.62	0.60	0.50	0.91	1.03	0.75	1.25	1.15	1.33
12	0.71	0.68	0.56	1.02	1.33	0.85	1.41	1.43	1.50
13	0.78	0.77	0.63	1.08	1.50	0.97	1.55	1.69	1.69
14	0.85	0.84	0.69	1.19	1.62	1.09	1.68	1.77	1.83
15	0.90	0.88	0.74	1.25	1.68	1.16	1.80	1.91	1.96
16	0.90	0.91	0.78	1.30	1.69	1.22	1.77	1.94	2.06
17	0.91	0.96	0.81	1.31	1.71	1.22	1.89	2.02	2.12
18	0.91	0.93	0.81	1.28	1.66	1.25	1.83	1.97	2.06
19	0.87	0.90	0.80	1.30	1.66	1.22	1.72	2.00	1.94
20	0.80	0.87	0.81	1.19	1.52	1.21	1.63	1.84	1.86
21	0.77	0.78	0.78	1.10	1.44	1.12	1.43	1.68	1.83
22	0.69	0.75	0.74	1.02	1.33	1.05	1.35	1.58	1.50
23	0.78	0.74	0.82	1.10	1.41	0.97	1.41	1.63	1.55
24	1.09	1.03	0.85	1.28	1.58	1.10	1.71	1.89	2.16

***Expressed as the ratio of the flux to the average flux in the core, which at 20 Mw was 1.12×10^{14} neutrons/cm². sec.

Table 2.1.6 (Continued)

Distance From Top (in.)	Flux Measurements***								
	Core Positions								
	C-6	C-7	D-1	D-2	D-3	D-5	D-7	D-8	D-9
1	0.34	0.40	0.29	0.44	0.35	0.28	0.43	0.56	0.37
2	0.27	0.32	0.22	0.37	0.31	0.25	0.37	0.47	0.27
3	0.32	0.34	0.25	0.44	0.35	0.29	0.41	0.49	0.28
4	0.38	0.43	0.31	0.52	0.44	0.37	0.53	0.57	0.32
5	0.46	0.49	0.35	0.60	0.53	0.43	0.62	0.68	0.37
6	0.54	0.54	0.40	0.71	0.60	0.50	0.74	0.77	0.43
7	0.66	0.68	0.44	0.82	0.68	0.57	0.84	0.87	0.47
8	0.75	0.75	0.50	0.93	0.77	0.66	1.00	1.00	0.52
9	0.90	0.88	0.56	1.02	0.88	0.74	1.09	1.10	0.57
10	1.00	1.02	0.60	1.13	1.00	0.87	1.27	1.22	0.63
11	1.21	1.18	0.63	1.24	1.18	1.06	1.35	1.31	0.66
12	1.41	1.38	0.69	1.30	1.30	1.37	1.49	1.37	0.69
13	1.66	1.53	0.72	1.37	1.53	1.77	1.69	1.44	0.71
14	1.83	1.69	0.72	1.47	1.71	2.08	1.78	1.46	0.75
15	1.97	1.78	0.74	1.41	1.78	2.12	1.89	1.49	0.75
16	2.05	1.87	0.72	1.47	1.84	2.15	1.93	1.49	0.75
17	2.11	1.83	0.71	1.46	1.83	2.19	1.90	1.46	0.71
18	2.08	1.81	0.69	1.43	1.78	2.19	1.87	1.38	0.66
19	1.99	1.78	0.65	1.38	1.71	2.14	1.81	1.31	0.63
20	1.89	1.62	0.62	1.28	1.61	2.05	1.68	1.19	0.59
21	1.68	1.53	0.56	1.16	1.41	1.87	1.55	1.12	0.53
22	1.52	1.40	0.52	1.03	1.28	1.68	1.37	0.99	0.50
23	1.44	1.55	0.53	0.97	1.22	1.58	1.25	1.08	0.65
24	1.90	1.81	0.57	1.16	1.63	1.71	1.46	1.24	0.77

Table 2.1.6 (Continued)

Distance From Top (in.)	Flux Measurements***								
	Core Positions								
	E-1	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9
1	0.29	0.46	0.44	0.43	0.40	0.43	0.43	0.46	0.38
2	0.21	0.40	0.41	0.37	0.32	0.37	0.38	0.40	0.27
3	0.24	0.43	0.46	0.43	0.38	0.44	0.43	0.44	0.28
4	0.29	0.50	0.54	0.52	0.46	0.50	0.50	0.54	0.32
5	0.32	0.62	0.63	0.60	0.53	0.60	0.60	0.63	0.37
6	0.37	0.69	0.75	0.69	0.62	0.71	0.71	0.75	0.43
7	0.43	0.81	0.85	0.80	0.71	0.82	0.81	0.84	0.46
8	0.44	0.91	0.99	0.93	0.81	0.93	0.91	0.96	0.50
9	0.50	1.02	1.12	1.05	0.91	1.10	1.02	1.05	0.54
10	0.52	1.10	1.19	1.16	1.03	1.19	1.16	1.15	0.57
11	0.57	1.22	1.30	1.28	1.13	1.35	1.25	1.21	0.60
12	0.59	1.30	1.41	1.49	1.28	1.50	1.34	1.30	0.63
13	0.60	1.40	1.53	1.58	1.40	1.63	1.40	1.35	0.65
14	0.62	1.49	1.56	1.78	1.50	1.74	1.46	1.43	0.69
15	0.62	1.58	1.62	1.80	1.59	1.84	1.55	1.43	0.71
16	0.62	1.59	1.63	1.86	1.66	1.81	1.55	1.47	0.69
17	0.60	1.55	1.61	1.87	1.62	1.89	1.55	1.37	0.71
18	0.57	1.50	1.53	1.77	1.59	1.80	1.53	1.35	0.65
19	0.54	1.41	1.46	1.71	1.56	1.68	1.46	1.28	0.63
20	0.50	1.33	1.33	1.56	1.44	1.58	1.38	1.16	0.62
21	0.44	1.21	1.21	1.40	1.31	1.43	1.27	1.06	0.54
22	0.41	1.10	1.08	1.30	1.21	1.33	1.10	0.91	0.52
23	0.43	1.18	1.12	1.40	1.28	1.30	1.03	0.94	0.44
24	0.57	1.24	1.41	1.68	1.58	1.74	1.21	1.18	0.84

Table 2.1.6 (Continued)

Distance From Top (in.)	Flux Measurements***									
	Reflector Positions						Shim Rods			
	F-1	F-2	F-4	F-6	F-8	F-9	B-4	B-6	D-4	D-6
1	0.13	0.19	0.22	0.21	0.21	0.15				
2	0.19	0.27	0.31	0.29	0.28	0.22				
3	0.24	0.32	0.40	0.38	0.38	0.28				
4	0.29	0.40	0.49	0.47	0.44	0.32				
5	0.34	0.46	0.57	0.54	0.53	0.40				
6	0.40	0.54	0.66	0.66	0.62	0.43				
7	0.46	0.62	0.78	0.81	0.72	0.52				
8	0.53	0.74	0.93	0.90	0.82	0.60				
9	0.62	0.80	1.05	1.05	0.93	0.68				
10	0.69	0.88	1.19	1.19	1.03	0.75				
11	0.74	0.97	1.31	1.33	1.16	0.78				
12	0.80	1.08	1.49	1.46	1.25	0.88				
13	0.87	1.15	1.65	1.61	1.37	0.91				
14	0.91	1.25	1.75	1.81	1.46	1.00				
15	0.96	1.28	1.84	1.90	1.50	1.06	1.77	1.97	2.42	2.14
16	1.00	1.37	1.99	2.05	1.56	1.06	1.47	1.40	2.03	1.77
17	1.03	1.38	2.05	2.14	1.62	1.10	1.50	1.33	2.08	1.71
18	1.03	1.43	2.14	2.19	1.66	1.10	1.46	1.35	2.09	1.74
19	1.03	1.40	2.19	2.25	1.66	1.12	1.47	1.31	1.96	1.68
20	1.03	1.41	2.16	2.24	1.62	1.09	1.40	1.24	1.91	1.62
21	1.02	1.38	2.15	2.30	1.59	1.08	1.30	1.16	1.78	1.50
22	0.94	1.28	2.08	2.19	1.56	1.00	1.19	1.08	1.58	1.37
23	0.90	1.22	1.90	2.05	1.43	0.91	1.12	0.99	1.41	1.22
24	0.82	1.13	1.81	1.89	1.31	0.87	1.05	0.91	1.28	1.13
25							0.97	0.85	1.22	1.03
26							0.82	0.75	0.99	0.84
27							0.63	0.62	0.75	0.62
28							0.44	0.43	0.52	0.46
29							0.27	0.27	0.31	0.27
30							0.15	0.15	0.18	0.18

Fig. 2.1.8. Thermal Neutron Flux Traverse for Position C-1.

Fig. 2.1.10. Thermal Neutron Flux Traverse for Position F-1.

Fig. 2.1.11. Thermal Neutron Flux Traverse for Position F-2.

Fig. 2.1.12. Thermal Neutron Flux Traverse for Position F-4.

Fig. 2.1.13. Thermal Neutron Flux Traverse
for Position F-6.

Fig. 2.1.14. Thermal Neutron Flux Traverse for Position F-8.

Fig. 2.1.15. Thermal Neutron Flux Traverse for Position F-9.

2.2 Flux Trap Tests

F. T. Binford

On September 15, and 16, 1958, two experiments were performed in the ORR for the purpose of observing the effect of a "flux trap" loading in the reactor.

The first experiment consisted of loading fuel in the form of a hollow square, five elements on a side, enclosing a square array of nine beryllium reflector pieces. One row of beryllium was placed around the outside of the fuel section and the entire loading was backed up by a minimum of three inches of water. Since only 29 pieces of beryllium were available, the four corners of the outer reflector were filled with water. This configuration is shown in Figure 2.2.1.

The central island, the beryllium in positions A-3, A-4, A-5, A-6, A-7, G-3, G-4, G-6, and G-7, the shim rods in B-4, B-6, F-4, and F-6, and the fuel in B-3, B-5, B-7, F-3, F-5, and F-7 were loaded initially. Fuel was then added symmetrically, two pieces at a time, to the other positions. When the fuel addition was completed, beryllium was added two pieces at a time in the 2 and 8 columns. Criticality was achieved prior to adding beryllium to positions D-2 and D-8. The rod positions were 24-in. Beryllium pieces were then added, one at a time, to positions D-2 and D-8 thus completing the square. The final rod positions were 21.5-in. when critical. The total mass was 2445-g and the critical mass is estimated to be 2200-g. The loading was quite symmetric. All fuel elements used ranged in U^{235} content between 155- and 168-g. Three of the shim rods contained approximately 100-g and the fourth one 130-g.

Core Configuration for Flux Trap Experiment No. 1.

Fig. 2.2.1

Flux measurements were made in one quadrant of the core by making vertical traverses using cobalt wires. Only measurements of thermal flux were made. Table 2.2.1 gives the results of these measurements. The relative flux figures given are based upon the average flux in the fuel taken as unity.

The flux in the island position, D-5, at a point 4-in. below the core centerline was found to be the maximum and was higher than the core average by a factor of 3.86. Based upon previous measurements of ORR cores this would represent a maximum flux of 7.6×10^{14} at 20 Mw for the case of the 2445-g core. A vertical section through the centerline of the core and a horizontal section through the point of maximum flux showing lines of constant flux is shown in Figure 2.2.2.

The second experiment consisted of removing the central beryllium piece (from position D-5) and allowing it to be replaced with water. The reactor remained critical but the rods were now at 26.6-in. The critical mass for this configuration, shown in Figure 2.2.3, was approximately 2400-g. It was necessary to add fuel in order to maintain criticality during the flux run, thus 200-g elements were put into positions B-5, F-5, D-3, and D-7, adding 130-g and preserving the symmetry. The reactor was critical with the rods at 23.6-in. and a total mass of 2575-g.

Again flux measurements were made in one quadrant, and it was found that the thermal flux in position D-5, the water hole, exceeded the fuel average by a factor of 3.99. This corresponds to a maximum thermal flux of 7.4×10^{14} at 20 Mw. The relative fluxes obtained are given in Table 2.2.2.

The maximum in this case occurred at a point 3-in. below the core centerline. Vertical and horizontal sections of the core through this maximum point are shown in Figure 2.2.4.

Table 2.2.1 Relative Fluxes in Flux Trap Experiment No. 1

Position*	Be						Fuel	Be
	C-4	C-5	C-6	D-4	D-5	D-6	D-7	D-8
1	2.046	2.354	2.054	2.401	2.997	2.401	1.411	1.393
2	2.206	2.487	2.203	2.586	3.120	2.526	1.232	1.481
3	2.279	2.622	2.241	2.872	3.316	2.696	1.255	1.598
4	2.478	2.823	2.581	2.998	3.558	2.827	1.316	1.730
5	2.520	2.973	2.626	3.121	3.673	2.930	1.419	1.855
6	2.666	3.023	2.775	3.221	3.792	3.182	1.489	1.880
7	2.673	3.119	2.801	3.226	3.767	3.126	1.580	1.932
8	2.699	3.122	2.821	3.216	3.862	3.074	1.603	1.976
9	2.761	3.196	2.769	3.226	3.743	3.074	1.628	1.892
10	2.603	2.997	2.652	3.143	3.640	2.951	1.640	1.880
11	2.511	2.871	2.621	3.025	3.540	2.835	1.630	1.800
12	2.399	2.748	2.425	2.919	3.418	2.702	1.606	1.754
13	2.266	2.582	2.254	2.676	3.148	2.463	1.557	1.605
14	2.114	2.366	2.075	2.476	2.948	2.188	1.516	1.534
15	1.905	2.059	1.881	2.275	2.581	2.041	1.420	1.409
16	1.697	1.856	1.567	1.954	2.347	1.803	1.259	1.229
17	1.432	1.567	1.327	1.794	1.963	1.544	1.186	1.125
18	1.192	1.294	1.079	1.515	1.714	1.297	1.046	0.950
19	0.949	1.083	0.901	1.264	1.407	1.117	0.936	0.829
20	0.784	0.895	0.761	1.081	1.186	0.939	0.824	0.697
21	0.628	0.720	0.619	0.898	0.963	0.756	0.680	0.598
22	0.510	0.581	0.490	0.733	0.761	0.621	0.564	0.482
23	0.393	0.449	0.392	0.584	0.585	0.463	0.484	0.395
24	0.290	0.331	0.297	0.429	0.429	0.313	0.620	0.259

*Position numbers refer to distance from bottom of the fuel bearing section in inches.

Table 2.2.1 (Continued)

Position*								Control	
	E-4	Be E-5	E-6	Fuel E-7	Be E-8	Fuel F-5	Rod F-6	Fuel F-7	Be F-8
1	2.272	2.473	2.015	1.056	1.292	1.217	0.104	0.921	1.072
2	2.399	2.666	2.261	0.945	1.792	0.845	0.169	0.819	1.159
3	2.548	2.909	2.501	0.986	1.523	0.892	0.272	0.793	1.210
4	2.711	2.974	2.614	1.080	1.607	0.966	0.387	0.866	1.310
5	2.837	3.103	2.688	1.168	1.741	1.108	0.511	0.918	1.359
6	2.897	3.244	2.796	1.228	1.753	1.177	0.620	0.979	1.396
7	2.974	3.302	2.873	1.342	1.774	1.248	0.706	1.043	1.426
8	2.944	3.168	2.806	1.366	1.788	1.331	0.792	1.078	1.427
9	2.898	3.171	2.776	1.407	1.758	1.366	0.901	1.101	1.430
10	2.778	3.035	2.749	1.388	1.746	1.384	0.998	1.168	1.368
11	2.625	2.979	2.698	1.431	1.711	1.350	1.097	1.158	1.353
12	2.452	2.707	2.518	1.384	1.635	1.327	1.215	1.133	1.273
13	2.282	2.570	2.331	1.328	1.501	1.303	1.238	1.079	1.191
14	2.140	2.427	2.151	1.286	1.414	1.234	1.296	1.048	1.088
15	1.908	2.165	1.928	1.189	1.254	1.104	1.339	0.990	0.955
16	1.656	1.848	1.674	1.099	1.166	1.022	1.370	0.873	0.880
17	1.376	1.534	1.389	0.987	1.009	0.972	1.371	0.808	0.776
18	1.107	1.296	1.129	0.882	0.875	0.829	1.330	0.706	0.688
19	0.935	1.062	0.894	0.784	0.732	0.653	1.258	0.628	0.559
20	0.755	0.881	0.774	0.666	0.648	0.477	1.227	0.510	0.483
21	0.630	0.720	0.650	0.561	0.535	0.372	1.177	0.438	0.395
22	0.507	0.576	0.517	0.459	0.451	0.284	1.271	0.342	0.323
23	0.393	0.460	0.408	0.422	0.353	0.231	1.623	0.291	0.253
24	0.279	0.315	0.300	0.571	0.250	0.278	1.709	0.352	0.174

Table 2.2.1 (Continued)

Position*	Be			Fuel		
	G-5	G-6	G-7	D-7 N	D-7 C	D-7 S**
1	1.131	1.092	0.949	1.223	1.411	1.363
2	1.208	1.172	1.036	0.828	1.232	1.158
3	1.314	1.236	1.104	0.845	1.255	1.208
4	1.405	1.352	1.167	0.981	1.316	1.296
5	1.481	1.383	1.248	1.079	1.419	1.483
6	1.514	1.465	1.248	1.177	1.489	1.610
7	1.538	1.472	1.283	1.292	1.580	1.656
8	1.514	1.490	1.284	1.385	1.603	1.761
9	1.475	1.491	1.227	1.430	1.628	1.830
10	1.465	1.420	1.288	1.464	1.640	1.879
11	1.384	1.361	1.147	1.459	1.630	1.844
12	1.270	1.251	1.102	1.482	1.606	1.903
13	1.186	1.159	1.013	1.407	1.557	1.805
14	1.061	1.073	0.910	1.332	1.516	1.730
15	0.898	0.918	0.811	1.288	1.420	1.703
16	0.785	0.761	0.693	1.211	1.259	1.569
17	0.632	0.629	0.568	1.123	1.186	1.454
18	0.484	0.452	0.477	1.046	1.046	1.310
19	0.382	0.361	0.388	0.920	0.936	1.135
20	0.298	0.280	0.313	0.789	0.824	1.007
21	0.239	0.215	0.256	0.656	0.680	0.835
22	0.183	0.164	0.196	0.561	0.564	0.674
23	0.140	0.117	0.150	0.495	0.484	0.606
24	0.094	0.088	0.109	0.586	0.620	0.709

**Three measurements designated north, center, and south were made in the fuel element in D-7.

Flux Trap Experiment No. 1.
Lines of Constant Thermal Neutron Flux.

Fig. 2.2.2

-148-

Core Configuration for Flux Trap Experiment No. 2.

Fig. 2.2.3

Table 2.2.2 Relative Fluxes in Flux-Trap Experiment No. 2

Position*	Be				H ₂ O	Be ¹	Fuel	Be
	C-4	C-5	C-6	D-4	D-5	D-6	D-7	D-8
1	1.862	2.096	1.854	2.343	2.886	2.151	1.445	1.327
2	2.075	2.197	2.010	2.471	3.099	2.304	1.055	1.425
3	2.286	2.421	2.210	2.648	3.386	2.525	0.850	1.637
4	2.368	2.603	2.453	2.786	3.567	2.770	0.978	1.699
5	2.450	2.747	2.459	2.948	3.682	2.864	1.121	1.829
6	2.423	2.781	2.599	3.031	3.892	2.890	1.213	1.875
7	2.660	2.962	2.667	3.113	3.944	2.929	1.278	1.971
8	2.595	2.897	2.796	3.204	3.881	3.109	1.364	2.017
9	2.558	2.944	2.638	3.010	3.988	2.858	1.320	1.013
10	2.611	2.844	2.599	3.038	3.753	2.859	1.390	1.990
11	2.486	2.763	2.602	3.011	3.694	2.779	1.367	1.953
12	2.352	2.650	2.449	2.680	3.483	2.670	1.429	1.824
13	2.295	2.466	2.331	2.619	3.235	2.594	1.393	1.689
14	2.090	2.310	2.131	2.338	2.932	2.420	1.428	1.589
15	1.928	2.101	1.944	2.163	2.636	2.158	1.323	1.478
16	1.775	1.911	1.766	1.896	2.362	1.906	1.199	1.267
17	1.527	1.641	1.468	1.709	1.952	1.675	1.063	1.164
18	1.249	1.384	1.223	1.489	1.678	1.450	1.027	1.060
19	1.036	1.144	0.989	1.219	1.431	1.060	0.841	0.919
20	0.840	0.885	0.754	1.008	1.150	0.995	0.770	0.786
21	0.663	0.738	0.617	0.853	0.882	0.852	0.637	0.673
22	0.538	0.602	0.498	0.658	0.652	0.671	0.508	0.543
23	0.387	0.442	0.358	0.518	0.441	0.504	0.584	0.401
24	0.305	0.308	0.286	0.328	0.266	0.369	0.301	0.300

*Position numbers refer to distance from bottom of the fuel bearing section in inches.

Table 2.2.2 (Continued)

Position*	Control								
	E-4	Be E-5	E-6	Fuel E-7	Be E-8	Fuel F-5	Rod F-6	Fuel F-7	Be F-8
1	1.870	2.249	1.979	1.156	1.287	1.044	0.123	2.453	1.105
2	2.266	2.307	2.171	0.835	1.428	0.810	0.134	0.683	1.189
3	2.310	2.599	2.331	0.866	1.547	0.859	0.190	0.712	1.320
4	2.454	2.817	2.502	0.982	1.680	0.958	0.305	0.862	1.395
5	2.637	2.831	2.615	1.149	1.764	1.047	0.416	0.891	1.461
6	2.749	3.051	2.734	1.240	1.818	1.177	0.510	1.020	1.559
7	2.755	3.080	2.906	1.362	1.854	1.188	0.645	1.127	1.547
8	2.800	3.112	2.877	1.404	1.912	1.236	0.729	1.117	1.542
9	2.852	3.073	2.892	1.437	1.874	1.286	0.830	1.149	1.536
10	2.780	3.086	2.683	1.542	1.830	1.274	0.940	1.207	1.499
11	2.685	2.939	2.640	1.529	1.882	1.328	1.049	1.194	1.500
12	2.537	2.802	2.504	1.533	1.768	1.231	1.135	1.181	1.424
13	2.523	2.608	2.376	1.475	1.593	1.260	1.171	1.156	1.350
14	2.251	2.355	2.286	1.406	1.477	1.194	1.293	1.106	1.259
15	2.046	2.075	1.979	1.365	1.353	1.090	1.311	1.046	1.103
16	7.790	1.918	1.755	1.295	1.207	1.037	1.288	0.996	1.004
17	1.575	1.600	1.623	1.197	1.102	0.900	1.351	0.909	0.884
18	1.304	1.364	1.290	1.019	0.965	0.810	1.346	0.805	0.787
19	1.042	1.139	1.027	0.936	0.818	0.708	1.266	0.708	0.642
20	0.828	0.881	0.849	0.840	0.716	0.570	1.229	0.570	0.583
21	0.714	0.741	0.656	0.700	0.601	0.390	1.192	0.483	0.487
22	0.609	0.545	0.530	0.571	0.501	0.322	1.099	0.381	0.385
23	0.464	0.439	0.429	0.483	0.382	0.251	1.016	0.332	0.291
24	0.310	0.310	0.284	0.649	0.247	0.311	1.355	0.443	0.192

Table 2.2.2 (Continued)

Position*	G-5	G-6	G-7	$\frac{N}{D-7^{**}}$	$\frac{C}{D-7^{**}}$	$\frac{S}{D-7^{**}}$
1	1.188	1.140	0.977	1.419	1.445	1.410
2	1.270	1.197	1.036	1.045	1.056	1.167
3	1.364	1.379	1.104	0.823	0.850	0.830
4	1.468	1.482	1.204	0.855	0.978	0.807
5	1.516	1.450	1.288	0.968	1.120	0.978
6	1.591	1.510	1.394	1.091	1.213	1.061
7	1.579	1.524	1.352	1.138	1.278	1.127
8	1.647	1.546	1.336	1.212	1.353	1.159
9	1.620	1.544	1.380	1.255	1.320	1.287
10	1.532	1.513	1.327	1.309	1.390	1.264
11	1.537	1.444	1.423	1.410	1.367	1.323
12	1.398	1.381	1.235	1.324	1.429	1.334
13	1.311	1.302	1.167	1.305	1.392	1.293
14	1.218	1.218	1.324	1.273	1.428	1.225
15	1.122	1.077	0.972	1.220	1.323	1.253
16	0.949	0.930	0.860	1.189	1.200	1.145
17	0.793	0.794	0.770	1.072	1.063	1.122
18	0.653	0.598	0.619	0.973	1.027	0.964
19	0.508	0.485	0.480	0.854	0.841	0.897
20	0.407	0.345	0.420	0.775	0.770	0.767
21	0.333	0.284	0.335	0.659	0.638	0.679
22	0.240	0.206	0.254	0.556	0.508	0.585
23	0.184	0.154	0.202	0.607	0.584	0.512
24	0.123	0.098	0.109	0.766	0.801	0.807

**Three measurements designated north, center, and south were made in the fuel element in D-7.

Flux Trap Experiment No. 2.
Lines of Constant Thermal Neutron Flux.

Fig. 2.2.4

It should be noted that in both of these experiments the core contained only about two-thirds as much fuel as the ORR operating core which presently achieves a maximum flux of 3.7×10^{14} . A regular ORR core loaded with only 2500-g of fuel, rather than the usual 4000-g, would yield a maximum flux of 5.5×10^{14} ; so that, if it is assumed that the peak-to-average ratios found are independent of core loading, the flux in these cases is improved by only a factor of about 1.4.

Further experiments are planned in order to determine the effect of varying the trap dimensions. There is, at present, sufficient beryllium available to examine traps containing four and six pieces of beryllium, respectively. If more beryllium can be made available, it is planned to investigate twelve- and fifteen-element traps. These results should give some indication of the relationship between the ratio of the average neutron path length in the trap to the slowing down length and the flux peaking at the center.

It is also planned to investigate the effect of heavier core loadings and of variation of metal-to-water ratio in the core on the flux peaking.

PART III

Taken from OPERATIONS DIVISION QUARTERLY REPORT

October - December, 1958, ORNL CF-58-12-147

OPERATIONS DIVISION

Quarterly Report

October - December 1958

SUMMARY

The trouble with spurious scrams at the ORR has been largely remedied by increasing the current on the magnets holding the shim rods and by some changes in the electronic circuits. During December only two spurious scrams occurred. Considerable amounts of air activity are observed in the ORR building for approximately a day after start up. A degasifier is being installed which should help this situation by removing argon from the water.

A new lattice arrangement was adopted at the ORR in which fuel elements at the north and south ends of the lattice are completely separated from the rest of the fuel by a row of beryllium. This arrangement appears to give higher flux in the large facilities.

Another set of flux trap experiments were done in the ORR with a 2 x 2, a 3 x 3, and a 3 x 5 beryllium island in the center. The 3 x 3 experiment was compared to a heavier 3 x 3 loading which might be used for operation. The heavier loading gave a somewhat lower value of the flux peaking than did the lighter loadings.

1. REACTOR OPERATIONS

W. R. Casto

1.1. Oak Ridge Research Reactor

The operating data for the ORR are given in Table 1.1.

TABLE 1.1 ORR OPERATIONS

Period October 1, 1958, through December 31, 1958

	This Quarter	Last Quarter	Year to Date*
Total energy, Mwd	1,216.48	797.8	2259.54
Average power, Mw/operating hour	19.43	18.0	
Time operating, %	68.0	48.2	
Unscheduled shutdowns, hr	44.783	82.99	
Regular shutdowns, hr	660.7	1,058.7	
Research shutdowns, hr	0.0	1.23	
Reactor inlet water temperature (av), °F	113.2	114.6	
Reactor exit water temperature (av), °F	120.8	122.0	
Pool inlet water temperature (av), °F	88.9	86.5	
Pool exit water temperature (av), °F	94.5	92.3	
Reactor water radioactivity (av), c/m/ml	27,003	22,087	
Pool water radioactivity (av), c/m/ml	1,359	712	
Reactor water resistivity (av), ohm-cm	841,000	844,200	
Pool water resistivity (av), ohm-cm	1,018,000	968,600	

*Continuous operation was not established until July. Prior to this date 254.26 Mwd of energy were accumulated during approach to power runs; therefore, completion of this column is unnecessary.

Operations

The Oak Ridge Research Reactor operated well during this quarter. It should be noted that the percent of operating time has increased from 48.2 to 68.

A new core configuration, Figure 1.1, was adopted in order to increase thermal and fast neutron fluxes in the large facilities and to reduce the core size.

Table 1.2 shows the cycles of operation.

TABLE 1.2. CYCLES OF OPERATION

Cycle No.	Date Began	Date Ended	Energy in Mwd
3	September 18	October 5	95.666*
4	October 11	November 2	380.957
5	November 7	November 30	451.535
6	December 13	December 28	288.325

*Accumulated October 1 through October 5--end of No. 3 cycle.

During a total operating time of 1502.517 hrs, 1216.48 Mwd of energy were accumulated this quarter.

Following the startup of cycles 4, 5, and 6, significant amounts of radioactivity were encountered inside the ORR building. This activity can be related to startup and operation during the time required to reach temperature equilibrium. The level of activity has been controlled by using the building roof fans. The degasifier which will be installed in the reactor water system should remove these gaseous activities and eliminate the problem.

Shutdowns

Four major shutdowns occurred during this quarter.

FIG. 1.1
RESEARCH ASSIGNMENTS AND
FUEL LOADING ON 12-31-58

October 5 through October 11. The reactor was at zero or low power for routine shutdown work, flux trap experiments, flux runs, experiment installations, and electrical and general maintenance.

A section of the 6 in. aluminum pool-cooling line, through the pipe chase wall, was replaced because of heavy corrosion.

November 2 through November 7. During this period routine shutdown work was completed. Maintenance work was continued on the installation of experiments.

Flux trap experiments were run November 3, 5, and 6.

A contractor began excavation of the pipe trench in the north section of the basement for the MSR high pressure water loop installation.

November 30 through December 13. Routine shutdown work, general maintenance, and experiment installation continued during this shutdown. Flux trap experiments and flux mapping for the new core arrangement were made. Tests on the forces acting on shim rods and magnets were completed.

December 28 through January 2. Installation of experiment equipment continued. This included shutter and collimator work on HB-1, insertion of the in-reactor section of the pneumatic tube in HB-4, insertion of the hydraulic tube for bracing and sizing in core position F-8, and tubing installation work in the reactor and center pools.

A summary of all shutdowns occurring this quarter is presented in Table 1.3.

TABLE 1.3. SHUTDOWN SUMMARY

Date	Duration (hr)	Remarks
Scheduled Shutdowns		
10-5 to 10-11	147.633	End of cycle No. 3 operation
11-2 to 11-7	115.016	End of cycle No. 4 operation
11-24	6.167	To change a depleted core
11-30 to 12-13	300.717	End of cycle No. 5 operation
12-17	11.167	Sample stuck in G.E. tube. Reactor shut down to remove the tube; xenon poisoning forced the reloading of the core
12-28 to 12-31	80.000	End of cycle No. 6 operation
	660.700	TOTAL
Unscheduled Shutdowns		
10-2	0.367	Dropped No. 6 rod, reason unknown
10-2	0.167	Dropped No. 3 rod, reason unknown
10-5	0.100	Reverse was caused by failure of No. 1 safety recorder
10-5	0.217	Dropped No. 3 rod, reason unknown
10-12	0.083	Dropped No. 6 rod, reason unknown
10-13	0.517	Dropped No. 3 rod, three times, reason unknown
10-17	0.333	Dropped No. 3 rod twice, reason unknown
10-17	15.250	Power outage (plant wide); emergency reloading of fuel was necessary
10-19	0.283	Dropped No. 3 rod twice
10-22	16.183	Dropped No. 3 rod; while trying to recover No. 4, 5, and 6 rods dropped. Magnet and clutch bad on No. 3 rod. Lead wire to No. 3 magnet shorted to ground causing damage to No. 3 magnet and electrical leads. Replaced by magnet and clutch from No. 1 rod drive.
11-1	10.100	Dropped No. 4 rod, reason unknown; xenon poisoning forced an emergency fuel reloading
11-10	0.217	Dropped No. 4 rod, reason unknown
11-10	0.150	Dropped No. 4 rod, reason unknown
11-16	0.333	Dropped No. 3 rod, reason unknown
11-21	0.133	Dropped No. 3 rod, reason unknown
11-22	0.150	Dropped No. 3 rod, reason unknown
12-20	0.083	Tube failure in No. 6 magnet amplifier
12-27	0.117	Dropped No. 6 rod, reason unknown
	44.783	TOTAL

The total down time, scheduled and unscheduled, was 705.483 hr.

An analysis of the causes of shutdowns for this quarter is given in Table 1.4.

TABLE 1.4, ANALYSIS OF ORR SHUTDOWNS

	Number	Total Downtime (hr)
Scheduled Shutdowns		
Regular, End of cycle	4	643.366
Regular, Mid-cycle	1	6.167
Isotope	<u>1</u>	<u>11.167</u>
Subtotal	6	660.700
Unscheduled Shutdowns		
Human error	0	
Instrument failure	17	29.533
Other equipment failure	<u>1</u>	<u>15.250</u>
Subtotal	18	44.783
TOTAL	24	705.483

Reactor Water System

A water-flow decay experiment was conducted at flows of 18,000 gpm, 12,000 gpm, and 6,000 gpm to determine the time-versus-flow relationship when a power failure at the pumps and motorized valves occurred. Results indicate that it requires 25 seconds for the flow rate to drop to 10% of the initial flow rate, see Figure 1.2.

The section of 6-in. aluminum line of the pool-cooling system which failed due to corrosion was removed and replaced with a new section. This new section was insulated in a similar manner, omitting the concrete grout at the points of

FIG. 1.2
ORR WATER FLOW RATE DECAY
DATA TAKEN 10-11-58 & 11-5-58

entry and departure through the concrete shield.

The drilling of core holes in the reactor shielding to drain water from the spaces around the aluminum water lines has been completed. A vacuum has been kept on these holes utilizing a temporary vacuum system. On several occasions the vacuum pump has been out of service for repairs, thereby preventing continuous operation. The permanent vacuum system is 95% complete and should be in service shortly after January 1, 1959.

Table 1.5. gives ORR demineralizer data.

Reactor Water Heat Exchangers

During cycles 4, 5, and 6, only six of the eight Trane heat-exchanger units were used. Failures in units 4 and 6 required removal of turbulators. These were removed from units 1 through 6 only since it was possible to operate with six units during the winter. Units 7 and 8 still contain turbulators, and negotiations are under way with the manufacturer to furnish a remedy for this.

On October 4, a leak was discovered in the No. 4 unit of the Trane air-cooled heat exchangers. The unit was taken out of service to await repair.

During the major shutdown following cycle 3 operation, units 4 and 6 were opened and inspected and the leaks repaired. Inspection of the tubes revealed that several in each section had been damaged by turbulator vibration. The decision was made to remove all turbulators from units 1 through 6 to prevent further tube damage. The leaking tubes were plugged to prevent further leakage. Units 1 through 6 will be used in this condition. Units 7 and 8 were left out of service and will remain so until a final decision is reached by the AEC and the Trane Company.

TABLE 1.5. ORR DEMINERALIZER DATA

Column	Run No.	Initiation Date	Termination Date	Throughput (gal)	Specific Resistance ohm-cm		Average c/m/ml	
					Influent	Effluent	In	Out
Pool Demineralizer								
Anion	2	7-29-58	10-16-58	8,266,358		1,400,000		78
Anion	3	10-17-58	12-22-58	7,841,830		1,467,000		80
Anion	4	12-22-58	In service	744,782		1,560,000		83
Cation	1	2-5-58	In service	29,552,348	1,018,000		818	190
Reactor Demineralizers								
S. Cation	1	2-21-58	In service	15,748,415	886,000		23,000	
S. Anion	1	2-21-58	In service	15,748,415			4,796	
S. Mixed-Bed	2	10-15-58	10-29-58	1,654,070		1,390,000	2,959	2,644
S. Mixed-Bed	3	11-16-58	12-8-58	2,258,955		1,268,450	2,623	2,512
S. Mixed-Bed	4	12-26-58	In service	808,310		1,545,000	4,884	4,027
N. Cation	1	1-13-58	12-26-58	10,411,165	797,000		29,192	
N. Anion	1	1-13-58	12-26-58	10,411,165			8,122	
N. Mixed-Bed	1	1-13-58	10-15-58	7,351,620		1,242,000		1,591
N. Mixed-Bed	2	10-29-58	11-16-58	1,535,160		1,325,000	3,399	2,767
N. Mixed-Bed	3	12-8-58	12-26-58	1,524,385		1,329,000	3,952	3,414

Pool Secondary Water System

The pool secondary cooling loop was in manual operation during cycles 3, 4, and 5. Manual control was necessary since the automatic control system has not proven operable.

The Instrument and Control Division has designed another method of automatic control utilizing an automatic pH control valve in the secondary water system. Installation work is in progress.

Routine checks for radioactivity in the secondary pool cooling water were negative.

ORR Water Analysis

Ionic analysis of the reactor and pool water are given in Table 1.6. At the time of sampling, the reactor had been operating at 20 Mw with a flow rate of 15,600 gpm for 9 days. The pool flow rate was 730 gpm. The flow through the reactor and pool demineralizers was approximately 67 gpm and 75 gpm, respectively.

TABLE 1.6. WATER ANALYSIS OF ORR WATER

Impurities	Quantity, ppm	
	Reactor	Pool
Al	< .05	< .05
Fe	< .05	< .05
Ni	< .05	< .05
Co	< .05	< .05
Pb	< .05	< .05
Si	2	< 0.1
OH ⁻ as CaCO ₃	3	3
pH	5.65	5.75
Specific Resistance	8.94 x 10 ⁵ ohm-cm	1.07 x 10 ⁶ ohm-cm
T.S.	4.4	2.1
Cr	< 10	< 10

TABLE 1.6. (Continued)

Impurities	Quantity, ppm	
	Reactor	Pool
Ca	< .05	< .07
Cl	< 1	< 1
Cu	< .05	< .05
Na	< .1	< .1

A special aluminum determination was performed and details of results are given in ORNL-CF-58-9-20, Aluminum Determination in Reactor Cool Water, by Emery and Leddicotte. Table I of this report lists the following information.

Sample				Aluminum Concentration g/ml
1.	ORR (Cooling)	6-5-68	05:30	$< 3 \times 10^{-9}$
2.	ORR (Cooling)	6-23-58	10:32	2.1×10^{-8}
3.	ORR (Pool)	6-23-58	10:32	2.6×10^{-8}
4.	ORR (Cooling)	6-24-58	08:40	2.9×10^{-8}

The results of the routine analysis of the cooling water for principal radioactive constituents are given in Table 1.7.

TABLE 1.7. REACTOR AND POOL WATER ANALYSIS

Constituent	Activity (d/m/ml)	
	Reactor	Pool
Na ²⁴	4.6×10^4	2.1×10^3
Np ²³⁹	~ 67	~ 18
I ¹³¹	~ 20	~ 3.4
Cd	0.02 µg/ml	0.002 µg/ml

Corrosion

Exposure of corrosion specimens representing the various types of metals used in the ORR water system is continuing on a long-range program.

Samples were removed from the reactor core on August 11 after 500 hours of exposure during which 7,582 Mwhr were accumulated. A total of 32 coupons were removed and weighed. Twenty-three (23) had corrosion rates greater than 1 mpy and three (alloys 61-S, 54-S, and 52-S) showed a corrosion rate of 4 mpy. Only two samples showed a corrosion rate of zero. Alloys 2-S and 3-S indicated rates of < 1 mpy.

A visual inspection of the tube bundle of the shell and tube heat exchanger was made during the week of November 3. Two holes were found in the tubes. Apparently they were caused by vibration of rocks which were found in the shell of the exchanger. The holes were repaired. Inspection of both the interior and the exterior of the tubes indicated that no serious corrosion problems exist. A corrosion control, recommended by the Nalcite Corporation, is being used in this system. This is based upon chromate and pH control.

Facility Changes

Facility changes which have been made during this quarter are listed in Table 1.8.

TABLE 1.8. FACILITY CHANGES

Facility	Date In	Date Out	Nature of Experiment	Division Sponsor
C-3	8-18	12-11	Samples for fast neutron exposure	Solid State
C-3	12-11	12-28	Flux monitor	Solid State
C-3	12-28		Samples for fast neutron exposure	Solid State

TABLE 1.8. (Continued)

Facility	Date In	Date Out	Nature of Experiment	Division Sponsor
F-8	12-5	12-9	Hydraulic tube	Operations
B-1		10-10	Exposure tube	Reactor Chemistry (G.E.)
B-1	11-6	12-7	Exposure tube	Reactor Chemistry (G.E.)
Pool side	12-3		Exposure tube	Operations
B-9	11-6	12-1	Flux monitors	Solid State
B-9	7-18	12-28	Exposure tube and contents (thermocouples and flux monitors)	Solid State
Pool side	10-9	12-29	Exposure tube	Physics
HB-1	12-29		Collimator plug	Physics
HB-3	12-12		Collimator plug	Physics
HB-4	12-12		Collimator plug	Physics
HB-5	12-12		Collimator plug	Physics
HN-3	12-29		Pneumatic tube	Analytical Chemistry, Chemistry
Pool side		10-27	Isotope irradiation	Isotopes
Pool side	10-29	11-2	Isotope irradiation	Isotopes

Reactor Controls

Mechanical. During the shutdown following cycle 5, a series of tests were conducted to determine the hydraulic forces exerted on the shim rods and the forces transmitted to the electromagnet. Results of the test indicated that the present magnets are not strong enough. The measured force on the magnet due to hydraulics is about 55 pounds. The release spring adds an additional 55 pounds of force. A new magnet has been designed based on these findings and is presently undergoing a series of tests.

A flexible piston section was installed on a shim rod and used in a series of tests in a special test stand to determine the criticality of alignment on the mechanical controls. It appears that with this type of piston, alignment tolerances specified on the original design may be less critical. Further development work is in progress.

While making pre-startup checks on the shim rod drive mechanism and magnets on December 12, a failure in the No. 3 drive rod release mechanism assembly occurred. The drive tube assembly was removed and replaced by a spare unit. Disassembly showed that the failure may have been due to an accumulation of foreign matter (chips, sand, etc.) in the region of the engagement head. Inspection of the parts and reassembly after clearing revealed no component damage. As a result of this failure, a periodic inspection of each assembly will be made.

The results of tests performed in the magnets to determine the release times are indicated in Table 1.13.

TABLE 1.13. MAGNET RELEASE TIME

Rod Number	Flow (gpm)	Magnet Current	Release Time (msec)	Rod Position	R. C.
3	18,000	60 ma	1.3	20 in.	No
4	18,000	60 ma	18	20 in.	No
5	18,000	60 ma	1.4	20 in.	No
6	18,000	60 ma	4.6	20 in.	No
3	18,000	80 ma	5.5	20 in.	No
4	18,000	80 ma	30	20 in.	No
5	18,000	80 ma	14	20 in.	No
6	18,000	80 ma	12	20 in.	No
3	18,000	80 ma	12.5	20 in.	Yes
4	18,000	80 ma	27	20 in.	Yes
5	18,000	80 ma	19	20 in.	Yes
6	18,000	80 ma	17	20 in.	Yes
3	18,000	80 ma	14	3 in.	Yes
4	18,000	80 ma	27	3 in.	Yes
5	18,000	80 ma	21	3 in.	Yes
6	18,000	80 ma	24	3 in.	Yes

Table 1.14. shows shim rod release times and drop times.

TABLE 1.14. SHIM ROD RELEASE AND DROP TIMES

Shim Rod	Drop Time (msec)	Release Time (msec)
Flow--18,000 gpm		
3	~ 320	18
4	~ 320	18
5	~ 320	21
6	~ 320	25
Flow--0 gpm		
3	~ 780	24
4	~ 780	24
5	~ 780	23
6	~ 780	29

Electronic. The Reactor Control Department has made modifications to the reactor control electronic circuitry in an effort to reduce the spurious scrams which were prevalent during early cycles of operation. Tests and checks performed indicate that the present magnet is about 40% short of holding force. To compensate for this the following modifications have been made:

1. The clutch switch has been wired in parallel with the seat switch, thereby permitting magnet current to remain on the magnet until both the clutch switch and seat switch are actuated. This will eliminate any possibility of faulty clutch switches.

2. Changes to Magnet Amplifiers.

(a) Silicon rectifiers were installed in the power supply.

This is expected to give longer life and more reliability.

(b) The V-7 (QA2) tube was replaced with two 5651 tubes.

Monitoring the output of the V-7 (QA2) tube for about two weeks indicated that it was unstable and was subject to spikes capable of scrambling. Under the same test, the 5651 tubes appeared to be free of spikes but subject to slight drifts.

(c) A 5651 tube was added in the bias circuitry for the V-6 tube to improve stability and spike conditions.

(d) To permit larger currents without raising the scram level excessively, the gain of the amplifier was increased by reducing negative feedback. This was done by using the amplifier in the exchange position and altering the feedback resistors. Reducing the feedback necessarily decreases the stability of the amplifier.

(e) Time constants in the order of 10 milliseconds were incorporated in the magnet and sigma amplifier.

3. Changes to Sigma Amplifier:

(a) Silicon rectifiers were installed in the power supply to give longer life and greater reliability.

(b) Silicon diodes were installed in the damping circuit to provide better current characteristics between N_L and N_F . This allows smaller change in magnet current between N_L and N_F power levels.

Reactor Control Department personnel are still closely observing the performance of the reactor instrumentation. Additional modifications will be made if necessary to completely eliminate the spurious scrams.

PART IV

Taken from OPERATIONS DIVISION QUARTERLY REPORT

January - March, 1959, ORNL CF-59-3-1

OPERATIONS DIVISION QUARTERLY REPORT

JANUARY - MARCH 1959

Summary

The ORR operated very well during the quarter. No scrams occurred due to experiment instrumentation, and the over-all operating time was 76.4%. Some trouble was experienced from gaseous radioactivity but the installation of a vacuum degasifier has reduced the radiation considerably. Improved standards on welding of experiment capsules are also being prepared to prevent releases from experiments. The effect on the neutron chambers of draining and filling the beam holes has been reduced to a safe level by adding gamma chambers in the control system and by limiting the portion of the hole which may be drained and filled to the collimator section.

1. REACTOR OPERATIONS

W. R. Casto

1.1. Oak Ridge Research Reactor

Operations

The operations data for the ORR are given in Table 1.1. Total operating time at the end of the quarter was 1,650.867 hr.

TABLE 1.1. ORR OPERATIONS

Period January 1, 1959, through March 31, 1959

	This Quarter	Last Quarter	Year to Date
Total energy, Mwd	1,315.4	1,216.48	1,315.4
Average power, Mw-operating hour	19.1	19.4	19.1
Time operating, %	76.4	68.0	76.4
Reactor water radioactivity, c/m/ml (av)	28,375	27,003	28,374
Pool water radioactivity, c/m/ml (av)	670	1,359	670
Reactor water resistivity, ohm-cm (av)	780,000	841,000	780,000
Pool water resistivity, ohm-cm (av)	950,000	1,018,000	950,000

A slight variation in core configuration, Figure 1.1, was made to determine the effect on neutron flux at HB-6.

The recent cycles of operation are shown in Table 1.2.

LEGEND

BROWNING - F-9
CUNNINGHAM - F-1
GENERAL ELECTRIC - F-2
HYDRAULIC TUBE - F-8
ISOTOPE - A-7, F-4, F-5, F-6, E-2*
McBRIDE - A-9, F-3
TRAUGER - A-1, A-2, B-1, B-2
WITTLES - C-3
WILSON - P-4, P-5
PLEASANTON - P-6
GCR - P-1 → 3, P-7 → 8

NOTE:
V-1 THRU V-10 ARE ACCESS HOLES
IN TOP COVER OF REACTOR VESSEL.

O.R.N.L. RESEARCH REACTOR
LATTICE PATTERN AND EXPERIMENT LOCATIONS

TEMPORARY ASSIGNMENT *

TABLE 1.2. CYCLES OF OPERATION

Cycle No.	Date Begun	Date Ended	Accumulated Energy (Mwd)
7	January 2	January 25	465.1
8	January 30	February 23	404.8
9	March 1	March 27	454.5

Radioactive Release

Significant amounts of radioactivity inside the ORR building were encountered during the beginning of cycles 7, 8, and 9. Effective use of the building ventilation system kept this activity at a permissible level, and during the shutdown on March 29 a capsule-type experiment in core position A-9 was found to be leaking fission gases. During the removal of this capsule from the reactor, so much radioactive gas was released that the building had to be evacuated for about one hour.

Experiment Instrumentation

Experiments in the ORR have given remarkably little trouble from instrument failure. This is due to a program, begun over a year ago, to prevent trouble from experiments similar to that which occurred at the LITR. In 1957 there were 100 shutdowns due to trouble at 11 experiment facilities at the LITR. An analysis of these indicated that the basic causes were: (1) use of nonstandard circuits in the safety instrumentation rather than proved standard circuits; (2) lack of standards for instrumentation; and (3) use of unreliable components.

To prevent excessive downtimes at the ORR, standard safety circuits were designed, a list of preferred instruments was prepared, and an engineer was appointed to review designs of experiment instrumentation. The results of this

program are shown in the lack of trouble at the ORR where no shutdowns this quarter were due to experiment instrumentation.

Shutdowns

Three major shutdowns occurred during this period.

January 25 through January 30. Routine shutdown work was completed.

Experiment equipment installation work continued in the pools and pipechase.

February 23 through March 1. Work performed included routine shutdown work; flux trap experiments; the installation of a modified plug in HB-2 and tests to determine effects on ionization chambers of draining this plug; and continuation of the experiment equipment installation work in the pools and pipechase.

March 29 through March 31. This shutdown (continued into next quarter) was scheduled for ten days to permit the GCR group to complete equipment installation and to install their experiment.

Table 1.3 lists the unscheduled shutdowns which occurred this quarter.

TABLE 1.3. UNSCHEDULED SHUTDOWNS

Date	Duration (hr)	Remarks
2-7	0.083	Dropped No. 5 rod, reason unknown
2-13	0.830	Dropped No. 6 rod, bad magnet amplifier
3-2	0.033	Instrument mechanic accidentally shorted wire in instrument
3-9	0.100	Maintenance man leaned against setback switch at C-1 experiment
3-16	6.917	While changing a relay, the control voltage line was broken, causing a $3N_1$ reverse. Since the rods could not be immediately withdrawn, xenon growth prevented start-up. A reloading of fuel was required.
	<u>7.963</u>	TOTAL

Table 1.4 gives an analysis of the causes of shutdowns for this quarter.

TABLE 1.4. ANALYSIS OF ORR SHUTDOWNS

	Number	Total Downtime (hr)
Scheduled Shutdowns		
Regular, end of cycle	4	386.300
Regular, mid-cycle	2	73.470
Research	<u>3</u>	<u>41.400</u>
Subtotal	9	501.170
Unscheduled Shutdowns		
Instrument failure	2	0.946
Human error	<u>3</u>	<u>7.017</u>
Subtotal	5	7.963
TOTAL	14	509.133

Water Systems

The reactor water system was operated under special conditions to permit the Trane Company to perform modifications on all eight units of the air-cooled heat exchangers. During most of this quarter, only five of the units were in service at any one time. Modifications, made at the Trane Company's expense, included the following: converting units from forced draft to induced draft; attaching all turbulators with special nozzles to prevent vibration and tube wear; and installing metal skirts for freezing protection. Efficiency and pressure drop tests are planned as soon as weather conditions permit.

A permanent vacuum system has been installed on the holes drilled through the reactor shielding to the major water lines. This replaced the temporary

system installed last summer to remove water from the concrete surrounding the aluminum water lines. Figures 1.2 and 1.3 show the location of holes drilled in the concrete shield to water lines. A constant vacuum of 17 to 20 inches of Hg is being maintained at all times. Checks on the condensate indicate a current rate of about 25 ml/hr. Most of this is probably due to inward leakage of building air.

The degasifier was placed in operation as a bypass unit on the reactor system in February. Gaseous analysis of reactor water indicating its effectiveness are indicated in Table 1.5.

TABLE 1.5. GASES IN ORR WATER

Gas	% of Volume	cc STP/Liter of Water
January 26, Before Degasifier Operation		
O ₂	0	0
H ₂	6.7 ±3	1.28
CO ₂	4.6 ±3	0.88
N ₂	88.7	16.9
March 4, After Degasifier Operation		
O ₂	18.5	1.29
H ₂	42.6	2.98
CO ₂	4.8	0.34
N ₂	34.1	2.39

Rechecks are being made to determine whether the O₂ and H₂ analyses are correct.

The air radioactivity in the reactor building decreased by a factor of

Fig. 1.2. Aluminum Pipe in ORR Structure. Stippling on pipes denotes portion embedded in concrete.

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PIPE NO.	I.P.S. (IN.)	PIPE MATERIAL	SCHED. NO. WALL THKS.	DESCRIPTION
101	24	54S-AI	0.313 IN. THKS.	REACTOR COOLING WATER RETURN MAIN
101	18	54S-AI	0.250 IN. THKS.	REACTOR COOLING WATER RETURN (S. SIDE)
102	18	54S-AI	0.250 IN. THKS.	REACTOR COOLING WATER RETURN (N. SIDE)
110	24	54S-AI	0.313 IN. THKS.	REACTOR COOLING WATER SUPPLY MAIN
110	18	54S-AI	0.250 IN. THKS.	REACTOR COOLING WATER SUPPLY (S. SIDE)
111	18	54S-AI	0.250 IN. THKS.	REACTOR COOLING WATER SUPPLY (N. SIDE)
112X	3	63ST-6-AI	SCHED. 40	DEMINERALIZER CROSSOVER LINE
114	4	63ST-6-AI	SCHED. 40	REACTOR DEMINERALIZER EFFLUENT LINE
137	2	AI		GAS REMOVAL LINE (S. SIDE)
138	2	AI		GAS REMOVAL LINE (N. SIDE)
201	6	63ST-6-AI	SCHED. 40	REACTOR POOL EFFLUENT CIRCULATION LINE (S. SIDE)
203	6	63ST-6-AI	SCHED. 40	REACTOR POOL INFLUENT CIRCULATION LINE (N. SIDE)
204	2	63ST-6-AI	SCHED. 40	STORAGE POOL DRAIN LINE
205	4	63ST-6-AI	SCHED. 40	STORAGE POOL FILL LINE
206	2	63ST-6-AI	SCHED. 40	STORAGE POOL DRAIN LINE
207	4	63ST-6-AI	SCHED. 40	STORAGE POOL FILL LINE
210	6	63ST-6-AI	SCHED. 40	POOL OVERFLOW TO RESERVOIR (S. SIDE)
219	6	63ST-6-AI	SCHED. 40	SUPPLY LINE FROM STORAGE TANKS
229	6	63ST-6-AI	SCHED. 40	POOL OVERFLOW TO RESERVOIR (N. SIDE)
230	2	63ST-6-AI	SCHED. 40	SPARE IN NORTH SIDE REACTOR POOL
231	4	63ST-6-AI	SCHED. 40	SPARE IN NORTH SIDE REACTOR POOL
232	2	63ST-6-AI	SCHED. 40	SPARE IN SOUTH SIDE REACTOR POOL
233	4	63ST-6-AI	SCHED. 40	SPARE IN SOUTH SIDE REACTOR POOL
401	2	63ST-6-AI	SCHED. 40	PLANT PROCESS WATER FOR EMERGENCY REACTOR COOLING
413	2	63ST-6-AI	SCHED. 40	DEMINERALIZED WATER FROM STORAGE TANK TO REACTOR SYSTEM
501	6	63ST-6-AI	SCHED. 40	RESERVOIR TANK OVERFLOW LINE TO RETENTION POND
A	2	63ST-6-AI	SCHED. 40	TWO GAS REMOVAL LINES
B	1½	63ST-6-AI	SCHED. 40	TWO FACILITY VENT LINES
C	1½	63ST-6-AI	SCHED. 40	BEAM HOLE OFF GAS LINE - ONE FOR EACH OF SIX HOLES
D	9⅛ ID	61ST-6-AI	3⅛ IN. THKS.	BEAM HOLE LINER - TOTAL OF SIX LINERS IN EAST SIDE
E	65 ID	61ST-6-AI	2 IN. THKS.	TWO LARGE FACILITY PLUG LINERS
F		AI		BOTTOM PLUG LINER
G	10	61ST-6-AI	SCHED. 60	TWO-5-FT 1-IN.-LONG SLEEVES FOR STAND PIPE
H	8	63ST-6-AI	SCHED. 40	18 ACCESS THIMBLES (9 S. SIDE-9 N. SIDE)
J	6	63ST-6-AI	SCHED. 40	8 ACCESS THIMBLES (W. SIDE)
K	1½	63ST-6-AI	SCHED. 40	FACILITY DRAIN LINES
L		AI	¼ IN. THKS.	1-FT.-SQ. × 4½-IN.-DEEP FILL LINE STRAINER BOX
M		AI	¼ IN. THKS.	8-IN.-SQ. × 4½-IN.-DEEP DRAIN LINE STRAINER BOX

Fig. 1.3. Legend for Aluminum Pipe (Shown on ORNL-LR-DWG. 34474) in ORR Structure.

about 2 following installation of the degasifier.

Reactor Controls

The effects upon neutron ionization chamber performance of draining or filling horizontal beam holes is under study. Tests indicate that the chamber currents can be varied by as much as a factor of five by filling or emptying a beam hole.

Four gamma chambers have been located in the pool adjacent to the reactor. They appear to be much less affected by beam changes than the neutron chambers; and work is continuing on adapting the gamma chambers to provide level safeties, supplementing the neutron level safety instruments

Ionization Currents vs. Beam Hole Environment

On March 1 a modified beam hole plug, Figure 1.4, was installed in HB-2 to study its effect on the neutron ionization chambers. The reactor was operated at power levels of 1.69 Mw, 3.38 Mw, and 4.9 Mw with the collimator section of the plug full and with it empty. Results of the test are given in Table 1.6. The percentage of change is an average of the readings at the three power levels and indicates the increase of chamber current with the plug empty.

TABLE 1.6. % INCREASE OF IONIZATION CHAMBER CURRENT
EMPTY VS. FULL

<u>Chamber</u>	<u>Percent</u>
No. 1 Safety	4.1
No. 2 Safety	3.9
No. 3 Safety	4.3
Log N	8.9
μ p Ammeter	3.1

Fig. 1.4. Typical Section Thru Modified Beam Hole Plug.

On April 16 the collimator section of the HB-4 beam hole plug was drained with the reactor operating at 20 Mw. No apparent change in ionization chamber currents was observed. Radiation readings taken at the exterior shielding are indicated in Table 1.7. A diagram of the beam hole, collimator, shutter, and shield is shown in Figure 1.5.

TABLE 1.7. RADIATION READINGS AT HB-4

Location	N_T (n/cm ² /sec)	N_F (mrep/hr)	$\frac{BX}{(mr/hr)}$
Shutter Open, Hole Drained			
Plug, east side	3000	30	60
Top	2500	18	110
North side	3000	1.5	60
South side	3000	11	100
Shutter Closed, Hole Empty			
Plug	Neg.	Neg.	0.2
Top	2500	18	10
North side	3000	1.5	60
South side	3000	11	100

Fig. 1.5. Typical Section Thru East Beam Hole Shielding.

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