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ORNL-TM-10

ORR OPERATIONS

FOR PERIOD APRIL 1960 TO APRIL 1961

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ORR OPERATIONS

FOR PERIOD APRIL 1960 TO APRIL 1961

By

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Oak Ridge, Tennessee
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PART I

Taken from OPERATIONS DIVISION QUARTERLY REPORT

April - June, 1960, ORNL CF-60-6-127

INTRODUCTION

The third year of operation of the Oak Ridge Research Reactor saw the successful conversion from an operating level of twenty megawatts to an operating power level of thirty megawatts. The new cooling system was completed early in July and thirty-megawatt operation began with cycle 27, July 29, after an extended shutdown for the conversion. Operating time reached a high of 82% during the last quarter of 1960, and the first quarter of 1961 had an operating time of 80% in spite of two major, bimonthly shutdowns and some additional down time to repair the ball-latch mechanisms on the shim rods.

The most notable addition to the experiment facilities was provided by the changes made in the south engineering test facility for the GCR test loops.

REACTOR OPERATIONS

AND RADIOACTIVE WASTES OPERATIONS

QUARTERLY REPORT

Summary

Preparations are almost complete for the conversion to the 30-Mw cooling system scheduled during the July shutdown. It is planned to change the south engineering test facility plug during this shutdown to provide space for a new experiment.

1. OAK RIDGE RESEARCH REACTOR

1.1. Operations

W. R. Casto

Operations

The ORR was operated during this period at a power level of 20 Mw until the beginning of cycle 24 in April. The power level was then reduced to 16 Mw due to high maximum ambient air temperature. Total operating time for the quarter was 1719.135 hours. The operations data for the quarter are given in Table 1.1.

TABLE 1.1. ORR OPERATIONS

Period April 1, through June 30, 1960

	This Quarter	Last Quarter	Year to Date
Total energy, Mwd	1204.3	1471.4	2675.7
Average power, Mw operating hour	16.8	19.9	18.4
Time operating, %	78.7	81.3	80.0
Reactor water radioactivity, c/m/ml (av)	16,279	20,942	18,611
Pool water radioactivity, c/m/ml	596	396	496
Reactor water resistivity, ohm-cm (av)	592,000	616,000	604,000
Pool water resistivity, ohm-cm (av)	776,000	805,000	791,000
Research samples	21	22	43
Radioisotope samples	110	116	226

The core configuration at the end of the quarter is indicated in Figure 1.1.

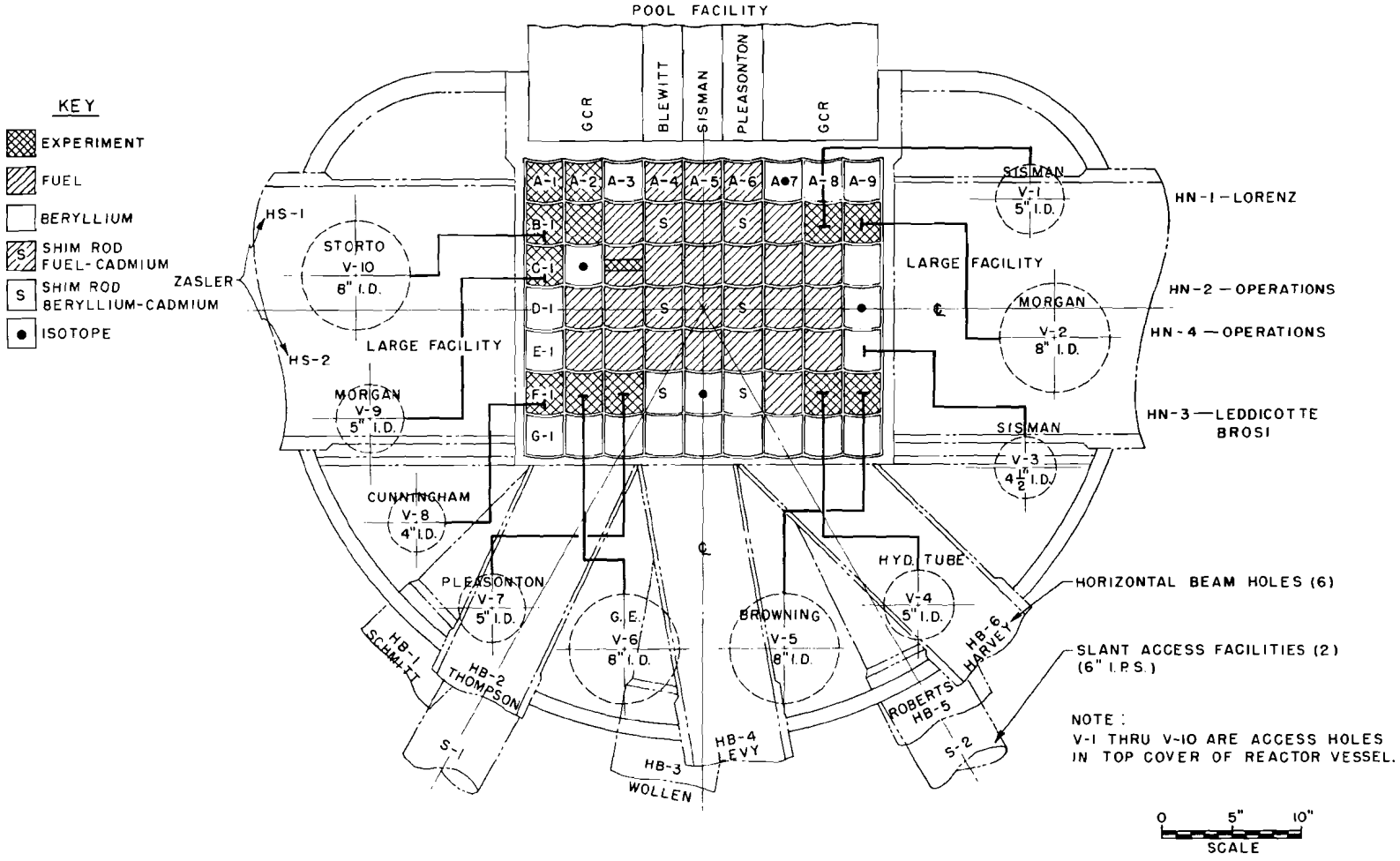

FIG. 1.1

O.R.N.L. RESEARCH REACTOR

LATTICE PATTERN AND EXPERIMENT LOCATIONS

RESEARCH ASSIGNMENTS 8
FUEL LOADING ON 6-30-60

C-33561

Cycles of operation during this period are shown in Table 1.2.

TABLE 1.2. CYCLES OF OPERATION

Cycle No.	Date Begun	Date Ended	Accumulated Energy (Mwd)
23	In progress	March 17	320.74
24	April 22	May 14	345.98
25	May 21	June 11	333.77
26	June 17	In progress	203.81

Figures 1.2, 1.3, and 1.4 indicate shim-rod positions versus the operating time during cycles 23, 24, and 25, respectively.

Shutdowns

Three major shutdowns occurred during this period.

April 17 through April 22. A shielding experiment was performed in conjunction with Neutron Physics Division and Health Physics Division personnel to determine the radiation level caused by an open beam at the south experiment facility. A report on this experiment is to be published by D. K. Trubey, T. V. Blosser, R. L. Clark, and H. V. Heacker. Measurements were taken with the reactor shut down and at 20 Mw. These data will be used in the design of shielding for EGCR He-cooled loop #2. A flux run was performed to map the fuel region. The radiation background with the pool water lowered required the use of temporary shielding on a section of one loop. In addition, the No. 3 drive tube was replaced with a modified unit utilizing a solid push rod.

May 14 through May 21. In-pool installation work on EGCR loop #1 continued. Radiation from sections of three other loops, with the pool water lowered, required the use of temporary lead shielding. A major revision of the layout of the control room panel board was begun in preparation for 30-Mw operation. Relocation of a portion of the existing equipment was completed. Tests were performed to determine the reactivity worth (see section 1.3) of beryllium-cadmium safety rods in core positions F-4 and F-6 as well as the resulting effect on flux distribution.

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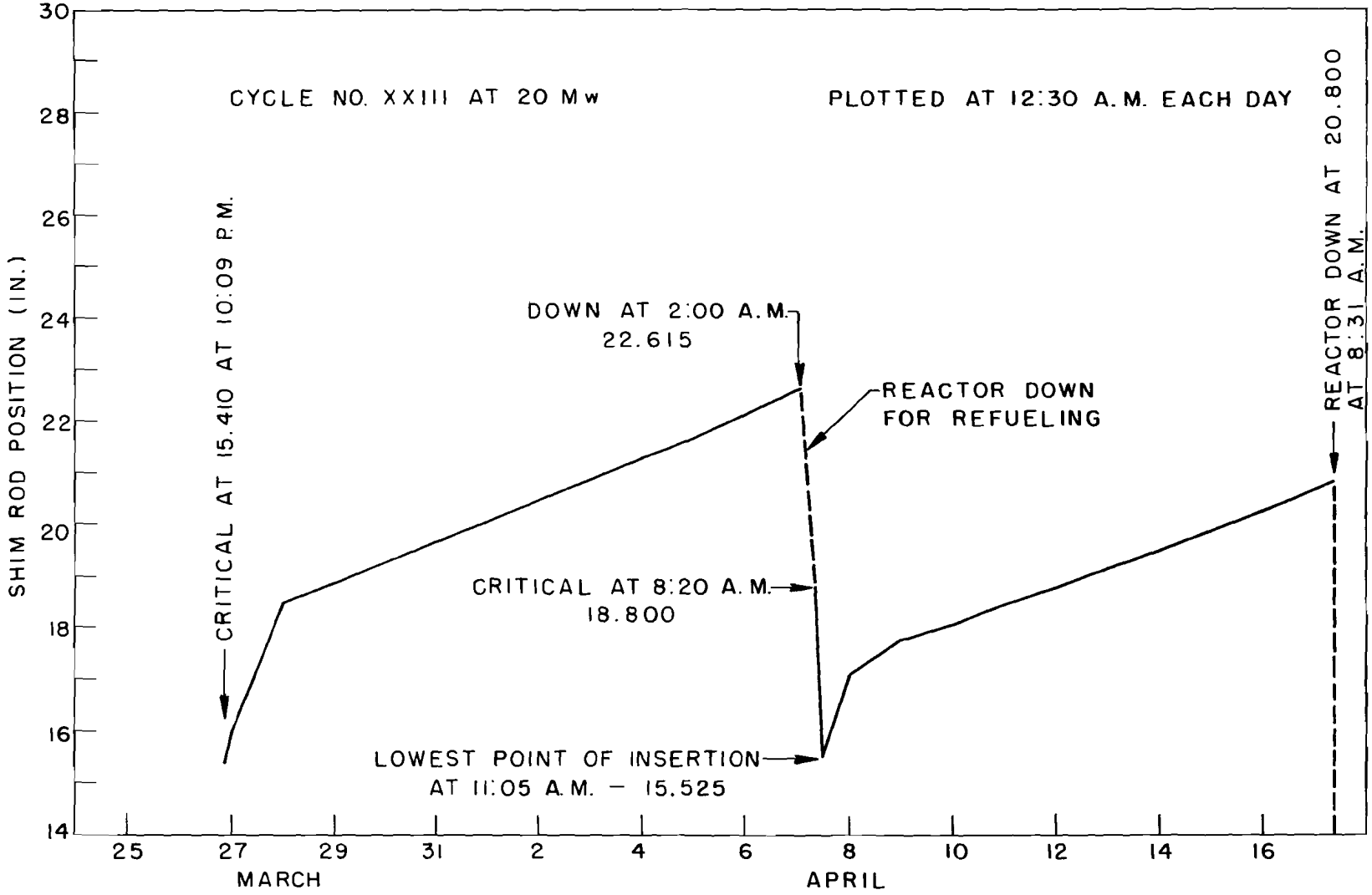

FIG. 1.2 – SHIM ROD POSITION VS. TIME

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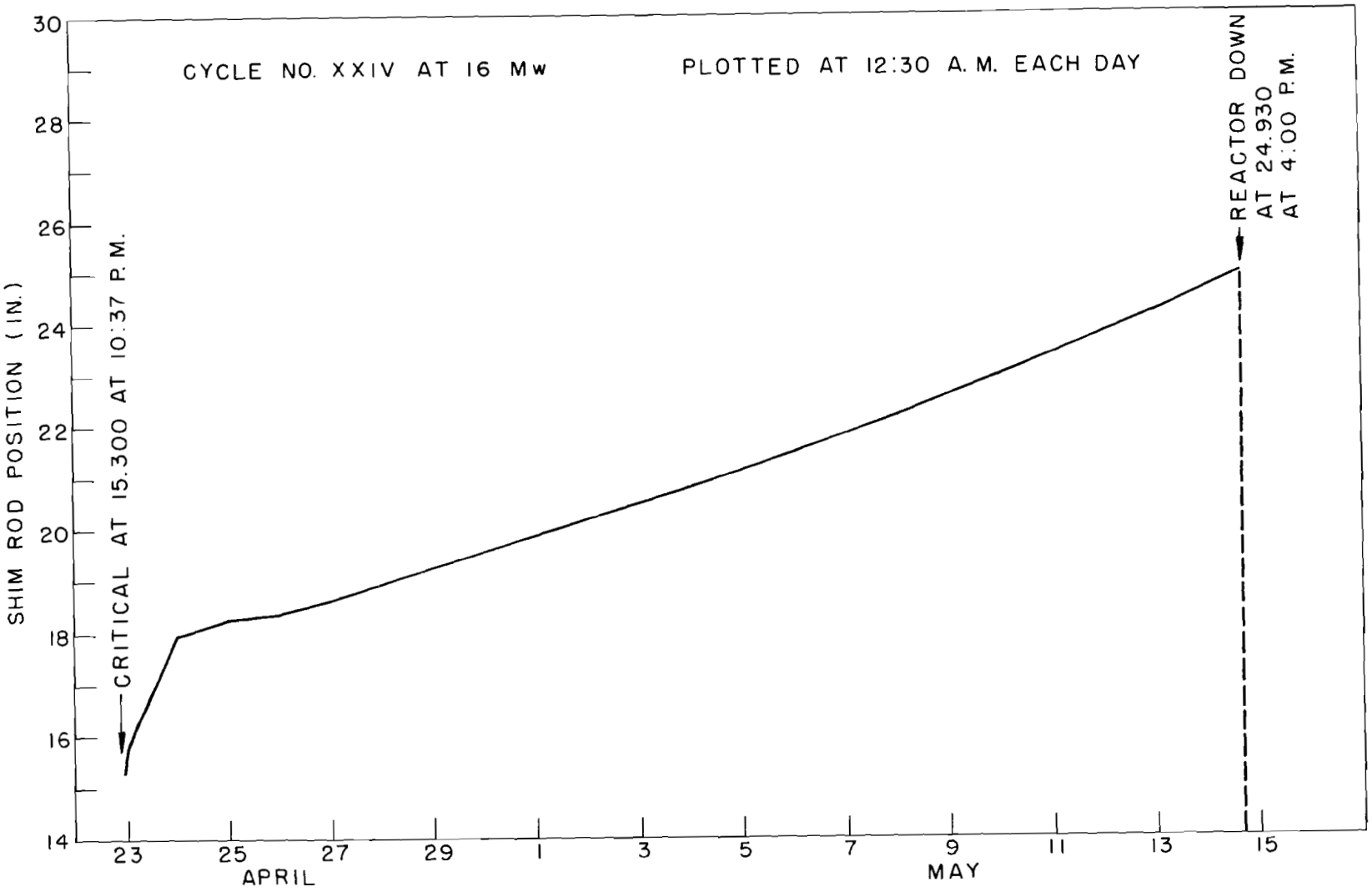

FIG. 1.3 – SHIM ROD POSITION VS. TIME

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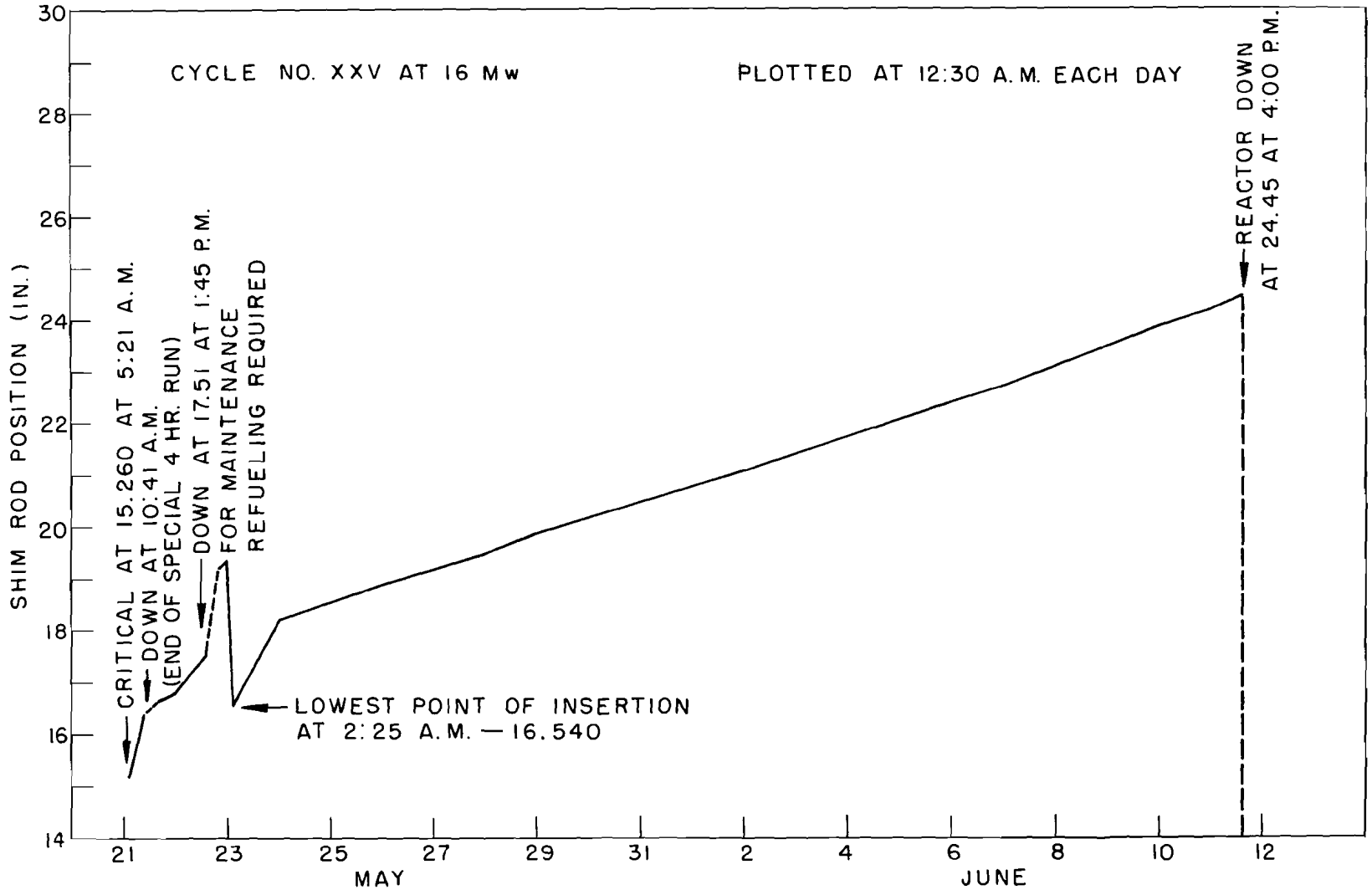

FIG. 1.4 — SHIM ROD POSITION VS. TIME

June 11 through June 17. Work on GCR loop #1 was continued. This included leak checks on in-pool lines and installation of an emergency by-pass line on the cooling-water pumps located on the south balcony, second level. A test was performed to determine the effect of replacing with a fuel element the beryllium piece (with isotope stringer insert) between the two beryllium-cadmium safety rods (see section 1.3).

Table 1.3 lists the unscheduled shutdowns which occurred this quarter.

TABLE 1.3. UNSCHEDULED SHUTDOWNS AT THE ORR

Date	Duration (hr)	Remarks
4-9-60	0.383	Setback from G.E. experiment (core position F-2). Thermocouple failure caused up-scale recorder "burnout".
4-23-60	0.200	Reverse from #3 safety while adjusting position for 16-Mw operation. Chamber inserted too rapidly.
4-25-60*	0.233	Setback and "back-up" reverse from G.E. experiment (CP F-2). Failure of air regulator caused high sample temperature.
4-26-60	0.167	Setback and "back-up" reverse from G.E. experiment (CP F-2). Thermocouple failure caused up-scale recorder "burnout".
5-3-60	0.317	Setback from Solid State's experiment (CP B-9). Thermocouple failure caused up-scale recorder "burnout".
6-8-60	0.133	Setback from MSR. An electronic tube burned out causing recorder to drive up scale.
6-22-60	0.550) 0.683)	A broken lead on S-2 contact of the E-panel resulted in the scram (drop out channel) causing a reactor shutdown when the power was cut off to GCRP-1 even though the E-panel switch was in the "test" position. The true cause of the shutdown was not discovered until the second shutdown.
6-23-60	0.550	Scram due to power outage, electrical storm. Startup delayed due to slow recovery of off-gas system vacuum.

*Shutdown due to real cause (i.e., where a condition existed such that without reactor power reduction an experiment and/or the reactor could be damaged).

TABLE 1.3. (Continued)

Date	Duration (hr)	Remarks
6-24-60	0.667	Scram due to power outage, electrical storm. Startup delayed due to blown fuses on primary cooling pump, motor-controlled valves.
6-24-60	0.300	Dropped No. 5 shim rod while increasing power after previous shutdown; unexplained.
6-24-60	0.333	Scram due to power failure which was caused by electricians switching from one breaker to another in the plant area.
6-24-60	9.583	Reactor had to be shut down due to heavy rainfall. The regular sump pump could not keep the water level down resulting in the flooding of pit and failure of transmitters for reactor inlet (coolant) temperature and reactor (coolant) flow information.
6-29-60	0.017	Setback from G.E. experiment (core position F-2). In attempting to replace a thermocouple on an "alarm only" circuit the wrong thermocouple plug was pulled.
6-29-60	0.217	Dropped No. 5 shim rod while increasing power after previous shutdown; unexplained.

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

TABLE 1.4. ANALYSIS OF ORR SHUTDOWNS

Description	Number	Down Time (hr)
Scheduled Shutdowns		
Regular, end of cycle	3	432.200
Regular, midcycle	1	6.333
Research	3	3.816
Maintenance, reactor tank cover	1	8.183
Subtotal	8	450.332

TABLE 1.4. (Continued)

Description	Number	Down Time (hr)
Unscheduled Shutdowns		
Instrument failure, reactor controls	2	0.517
Instrument failure, research	7	2.466
Power failure	3	1.550
Flooded instrument sump	1	9.583
Human error	2	0.217
Subtotal	15	14.333
TOTAL	23	464.865

Reactor Controls

A design error in the experiment tie-in circuit at the ORR was discovered. This defect caused two AC power-distribution circuits to be crossed under certain conditions through the experiment tie-in E-panels. To correct this condition the E-panels were modified slightly and their interconnecting wiring was changed.

To provide for extension of the process graphic panel for the new 30-Mw cooling system, most of the nuclear and process recorders in the ORR control panel were relocated.

In order to perform the test on the two additional beryllium-cadmium shim rods, it was necessary to make a temporary magnet-power supply installation consisting of two independent DC power supplies. The AC line supplying the power is connected to the "slow-scram" bus. Since the magnets are not in the "fast-scram" circuit, no credit is taken for the negative reactivity controlled by the new rods in determination of the excess reactivity of the reactor loading. Since the beginning of ORR operation, it has been an administrative procedure to operate the reactor with no less than two level safeties in use. In order to augment this procedure with an electronic control, the following changes were made in the safety system. Upon failure (or indicated failure) of one channel a "safety-trouble" annunciator is operated which cannot be cleared as long as the trouble persists. In order to annunciate the failure of a second channel a "two safety-troubles" annunciator is provided which is operated upon failure (or indicated failure) of two safety channels. A shim-rod reverse is initiated simultaneously.

The "E" family box on the south wall at the first floor was relocated to provide external access to the building as designed for GCR loop #2.

TABLE 1.5. MALFUNCTION OF REACTOR CONTROLS

Date	Description
4-19-60	No. 3 shim-rod magnet shorted due to a combination of the way the leads to the magnet and the magnet itself were installed, and it burned out. This prolonged the shutdown four hours.
4-16-60	Multipoint recorder for cooling water temperatures failed due to faulty connection to standard cell.
4-21-60	No. 2 safety recorder stuck due to worn section on fiber gear.
5-9-60	Log N spiked upscale and log-N period spiked to 15 sec. No other channels showed this; unexplained.
5-10-60	Broken wire in count-rate recorder; repaired.
5-24-60	Spasmodic positive and negative spikes were observed on log-N period recorder. The period amplifier was replaced.
5-26-60	Count rate and count-rate period signals were erratic. The A-1 amplifier and preamplifier were replaced.
5-27-60	The scaler in the fission-chamber circuit was replaced with a spare and repaired.
6-2-60	The count-rate period recorder stuck intermittently on an infinite period and later indicated a sustained positive period. The count-rate amplifier was calibrated and the trouble cleared.
6-5-60	Automatic pH controller for pool-cooling secondary loop failed due to acid corrosion of a solenoid valve.
6-22-60	A broken lead was discovered on S-2 contact of the E-panel resulting in GCRP-1 being in the safety circuit even though the E-panel switch was in "test" position.
6-24-60	Shim rod #5 dropped; unexplained.
6-29-60	Shim rod #5 dropped; unexplained.
6-29-60	Automatic pH controller for secondary loop for pool-cooling system failed due to acid corrosion of a solenoid valve.

TABLE 1.6. ORR FACILITY ASSIGNMENT

Facility	Access Flange	Nature of Experiment	Division Sponsor
A-1, A-2	V-11	Pressurized water loop, MSR	Reactor Projects
A-3, A-7, C-2, D-9, F-5		Radioisotope production	Isotopes
B-1, B-2	V-10	Gas-cooled loop	Reactor Projects
B-8, E-9, C-3	V-1, V-3	Irradiation damage studies	Solid State
B-9	V-2	Gas-cooled loop	Solid State
C-1	V-9	Fuel tests	Solid State
F-1	V-8	Solid fuel studies	Reactor Projects
F-2	V-6	Fuel tests	Reactor Projects (G.E.)
F-3	V-7	Ne^{23} studies	Physics
F-8	V-4	Hydraulic rabbit	Isotopes - Solid State
F-9	V-5	Fused-salt loop	Reactor Chemistry
P-1, 2, 3, 7, 8, and 9		EGCR capsule irradiations	Reactor Projects
P-4, P-5		Radiation damage studies	Solid State
P-6		He^6 studies	Physics
HN-1		Homogeneous fuel loop	REED
HN-3		Pneumatic rabbit for activation analysis	Chemistry - Analytical Chemistry
HN-2, HN-4			Operations
HS-1, HS-2		Gas-cooled loop	Reactor Projects
HB-1		Magnetic analysis of fission fragments	Physics
HB-2		Neutron spectrometer	Solid State
HB-3		Neutron spectrometer	Physics
HB-4		Neutron spectrometer	Chemistry
HB-5		Neutron spectrometer	Physics
HB-6		Time-of-flight spectrometer	Physics

A list of new experiments operated during the quarter is given in Table 1.7.

TABLE 1.7. NEW ORR EXPERIMENTS OPERATED

Date Installed	Division Sponsor	Expected Duration	Facility	Experiment Description
4-22-60	Solid State	3 cycles	P-5	Stress rupture
4-10-60	Solid State	Indefinite	B-9	Gas-cooled loop
5-14-60	Isotopes	Indefinite	C-2	Moved from F-4
5-14-60	Isotopes	Indefinite	D-9	Moved from F-6
5-14-60	Reactor Projects	2 cycles	A-1, A-2	MSR fuel test
6-16-60	Reactor Projects (G.E.)	1 cycle	F-2	Ceramic fuel test
6-24-60	Reactor Projects (G.E.)	1 cycle	B-1	Steel tensile specimen

Shown in Table 1.8 are the results of reactivity measurements of ORR experiments.

TABLE 1.8. EXPERIMENT REACTIVITY MEASUREMENTS

Experiment	Date	Facility	$\% \frac{\Delta k}{k}$	Remarks
Pressurized H_2O loop	9-9-59	A-1, 2	-0.107	Be replaced by experiment facility tube
			-0.135	Be replaced by experiment facility tube plus specimen
GCR Loop #1	1-27-61	B-1	-0.110	Be replaced by experiment facility tube
High-temperature Be irradiation	2-25-60	B-8	-0.140	Water replaced by experiment core piece plus experiment
Closed-cycle loop	4-58	B-9	-0.09	Be replaced by air-filled experiment facility tube
Fuel test	4-58	C-1	-0.35	Be replaced by air-filled experiment facility tube
Fuel test	6-20-60	F-2	+0.063	Water replaced by air-filled experiment facility tube
			-0.031	Fuel specimen inserted into facility tube

TABLE 1.8. (Continued)

Experiment	Date	Facility	$\% \frac{\Delta k}{k}$	Remarks
Ne^{23} experiment	3-24-60	F-3	+0.030	Water replaced by experiment tube plus experiment
EGCR capsule experiment		P-1, 2, 3, 7, 8, and 9	0.000	No detectable change on installing capsules
Radiation damage	3-1-59	P-4	-0.090	Water replaced by experiment box; P-5 experiment installed
Radiation damage	2-28-60	P-5	-0.135	Water replaced by experiment box; P-4 and P-6 empty
He^{6} recoil		P-6	-0.135*	(Estimated on basis of P-5 measurement)

*Maximum

1.2. ORR Start-up Accident Analysis

A. L. Colomb

Before raising the power of the ORR to 30 Mw, it was felt that an analysis of the start-up accident should be done. This analysis was carried out by R. S. Stone of the Instrumentation and Controls Division on the ORNL analog computer. A few results related to the operation of the reactor are reported here. A more detailed presentation of the analysis will be published in a CF memorandum.

Definition of the Start-up Accident

The start-up accident is, by definition, a situation in which the control rods are withdrawn from the reactor at their maximum speed and cannot be stopped. At the same time, the period meters or the period trips do not work.

The only protections left in the system are the safety level trips and the self-protecting effects due to temperature coefficient, void coefficient, etc.

ORR Simulator Block Diagram

The ORR was simulated on the analog computer by the system represented on Figure 1.5.

The nuclear network solves the reactor kinetic equations for the power with various reactivity inputs produced by the control-rod simulator. This simulator is used to introduce reactivity proportionally to the "S"-shaped control-rod calibration curve. When tripping the reactor it also simulates the delay due to the magnet release time and the rod's accelerated motion. Two feedback loops simulate temperature effect and safety level trip. The temperature feedback is sensitive to the amount of coolant flow, therefore a network solving the flow equations was added to this loop.

The boiling of the moderator was not included in the system. This implies that the results obtained are not valid when the metal temperature exceeds the moderator saturation temperature.

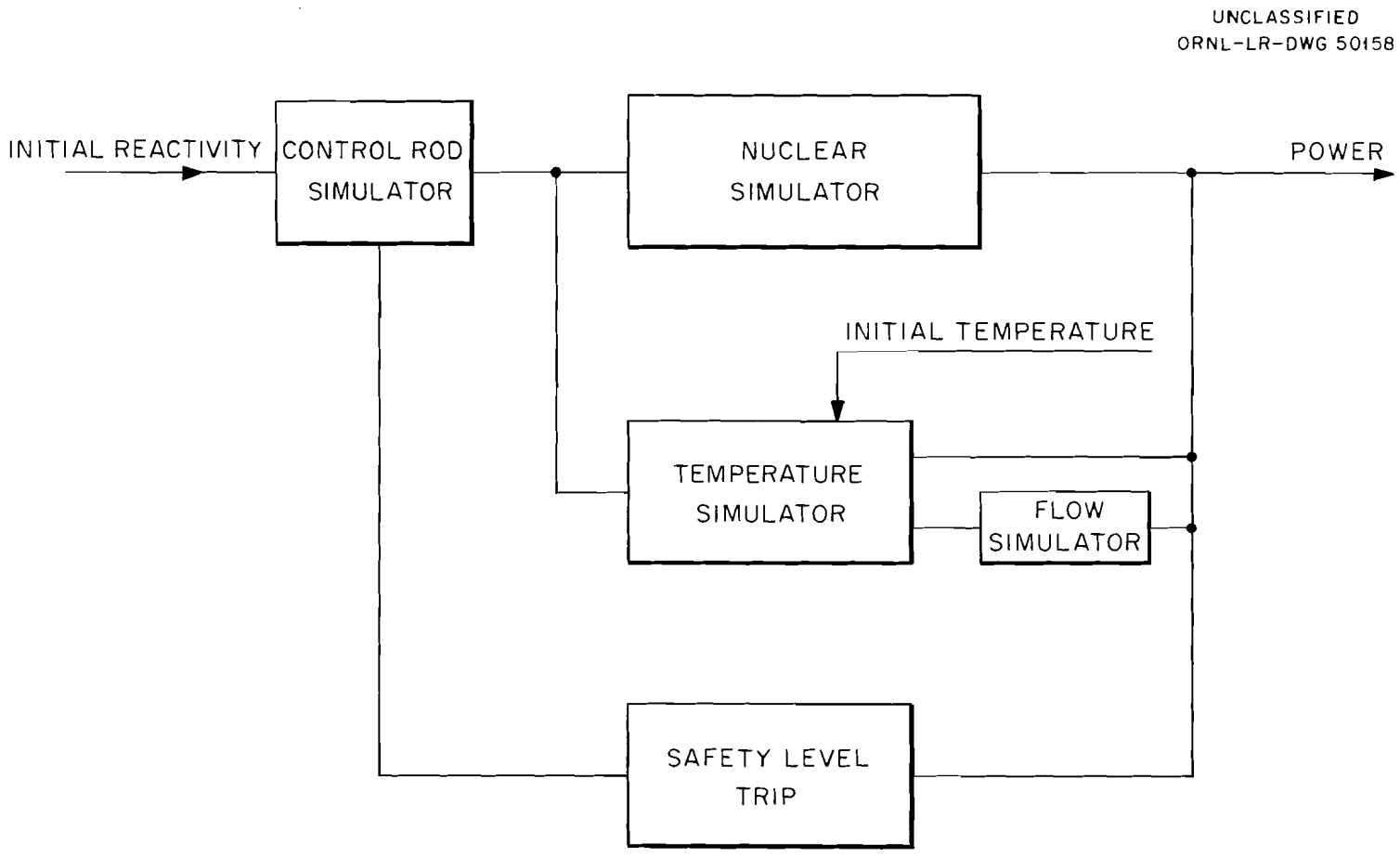

Fig. 1.5. ORR Simulator Block Diagram

ORR Data

Neutron generation time in the Be-reflected core

$$l^* = (6.4 \pm 0.6) \times 10^{-5} \text{ sec}$$

Total delayed neutron fraction

$$\beta = 0.00756 \pm 0.0008$$

Temperature effect

$$-\Delta k = 0.18 \times 6.6 \times 10^{-5}\ T_m \pm 0.82 \times 6.6 \times 10^{-5}\ T_w$$

Fraction of power generated in fuel

90%

Fraction of power generated in moderator

4.9%

Heat capacity of fuel

$$0.21\ \frac{\text{BTU}}{\text{lb °F}} \text{ or } 40.1\ \frac{\text{BTU}}{\text{°F}} \text{ for the core}$$

Heat capacity of moderator

$$1\ \frac{\text{BTU}}{\text{lb °F}} \text{ or } 108\ \frac{\text{BTU}}{\text{°F}} \text{ for the core}$$

Heat transfer coefficient between fuel and water

$$h = 120\ (1 + 0.012T)\ \frac{V^{0.84}}{D^{0.16}}$$

Safety level trip

150% of full power = 45 Mw

Magnet release time

25 msec

Control-rod acceleration

0.6 g

Source level

100 Mw

Initial negative reactivity

-0.5%

Results

The start-up accident was simulated for various reactivity ramp inputs with the control rods dropping from the corresponding height after the

level trip. Table 1.9 contains a summary of the results obtained with four different reactivity inputs. The initial temperature was 75°F and the coolant speed 30 ft/sec for the four cases.

These results show that with the safety level trip set at 45 Mw the ORR is always protected against a start-up accident as long as the coolant flow is not reduced below 20 ft/sec or 18,000 gpm.

The second and third columns are representative for the case of an accident happening during an emergency startup; that is, when because of xenon poisoning the reactor reaches criticality with the control rods withdrawn almost to the upper limit. Columns four and five show what is to be expected if an accident happens during a startup at the beginning of a cycle.

Another series of simulations were made with constant reactivity conditions, insertion ramp slope 0.1%/sec, and with various coolant speeds.

Figures 1.6 and 1.7 are plots of the power and the average metal temperature for various coolant speeds. It is important to notice that at flows smaller than 30 ft/sec, the excursion is not stopped by the safety level trips but by the temperature effect. Being in a start-up accident condition, the control rods will continue to move out of the core. If the coolant flow is large enough the flux will increase again and will trip the reactor when reaching the safety level. At low coolant flow, the flux will not increase to the safety level before an uncontrolled nucleate boiling situation is reached.

This situation is a complicated one, temperature will stay almost constant; thus, temperature effect will not cancel the reactivity inserted by the control rods. On the other hand, nucleate boiling will create some voids in the core and, therefore, introduce negative reactivity. The behavior of the reactor power under such conditions is difficult to foretell. Keeping in mind that criticality is very likely to be reached with the control rods at 15 inches so that the excess reactivity still available for insertion is about 15% $\Delta k/k$, it is reasonable to decide that the reactor has to be shut down.

TABLE 1.9. START-UP ACCIDENT WITH VARIOUS REACTIVITY INPUTS

	Reactivity: Ramp Slope = 0.025% Rods Drop From 28"	Reactivity: Ramp Slope = 0.05% Rods Drop From 26"	Reactivity: Ramp Slope = 0.1% Rods Drop in Linear Portion	Reactivity: Ramp Slope = 0.13% Rods Drop in Linear Portion
Time at 100 w	42 sec	23.17 sec	12.35 sec	9.61 sec
Time at 100 kw	47 sec	25.02 sec	13.13 sec	10.40 sec
Time at 45 Mw (trip)	49.9 sec	26.32 sec	13.69 sec	10.68 sec
Reactivity at 100 w	+0.55%	+0.658%	+0.735%	+0.75%
Reactivity at 100 kw	+0.675%	+0.751%	+0.813%	+0.853%
Reactivity at 45 Mw (trip)	+0.564%	+0.631%	+0.743%	+0.855%
Power at prompt critical			450 w	150 w
Period before temperature coefficient becomes noticeable	385 msec	140 msec	80 msec	44 msec
Peak power	46 Mw	47 Mw	50 Mw	76 Mw
Integrated power	>20 Mw·sec	>20 Mw·sec	10 Mw·sec	8.8 Mw·sec
Maximum average metal temperature	180°F	180°F	160°F	170°F

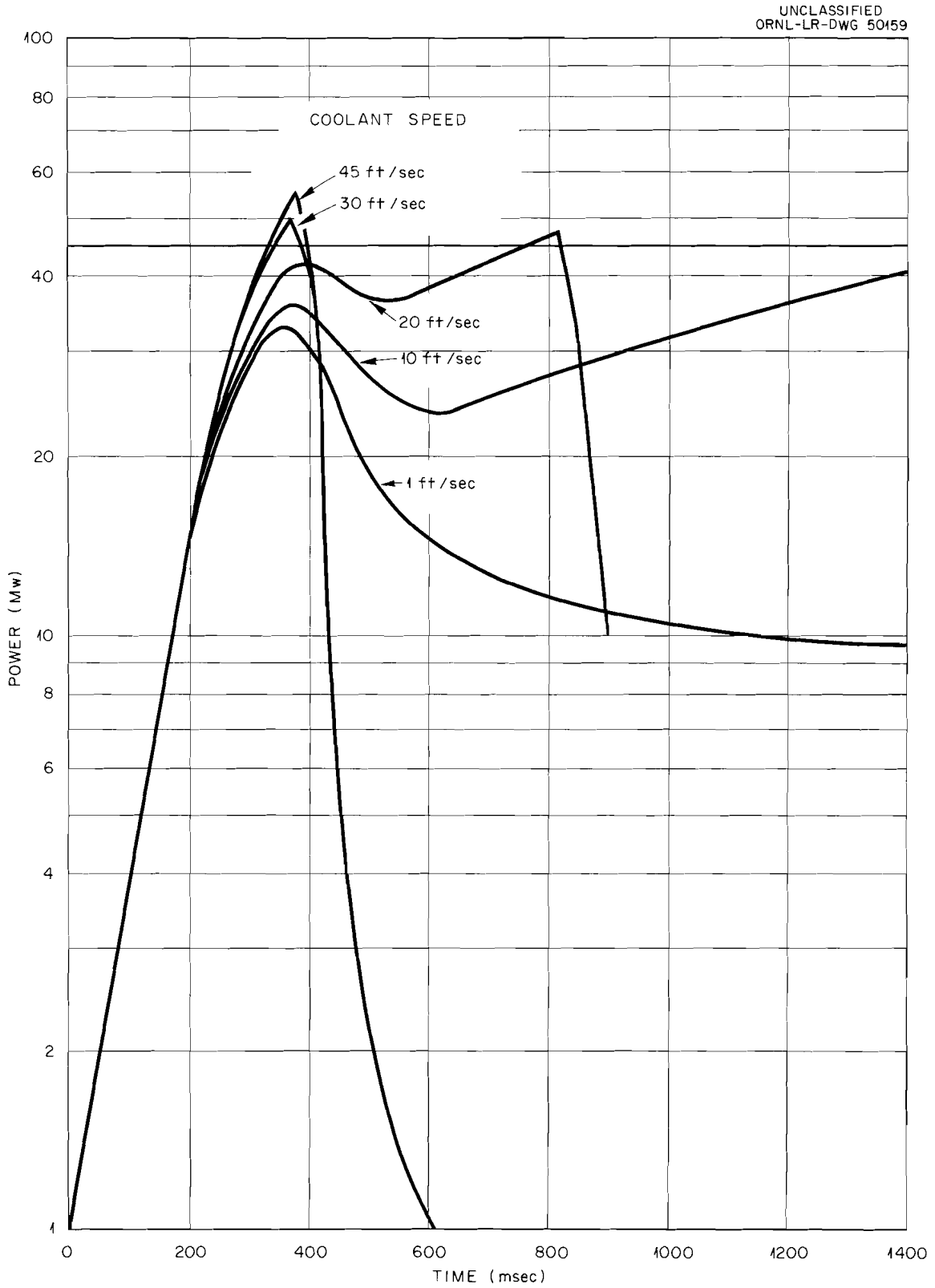

Fig. 1.6. Power Behavior for Various Coolant Speeds.

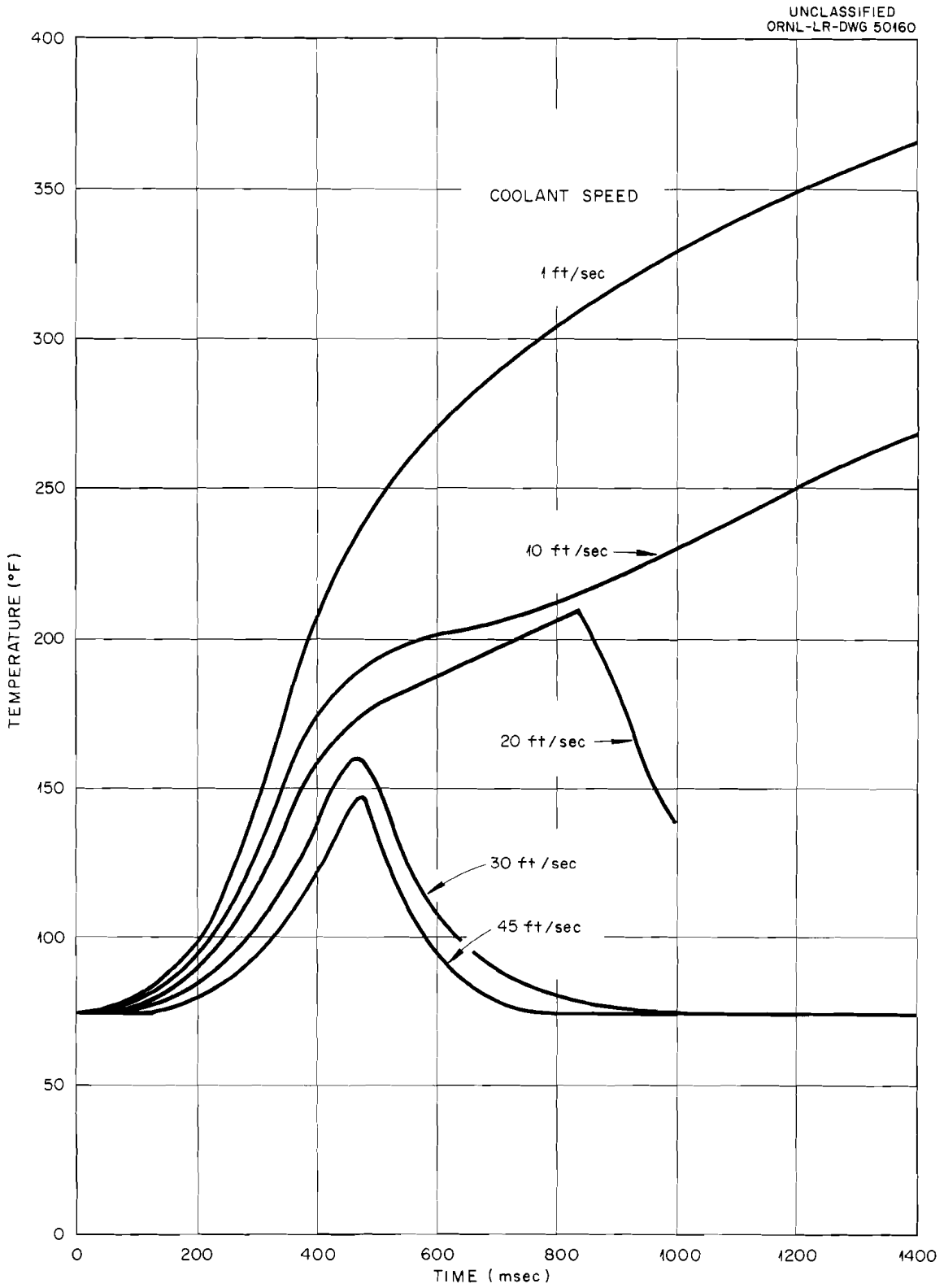

Fig. 1.7. Average Metal Temperature for Various Coolant Speeds.

It should also be remembered that all criticality tests are made with a coolant velocity of 1 ft/sec and that these tests are more numerous than normal startups at full flow. Therefore, something has to be done to protect the reactor against such conditions. It seems that the best solution at hand, although not completely satisfactory, consists in setting the safety level at some low flux value during all the runs at low flow. An interlock should be provided so as to make a startup with low flow impossible as long as the safety levels are not set at the correct value.

1.3. Calibration of Cadmium-Beryllium Shim Rods in the ORR Reflector

J. F. Wett, Jr., and A. L. Colomb

Two shim rods consisting of a cadmium section and a beryllium section were installed at position F-4 and F-6 in the ORR reflector.

The shim rods were calibrated for reactivity. The flux in the beryllium and in an adjacent fuel element was measured with cobalt wires.

Reactivity

A Cd-Be and a Cd-Al shim rod were calibrated in the reflector position F-4. A Cd-Be shim rod was calibrated in position F-6. The elements adjacent to F-4 and F-6 were: fuel elements in E row, beryllium in F-3, isotope tray in F-5, 200-gram fuel element in F-7, and beryllium in G row.

The calibration curves were obtained by comparing a reflector shim rod with the core shim rods and by measuring a few slopes with the inhour method. The reflector shim rod not being measured was in the withdrawn position during these calibrations.

Figures 1.8 and 1.9 show the measured calibration curves. The effect of the 200-gram fuel element located in F-7 almost doubled the worth of the adjacent shim rod. The Cd-Al rod is worth 85% of the Cd-Be rod.

A measurement of the total worth of both Cd-Be rods showed that they were equivalent to 3.34 inches of the four core shim rods. The fuel shim rods used during this measurement had an average of U^{235} content of 94 grams. This gives a differential reactivity of $0.86\% \frac{\Delta k}{k}$ in. in the linear part of their characteristic. Thus, the two Cd-Be reflector shim rods are worth 2.9% $\Delta k/k$. Comparing this value with that obtained by adding the reactivity worth ($1.98 + 3.65 = 5.63\% \frac{\Delta k}{k}$) of Figures 1.8 and 1.9 indicates that a strong shadowing effect takes place when the two reflector rods are moved simultaneously. The total worth of the reflector shim rods can be increased by 1.1% $\Delta k/k$ if a 200-gram fuel element is placed in position F-5.

Flux

Figure 1.10 shows the flux in the beryllium section of a shim rod located in F-4 as well as in the adjacent 200-gram fuel element. The fuel shim rod located in D-4 was withdrawn 15 inches. This accounts for the changes in flux

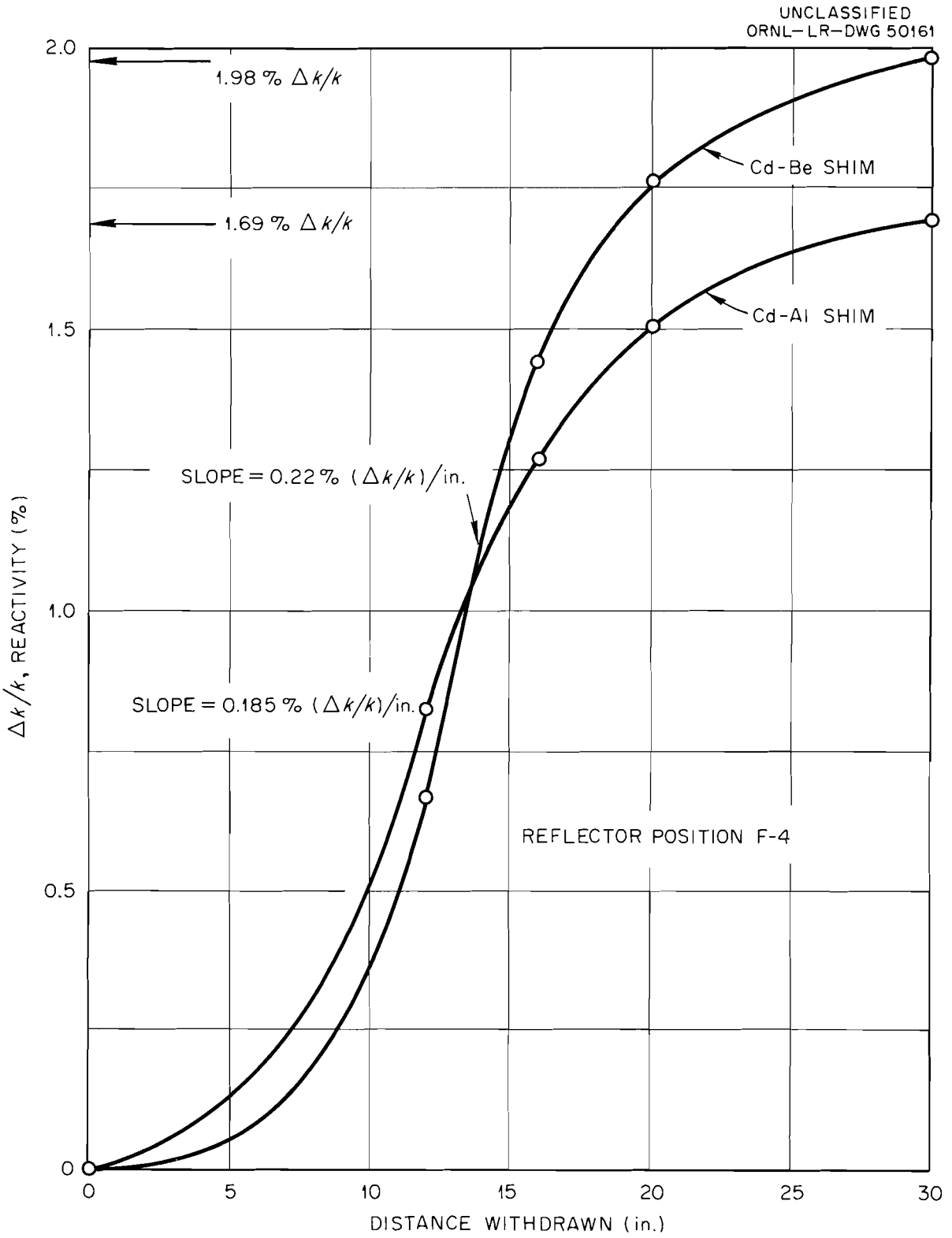

Fig. 1.8. Calibration Curves for Be-Cd and Al-Cd Shim Rods in ORR Reflector.

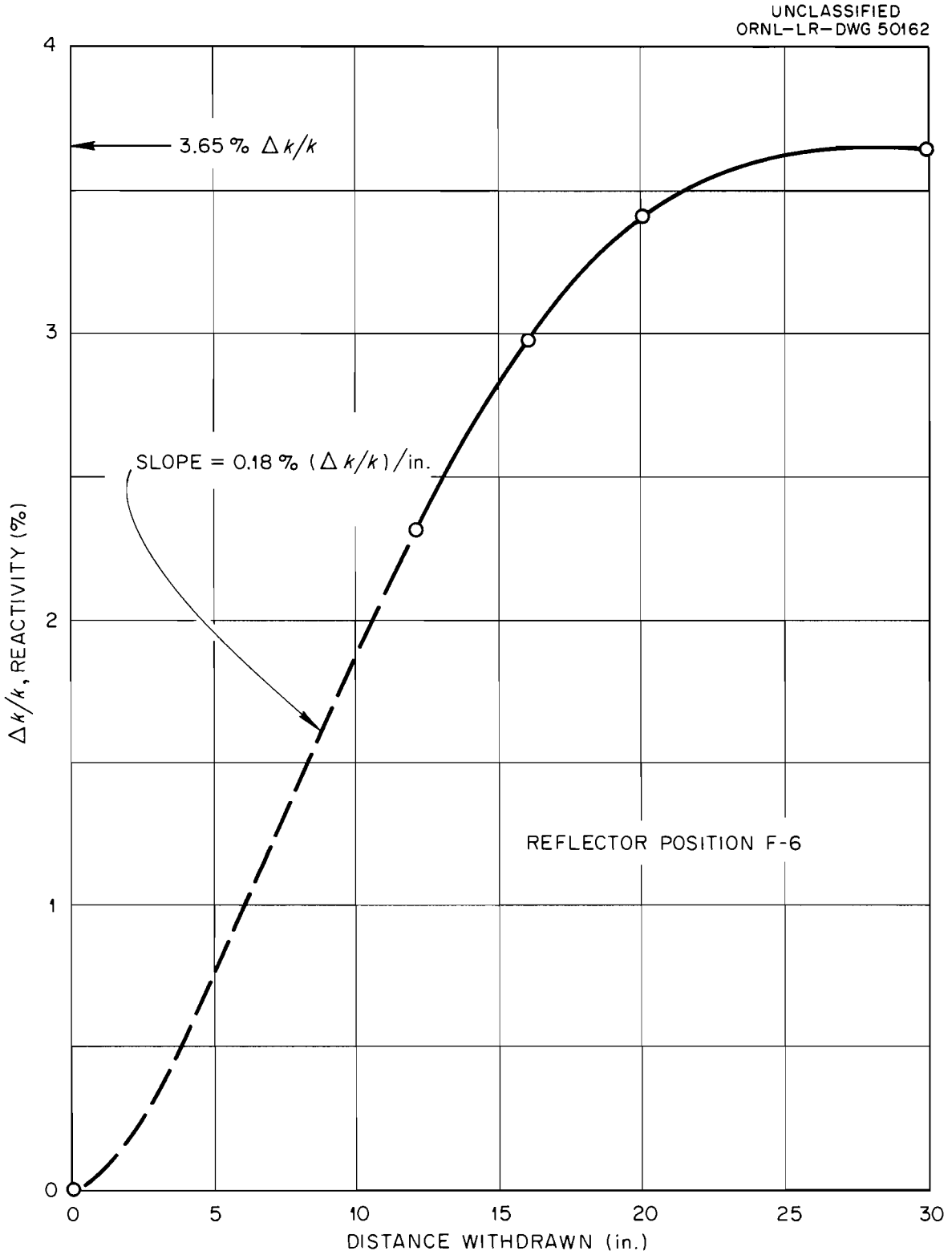

Fig. 1.9. Calibration Curve for Be-Cd Shim Rod in ORR Reflector.

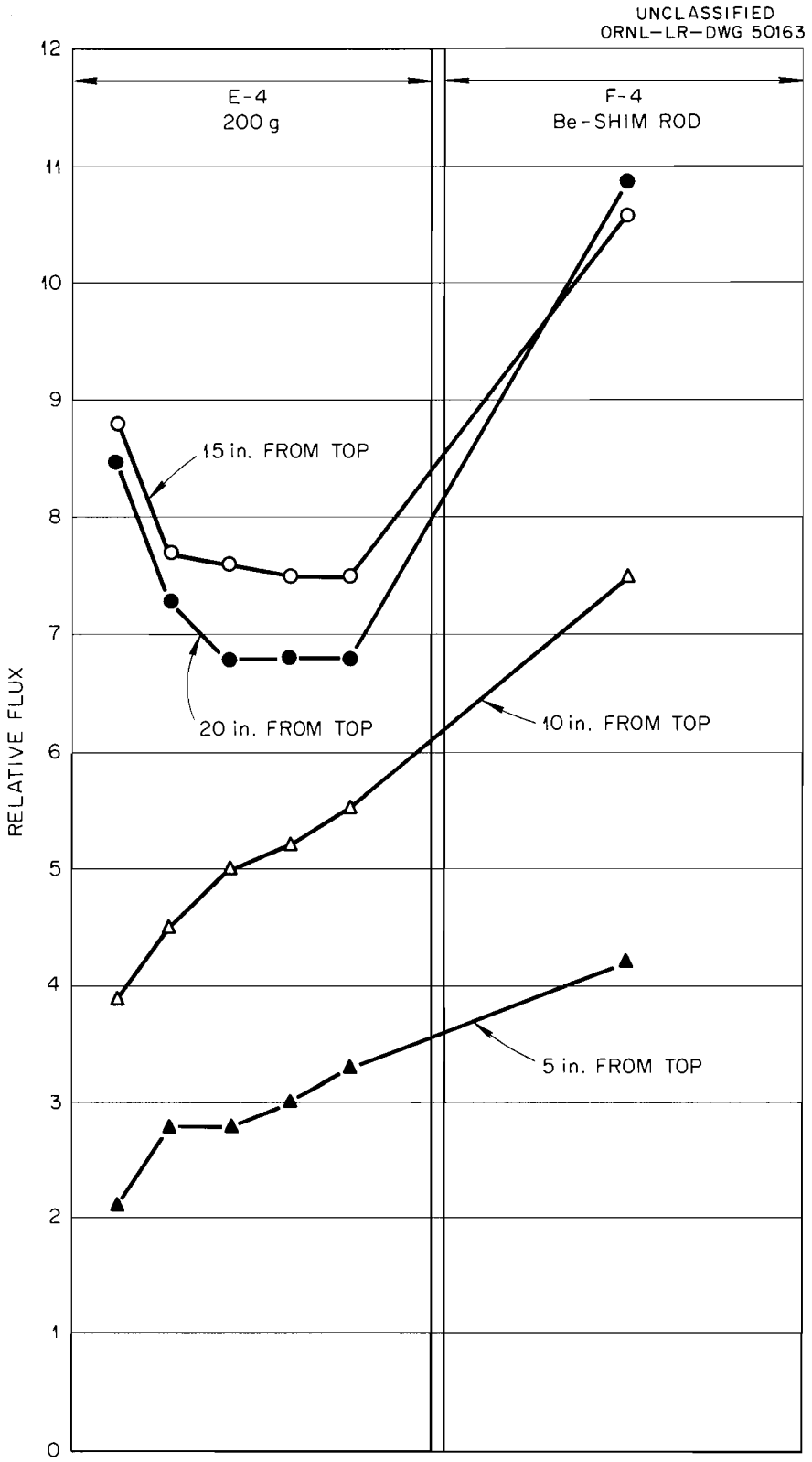

Fig. 1.10. Relative Flux in E-4 and F-4.

shape between the 5-inch and 10-inch measurements and the 15-inch and 20-inch measurements.

It can be seen that the beryllium section of the reflector shim rod does not create any serious flux peaking.

1.4. Requirements for Afterheat Removal for 30-Mw Operation of the ORR

J. F. Wett, Jr.

Computations of fuel-element surface temperatures due to afterheat for various flows were made. The following assumptions were made.

1. The flow partition below 1000 gpm is the same as it is above 3000 gpm.
2. The flux pattern at 30 Mw is essentially the same as it is at 20 Mw.
3. Nucleate boiling occurs at a wall temperature of 272°F.

Figure 1.11 shows the wall temperature as a function of flow for a nominal channel and the hottest channel. A full report on the subject has been issued as ORNL-CF-60-6-13.

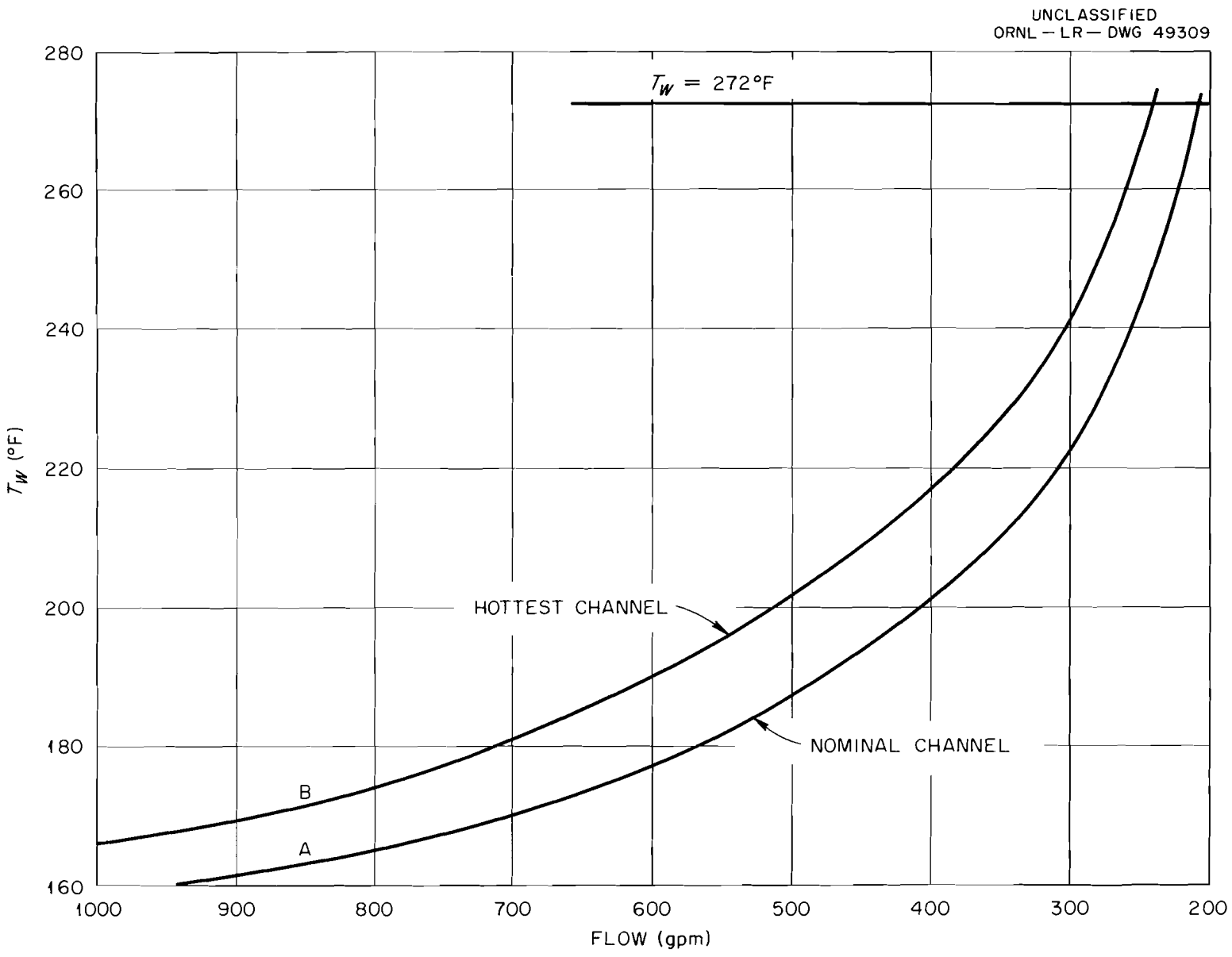

Fig. 1.11 Wall Temperature vs Flow Rate.

1.5. Beryllium Reflector Pieces

J. F. Wett, Jr.

During the quarter, the beryllium reflector pieces for use in the Poolside Critical Facility were received. Fabrication of the end boxes and assorted equipment is nearly complete. Assembly and final machining of the end boxes should be completed by September 1, 1960.

1.6. ORR Fuel Elements, Material Composition and Cross Sections

A. L. Colomb

The purpose of this work is to give standard data concerning the material composition and nuclear cross sections for ORR 200-gram fuel elements. These data will be useful mainly as reference design for the computation of burnup, reactivity changes, etc.

Geometrical

The effective length of a fuel element is by definition equal to the length of the fuel bearing section of the element. That is, $L = 23.625$ in. $= 60.01$ cm.

The effective volume V_{eff} of a fuel element is by definition the actual volume of the element plus half the water volume located between the element and its four neighbors.

$V_{eff} = 231.3 \text{ in.}^3 = 3790 \text{ cm}^3$.

The metal volume V_M is:

$V_M = 89.59 \text{ in.}^3 = 1468 \text{ cm}^3$.

The water volume V_{H_2O} is:

$V_{H_2O} = V_{eff} - V_M$,

$V_{H_2O} = 141.7 \text{ in.}^3 = 2322 \text{ cm}^3$

The metal-to-water volume ratio is:

$$\frac{V_M}{V_{H_2O}} = 0.6321$$

The heat transfer area A is:

$A = 2388 \text{ in.}^2 = 16.58 \text{ ft}^2 = 15406 \text{ cm}^2 = 1.5406 \text{ m}^2$

Table 1.10 contains the volumes, volume fractions, weights, apparent densities and atomic or molecular densities of the fuel-element constituents.

TABLE 1.10. COMPOSITION OF ORR FUEL ELEMENTS

Material	Volume (cm^3)	Volume Fraction	Weight (gm)	Apparent Density (gm/cm^3)	Atomic or Molecular Density (at. or mol/cm^3)
Uranium	11.26	0.002971	214	0.05645	1.7952×10^{20}
U-235	10.53	0.002777	200	0.05276	1.7018×10^{20}
U-238	0.73	0.0001944	14	0.003694	9.345×10^{18}
Al	1457	0.3843	3932	1.0373	2.3155×10^{22}
H_2O (20°C)	2322	0.6127	2319	0.6116	2.0793×10^{22}

Table 1.11 contains the microscopic and macroscopic fission, absorption, scattering and transport cross sections for the fuel element constituents. These cross sections are reduced to a temperature of 20°C and averaged over a Maxwell distribution.

Using these values:

The diffusion coefficient $D = 0.2490$ cm

The diffusion length $L = 1.445$ cm

$L^2 = 2.088\ cm^2$

And assuming the escape probability and the fast multiplication factor equal to one, the infinite multiplication factor is $K_\infty = 1.770$.

TABLE 1.11. CROSS SECTIONS FOR ORR FUEL ELEMENTS

Material	σ_f(b)	Σ_f (cm^{-1})	σ_a(b)	Σ_a (cm^{-1})	σ_{sc}(b)	Σ_{sc} (cm^{-1})	σ_{tr}(b)	Σ_{tr} (cm^{-1})
U-235	502.1	0.085447	601.0	0.102278	8.3	0.001412	8.28	0.001409
U-238			2.42	0.000023	8.3	0.000078	8.28	0.000077
Al			2.038	0.004720	1.4	0.032417	1.36	0.031491
H_2O			0.588	0.012226	105.0	2.183265	62.8	1.305800
Total		$\nu\Sigma_f$ = 0.21105		0.11925		2.2172		1.3388

PART II

Taken from OPERATIONS DIVISION QUARTERLY REPORT

July - September, 1960, ORNL CF-60-9-121

REACTOR OPERATIONS
RADIOACTIVE WASTES OPERATIONS
AND HOT CELLS OPERATIONS
QUARTERLY REPORT

Summary

The new 30-Mw cooling system was installed at the ORR during July, and the reactor is now operating routinely at this power. Because of the time required for the installation of the new cooling tower and heat exchangers, the operating time decreased to 48.5%.

Studies have been started on the operation of the ORR at 40 Mw. It appears that the new cooling tower would provide sufficient cooling for about six or seven months a year, but during summer months additional cooling capacity would be required. Heat transfer in the fuel during operation and immediately after a shutdown must also be studied.

1. OAK RIDGE RESEARCH REACTOR

1.1. Operations

W. R. Casto

Operations

The ORR was operated during this period at a power level of 30 Mw. The on-stream time was reduced to 48.5% because of the installation of a 30-Mw cooling system. The operations data for this period are given in Table 1.1.

TABLE 1.1. ORR OPERATIONS

Period July 1, through September 30, 1960

	This Quarter	Last Quarter	Year to Date
Total energy, Mwd	1075.9	1204.3	3751.6
Average power, Mw/operating hr	24.1	16.8	20.3
Time operating, %	48.5	78.7	69.4
Reactor water radioactivity, c/m/ml (av)	29,687	16,279	22,330
Pool water radioactivity, c/m/ml (av)	721	596	572
Reactor water resistivity, ohm-cm (av)	547,000	592,000	585,000
Pool water resistivity, ohm-cm (av)	699,000	776,000	760,000
Research samples	4	21	47
Radioisotope samples	124	110	560

The core configuration at the end of the quarter is unchanged from that of 6-30-60 and is indicated in Figure 1.1.

Cycles of operation during this period are shown in Table 1.2.

TABLE 1.2. CYCLES OF OPERATION

Cycle No.	Date Begun	Date Ended	Accumulated Energy (Mwd)
26	In progress July 1	July 9	134.44
27	July 29	August 7	120.00
28	August 14	September 5	519.10
29	September 15	September 25	302.36

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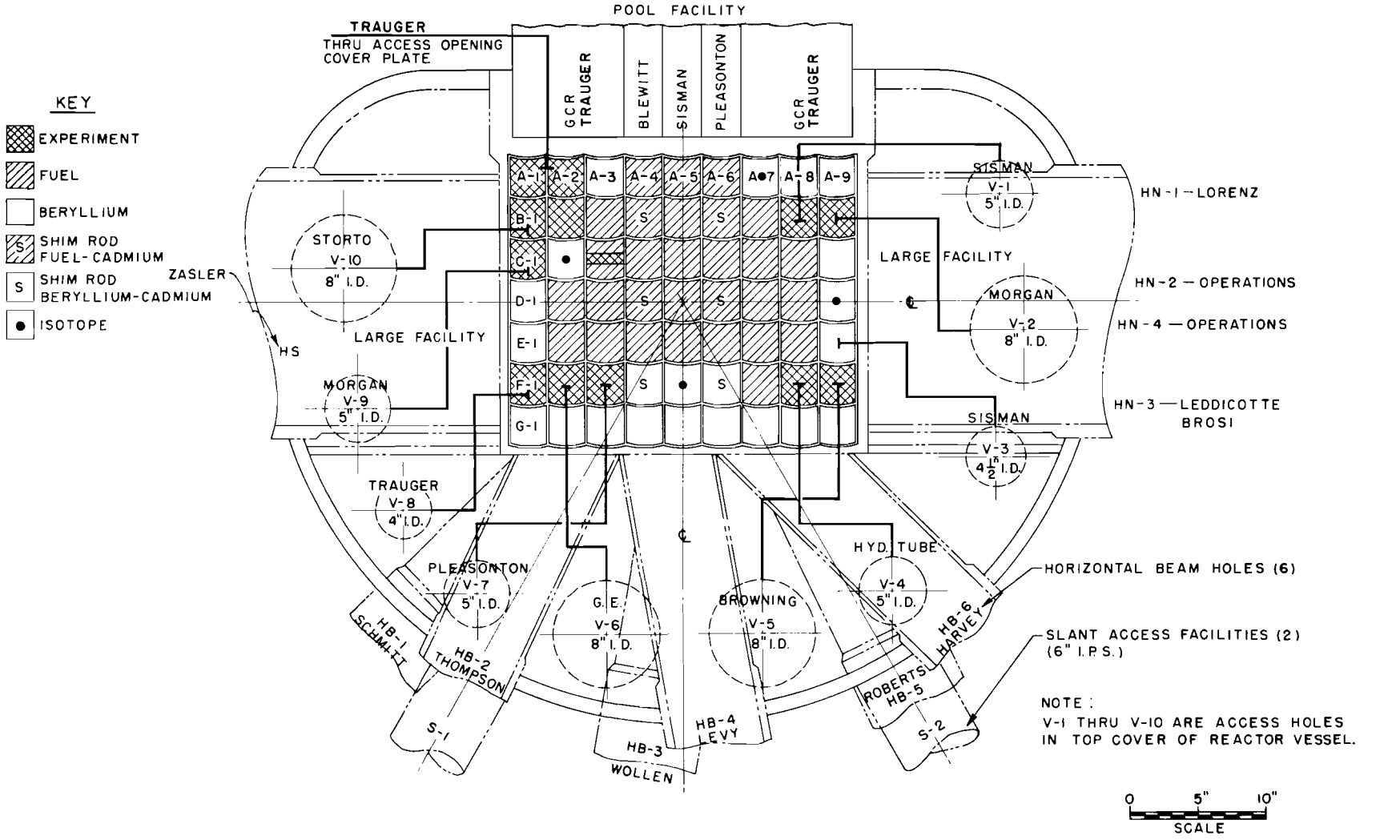

FIG. 1.1

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

RESEARCH ASSIGNMENTS & FUEL LOADING ON 9-30-60

C-33561

Figures 1.2, 1.3, 1.4, and 1.5 indicate shim rod positions versus the operating time during cycles 26, 27, 28, and 29, respectively.

Shutdowns

Four major shutdowns occurred during this period.

July 9 through July 29. The 5-ft diameter, outer plug was removed from the south engineering test facility and replaced with the outer plug for the GCR He-cooled loop No. 2. This plug has a hole 24 in. in diameter for the loop. During preparation for this work, a section of concrete on the south reactor shield, just west of the H-S facility, was discovered to be faulty. Core drilling to a depth of 12 in. showed a considerable volume was affected. It is believed that when the wall was constructed by the "prepak" method, the grout did not permeate the aggregate sufficiently for proper bonding. Investigation of the extent of the faulty construction as well as repair was scheduled for the next end-of-cycle shutdown.

Other work completed during this shutdown included replacing the collimator plug in HB-6.

August 7 through August 14. Activities during this period included installation of GCRP group III capsules, installation of the in-core section and tubing for GCRP loop No. 1, and installation of major piping for GCRP loop No. 2. The section of concrete wall found faulty during the previous shutdown was repaired.

September 5 through September 15. This extended shutdown was scheduled primarily to provide time for major construction work on GCRP loop No. 2 at the south facility. Two 5-Mw runs were made to investigate thermal stresses in the reactor tank structure.

September 25 through September 30 (in progress). This extended shutdown was scheduled primarily to provide time for the installation of lead shielding at GCRP loop No. 2. This installation was not complete at the end of the quarter.

Table 1.3 lists the unscheduled shutdowns which occurred this quarter.

There were no shutdowns due to real cause (i.e., a condition existed which was such that without reactor power reduction an experiment and/or the reactor could be damaged).

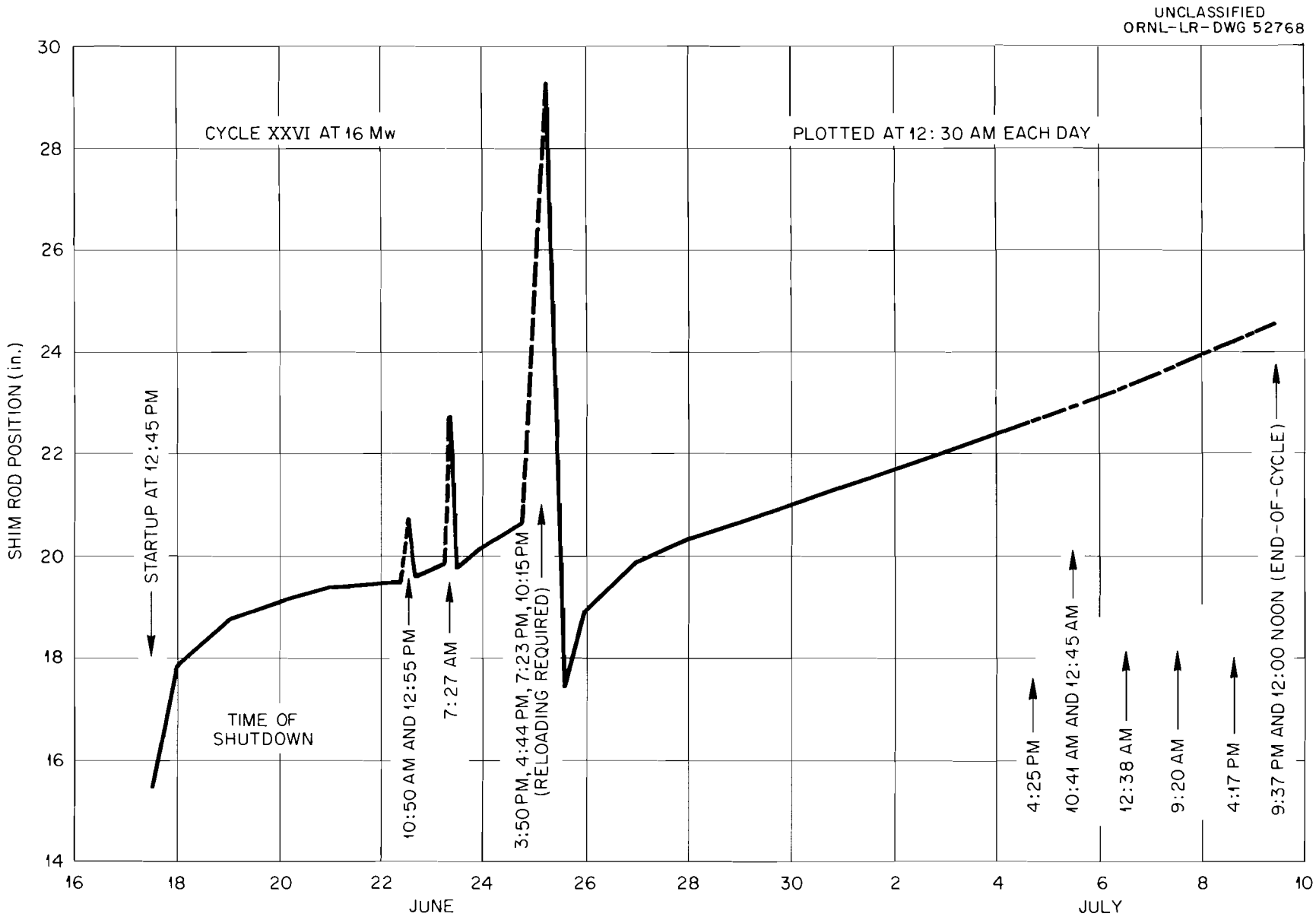

Fig. 1.2. Shim-Rod Position vs Time

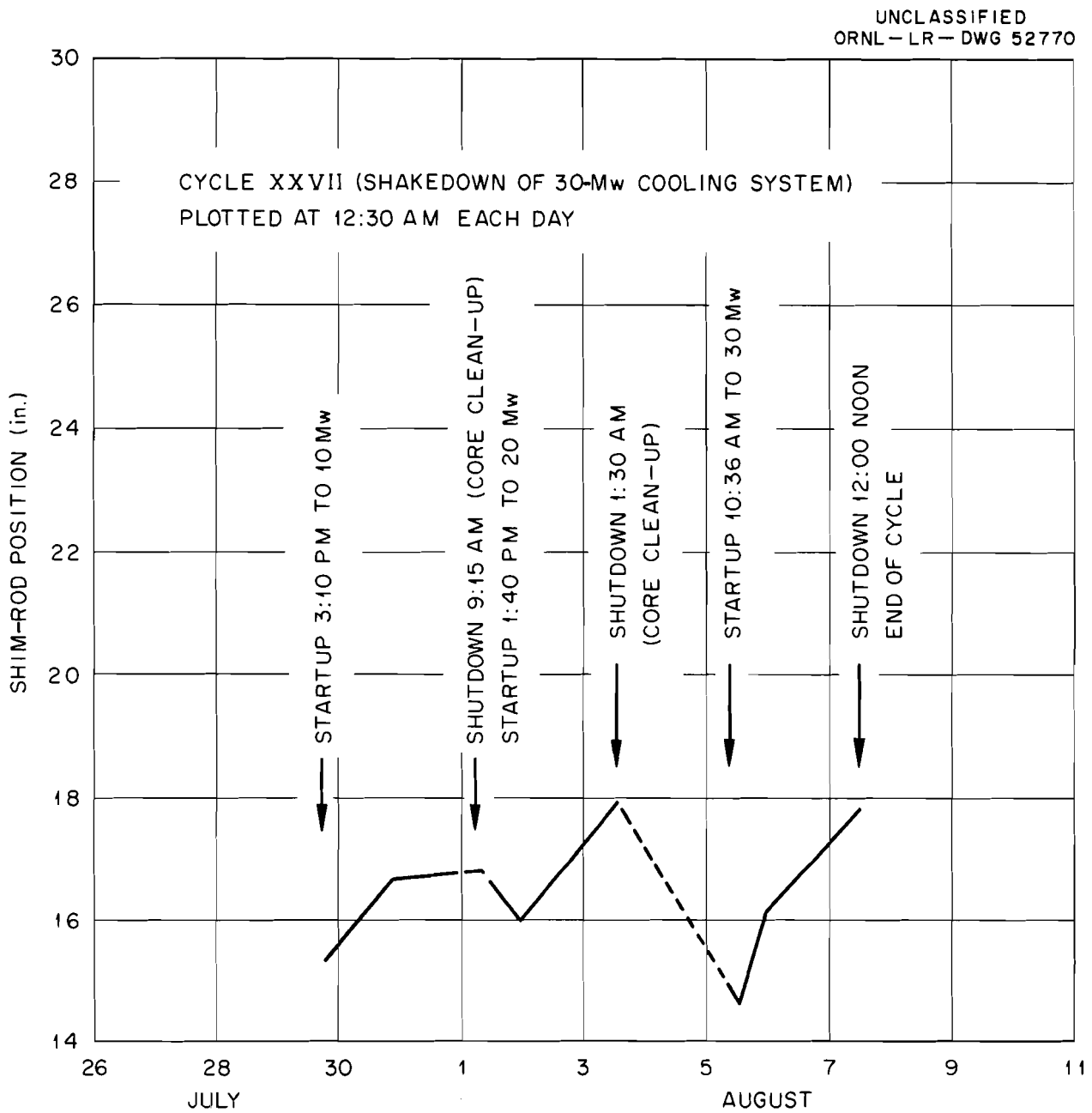

Fig. 1.3. Shim-Rod Position vs Time.

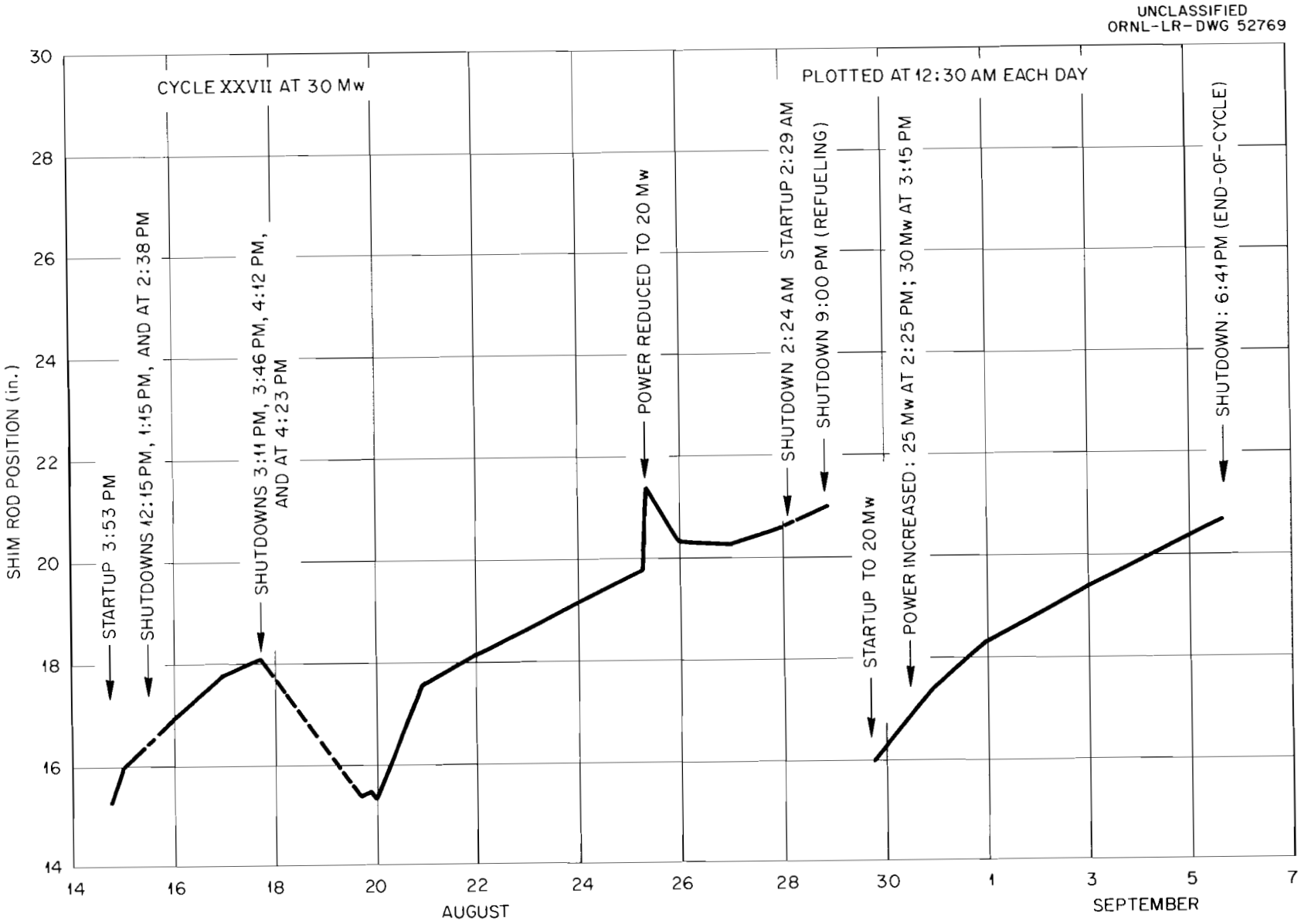

Fig. 1.4. Shim-Rod Position vs Time

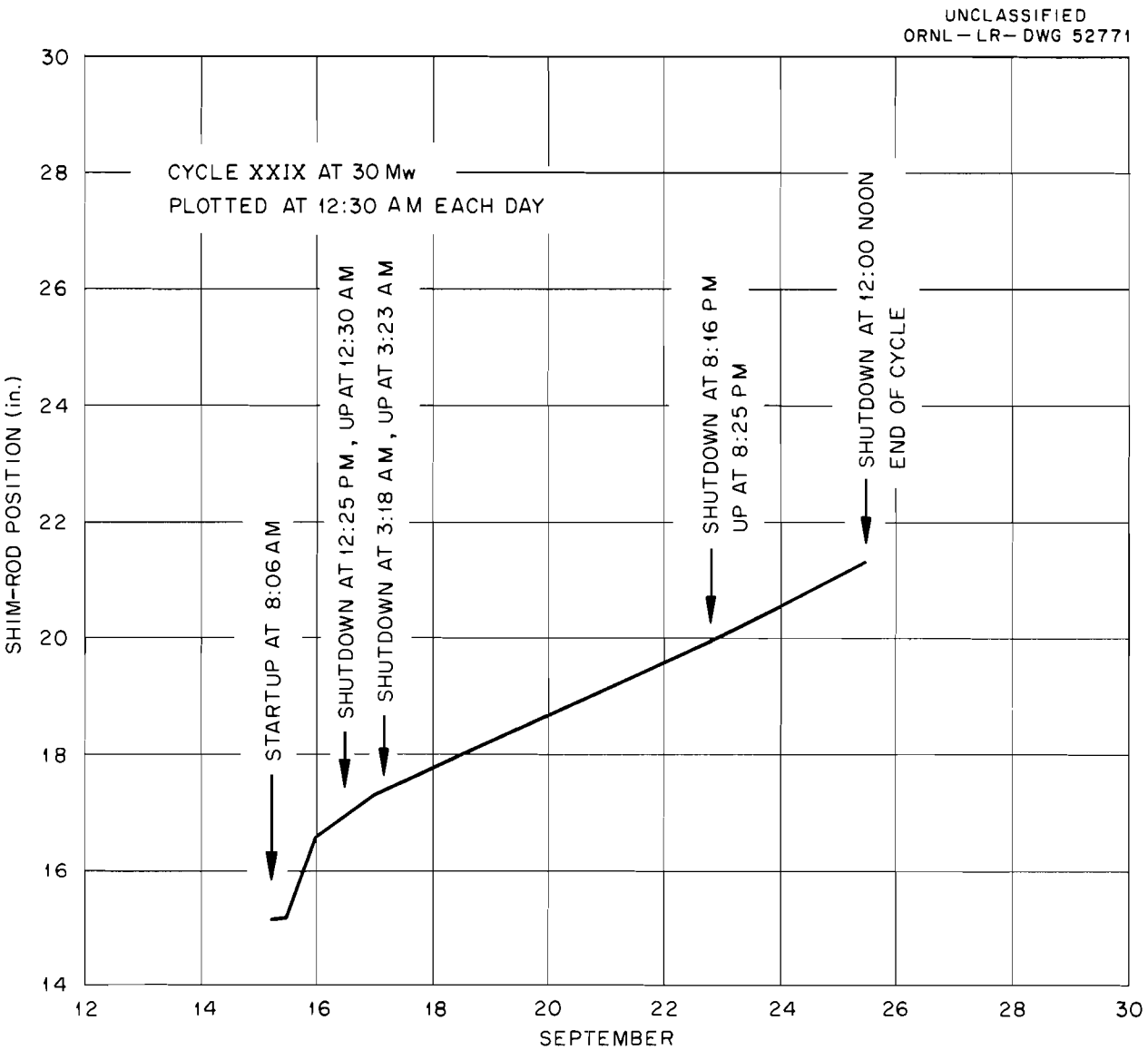

Fig. 1.5. Shim-Rod Position vs Time

TABLE 1.3. UNSCHEDULED SHUTDOWNS AT THE ORR

Date	Duration (hr)	Remarks
7-4-60	0.167	No. 5 shim rod dropped, reason unknown.*
7-5-60	0.033	Setback from GE, CP-B1 experiment. Recorder spiked upscale because of undetermined trouble in the recorder.
7-5-60	0.167	No. 5 shim rod dropped, reason unknown.*
7-6-60	0.200	Setback from GE, CP-F2 experiment. Thermocouple failure, recorder drove upscale, unexplained trouble in recorder.
7-7-60	0.183	Reverse from GE, CP-B1 experiment, while the recorder was being changed. Two wires had the same identification numbers, and the wrong one was removed.
7-8-60	0.217	No. 5 shim rod dropped, reason unknown.*
7-9-60	0.183	No. 5 shim rod dropped, reason unknown.*
8-15-60	0.050	No. 5 shim rod dropped, reason unknown.*
8-15-60	0.167	No. 6 shim rod dropped, reason unknown.*
8-15-60	0.283	An electrician transferred the emergency circuit from TVA power to the diesel-powered generator.
8-17-60	0.317	No. 5 shim rod dropped, reason unknown.*
8-17-60	0.367	No. 6 shim rod dropped, reason unknown.*
8-17-60	0.150	No. 5 shim rod dropped, reason unknown.*
8-17-60	52.917	No. 6 shim rod dropped, reason unknown.* Increased xenon-135 concentration made refueling necessary, and an investigation was made to determine the cause of the rod drops.
8-26-60	0.467	Momentary interruption of electrical power due to the loss of a "feeder" to the central ORNL power station (Building 3000).
8-28-60	0.083	Setback from CP-B9 experiment when being withdrawn from the flux by Operations after the sump inlet recorder circuit failed. The sample-temperature coolant-flow controller reduced flow when the set point was not lowered sufficiently.
9-16-60	0.083	Setback from GE, CP-F2 experiment due to loss of a thermocouple; replaced with a spare.
9-17-60	0.083	Setback from GE, CP-F2 experiment due to loss of a thermocouple; replaced with a spare.
9-22-60	0.067	Setback from GCRP capsule No. 6 due to loss of a thermocouple; replaced with a spare.

*Later investigations revealed various troubles which may have contributed to the shutdown.

Reactor Controls

The excessive number of unexplained rod drops which began during cycle 26 continued into this quarter. During the shutdown at the end of cycle 26, investigation revealed that the magnet "keeper" for the No. 5 shim rod was chrome plated and had a high spot on one edge. Both these features resulted in increased magnet spacing. Since the No. 5 shim rod had dropped most frequently, it was thought that the situation had been corrected. At the start of cycle 28, a series of spurious drops occurred involving both No. 5 and No. 6 shim rods. On August 17 a number of these drops resulted in a shutdown due to high xenon concentration. Since refueling was necessary, an investigation was instituted in an attempt to determine and correct the causes of the difficulty.

This investigation involved installing a load cell under the "push rod" of the No. 5 shim rod and measuring the applied forces while the rod was withdrawn and inserted.

It had been previously determined that the difficulty was not electronic in nature. The north hold-down arm, which contains the upper bearings for both No. 5 and No. 6 shim rods, was found to bind on the rods when they were being withdrawn. This binding applied excessive force on the "push rod" which resulted in separation of the magnet and "keeper." This hold-down arm was replaced; and, during subsequent operation, no further difficulty was observed.

A number of changes in the reactor controls were completed in preparation for 30-Mw operation. Two magnet amplifiers were provided for each of the two beryllium-cadmium shim rods. Also, these amplifiers were permanently wired into the safety system identically to those provided for the four fuel-cadmium shim rods. Resistance bulb thermometers were installed to measure reactor coolant temperatures to replace the thermocouples previously used and, thus, eliminate the need for a microvolt amplifier. In addition, recorder switch set points (for alarm, setback, and scram action) were adjusted to provide for increase in ΔT across the core, for increase in coolant flow from 16,000 gpm to 18,000 gpm, and for subsequent increases in exit temperature and pressure drop across the core.

For additional operational continuity and safety, three further changes were made. An individual key was provided for each experiment tie-in, E-panel switch. Two reactor water exit temperature recorders and an additional log-N channel were installed. This channel is identical to, and independent

of, the original channel up to the output of the period amplifier. A multi-stage, SB-1 switch can be used to select one or the other channel, but not both simultaneously, as the operating channel. Only the channel thus selected will be connected to either the reactor control and safety system or the safety trouble monitor circuits associated with the period sigma amplifier. In addition, the contacts on the SB-1 switch which are used for control and safety system transfer are of the make-before-break type; and, although only the selected channel has any control function, the signals to the recorders of both channels are not affected by the switch.

Data on the malfunction of reactor controls are given in Table 1.4.

TABLE 1.4. MALFUNCTION OF REACTOR CONTROLS--ORR

Date	Description
7-4-60	No. 5 shim rod dropped.
7-5-60	No. 5 shim rod dropped.
7-8-60	No. 5 shim rod dropped.
7-9-60	No. 5 shim rod dropped.
7-9-60	No. 2 shim rod did not drop completely but stuck about 5 in. above its seat when the reactor was shut down to terminate cycle 26. Upon investigation during the shutdown week, a small hex-nut was found wedged in the shock absorber section of the lower plug. The shock absorber was replaced with a spare. (Although this operation had never been performed since the original critical experiments, no difficulty was experienced.)
8-15-60	No. 5 shim rod dropped.
8-15-60	No. 6 shim rod dropped.
8-17-60	No. 5 shim rod dropped.
8-17-60	No. 6 shim rod dropped.
8-17-60	No. 5 shim rod dropped.
8-17-60	No. 6 shim rod dropped.

30-Mw Cooling System

Description. Since initial power operations, the ORR has operated at 20 Mw during the cool season from about October to April of each year. During the remaining months, the reactor power has been limited to 16 Mw because the coolers never performed at rated capacity. When it was decided

to increase the ORR power to 30 Mw, a spray tower was selected for cooling. This system was installed during an extended shutdown following cycle 26.

The 30-Mw cooling system was designed by making certain additions to the original system (Figure 1.6). The major new components are as follows:

1. Four stainless steel (type 304), shell-and-tube heat exchangers connected in parallel (Figure 1.7). Reactor cooling water passes through the shell side of the exchangers, and about 10,000 gpm of secondary loop cooling water makes two passes on the tube side. The tube sheets are the fixed, nonremovable type.

2. A 24-in., wafer-type, butterfly control valve with an air-motor positioner is installed in parallel with the four shell-and-tube heat exchangers. This valve is primarily of stainless steel (type 316) and is designed to close upon loss of actuating air pressure. This results in maximum flow through the heat exchangers.

3. Cooling of the secondary-loop water is done by a cross-flow, two-cell, cooling tower. Circulation is provided by two pumps driven by 300-hp motors. A third pump acts as a standby and has approximately the same capacity, but it is driven by a 250-hp motor. A 12-in. butterfly valve, similar to the one described in item 2, controls the amount of water by-passing the tower.

The new primary water system is tied into the original piping between the by-pass filters and the Trane coolers which have been isolated and drained.

Several changes were made in the original system. Direct-current motors directly coupled to the shafts of two of the three primary cooling pumps were installed. These motors are each connected to a bank of 18 batteries which are, in turn, connected to separate, continuous-duty battery chargers. Upon failure of plant power the two DC units, together, will provide somewhat greater than 1700 gpm flow for shutdown cooling of the fuel. The electrical contacts, which previously had caused the motorized valves to close upon loss of power to the pumps, were removed.

Startup Procedure

The new cooling tower was first washed down to remove dirt. The secondary loop was then filled and chemically treated for corrosion and algae control. The primary loop was circulated with depleted elements in the core. This was deemed necessary since the strainer in the return line to the reactor contained baskets with holes larger than the spacing between

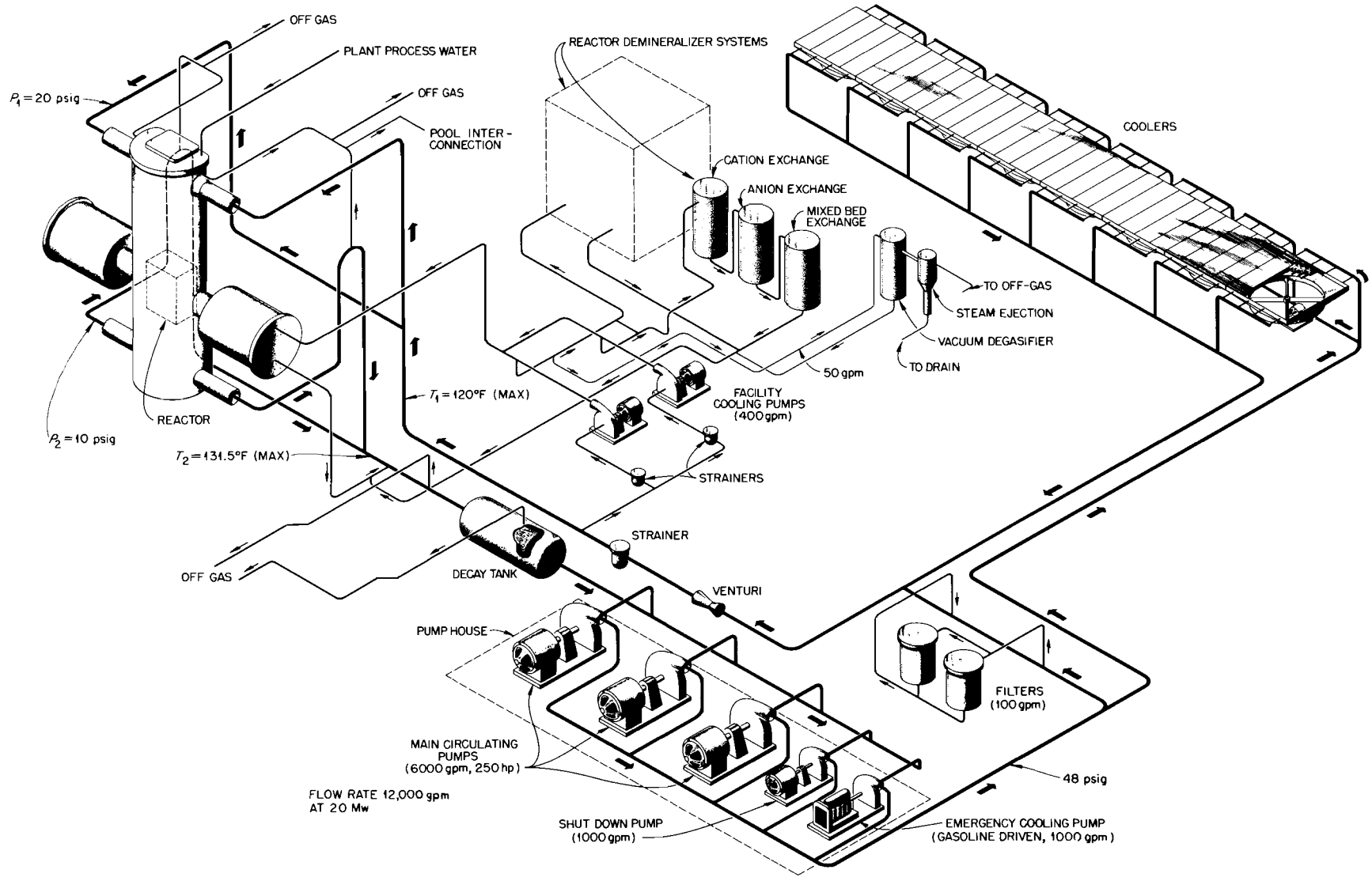

Fig. 1.6. 20 Mw Reactor Cooling System.

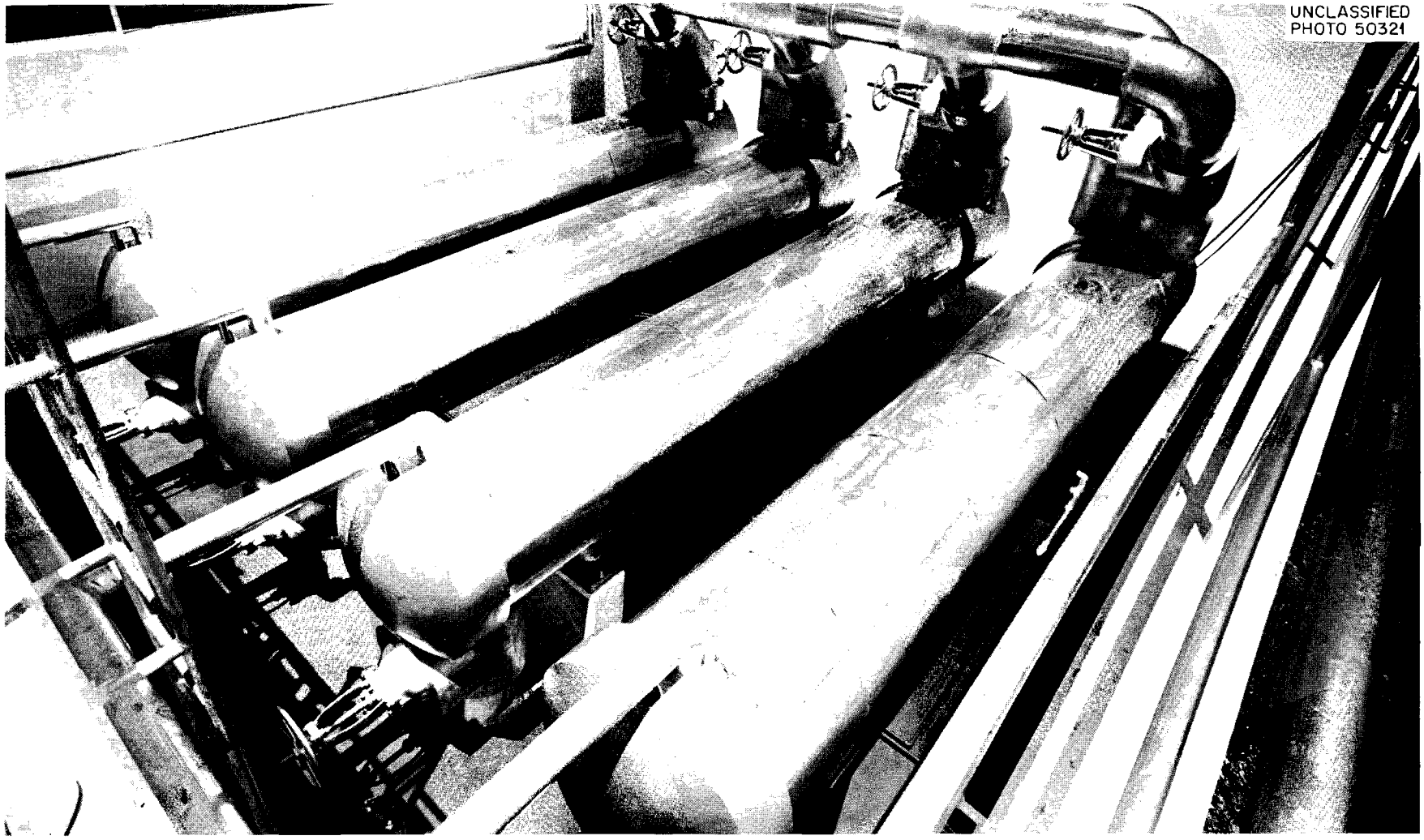

Fig. 1.7. 30-Mw Heat Exchangers

the fuel elements. As expected, a large amount of debris was collected in the fuel elements during this initial circulation of reactor water. This did not remove all debris from the system, however, and during the following cycle it was necessary to schedule two shutdowns to clean the fuel. For about a week the power level was kept below 20 Mw while the new cooling system was being tested. After the second cleaning of the fuel temporary, fine-mesh inserts were installed in the strainer baskets; and new baskets with holes smaller than the fuel-element plate spacing were ordered.

The butterfly control valve in the primary loop at one time was found stuck in the closed position. Investigation showed this was due to the force upon the flapper causing a deflection of the stainless steel shaft which had no inboard bearings. After such bearings were installed, the valve operated properly.

The 2300/460 transformer supplying power to the reactor cooling tower fans proved to be too small to carry starting loads while the fans were cycling from high to low, etc., and burned out. Because overheating had been observed for short periods previously, a spare power line had been run from the transformer which supplied the Trane coolers. In five hours this power supply was connected to the fan motors and operation was resumed. The impellers for two of the pumps had to be reduced in size to give the desired 10,500 gpm flow in the cooling tower.

Some difficulty has been experienced in maintaining the proper charge on the batteries for the DC motors. It has occasionally been necessary to run the gasoline-driven, shutdown pump in order to assure two independent methods of shutdown cooling while the batteries were being charged. Steps are being taken to correct this situation and to provide a third DC motor.

Removal of the South Facility Plug

The original 65 3/8-in.-diameter south facility plug (Dwg. No. D-29865) was removed during the July 10 shutdown and replaced by a specially designed plug (Dwg No. D-39150) for use in conjunction with the GCR-ORR Loop No. 2 experiment. Detailed preparations were made in planning the removal of the original plug and the installation of the new plug. These preparations included calculations of radiation levels to be expected, rearrangement of the core to minimize the radiation beam from the empty hole, fabrication of special shields, and preliminary radiation measurement in the 10-in. beam holes and obround section prior to removal of the original plug. The exchange of plugs was made on July 19, ten days after reactor shutdown.

Approximately eight hours were required to complete the job from the time of initial retraction of the original plug until full insertion of the new plug, but not including final bolting of the plug.

1. Preparatory Work--Criteria for design and fabrication of the new plug were provided by the Reactor Projects Division. The design was done by ORNL and the fabrication by K-25. Inspection services during fabrication were provided by both K-25 and the ORNL Inspection Division. The plug was fabricated in about 2 1/2 months at a cost of approximately $42,000, excluding design. Flow and hydraulic tests were made on the plug prior to installation.

A complete chemical analysis on the material that went into the fabrication of the plug is on file. Also samples of each type of material are on file for activation analysis, if desired.

2. Radiation Calculations--Calculations were made to evaluate the radiation dose rate that might be expected with the plug removed. These calculations were based on one-week decay of reactor components; removal of all fuel and shim rods; rearrangement of all beryllium to the seven, eight, and nine rows; water in rows three through six; lead in rows one and two and core positions C through G; U shield in core positions B-1 and B-2; and the MSR loop in core positions A-1 and A-2 with U-slugs inserted into the core position of the loop. The core configuration after rearrangement is shown in Figure 1.8. The calculations indicated the dose rate would be between 10 and 100 r/hr at the center of the hole, ten feet from the tank face with the MSR loop contributing 90% of the radiation. A 1-in. cube of 6061-T6 Al, the same type material as used in the fabrication of the original plug, was irradiated in the poolside facility for two weeks; and radiation measurements were made after three days' decay. These measurements were essentially zero, indicating that if the Al used in fabricating the plug was of comparable purity the radiation from the end of the plug would be negligible.

3. Preparation of Reactor Core and Tank--To reduce the radiation beam emerging from the hole during interchanging the plugs, extensive changes were made in the reactor core. These changes are given above.

It was decided that the MSR loop should be left in place, if possible, due to the expense and lost time for the experimenter's program if the loop were removed. Also, it was decided that the thermal shield would not contribute greatly to the radiation source so it was not removed.

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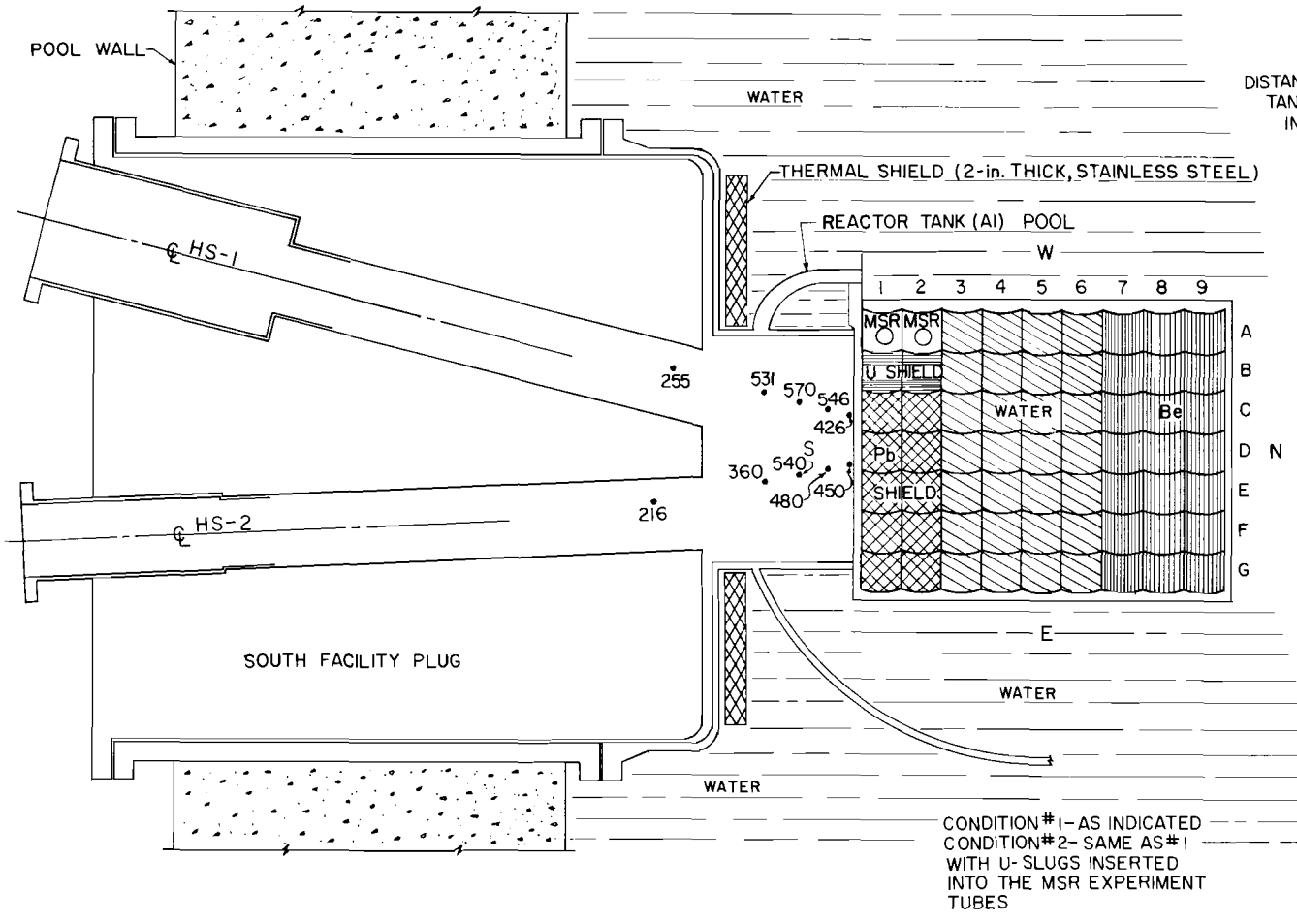

HS-1

DISTANCE FROM TANK FACE INCHES	CONDITION #1 r/hr	CONDITION #2 r/hr
0	600	426
4	1140	546
8	840	
10		570
16	588	531
28	372	255
40	120	69
112	1.2	0.9

HS-2

DISTANCE FROM TANK FACE INCHES	CONDITION #2 r/hr
0	450
6	480
10	540
18	360
30	216
42	120
54	24
66	12
150	0.35

FIG. 1.8 GAMMA MEASUREMENTS IN THE SOUTH ENGINEERING TEST FACILITY

The core arrangement at the time of plug removal is shown in Figure 1.8.

4. Preparation of the South Facility Area and Auxiliary Equipment--Site preparation for the removal of the plug was begun about a week in advance of the actual plug removal. These preparations included the following: (1) removal of the lead shielding and disconnecting the process piping from the plug; (2) installation of a monorail under an overhang in the reactor shield from which was suspended a 6-ft-square, 5 1/2-in.-thick steel shutter for shielding the hole while the plug was removed; (3) removal of the concrete floor slabs from in front of the south facility and placing the slabs on their sides around the pit to provide shielding during the plug removal; and (4) installation of the track and plug-removal dolly.

A shield cap (Dwg. No. D-35537) was fabricated for the inner end of the plug to reduce the radiation level in transit and during storage of the plug.

A remote saw was fabricated for cutting off the two 1 1/2-in.-OD, Al tubes which directed the water flow into the obround cavity.

5. Preliminary Radiation Measurements in HS-1 and HS-2--The PAR plug and liner were removed from HS-1 and the dummy plug removed from HS-2. Gamma measurements on 7-12-60 were as follows:

At the face of HS-2 flange(12 1/2 ft from tank face) -- 2.25 r/hr

8 ft from HS-2 flange (20 1/2 ft from tank face) -- 300 r/hr

At the time of these measurements all fuel, shim rods, and experiments were removed from the core except the MSR loop. Beryllium was in rows 7, 8, and 9; and water filled the remainder of the core.

The end of the HS-2 dummy plug read 2.5 r/hr at contact and 600 mr/hr at one foot.

Gamma measurements were made on 7-15-60 in HS-1 and HS-2 holes with a Victoreen R meter. The core configuration and results of these measurements are shown in Figure 1.8.

6. Removal of the Original Plug and Installation of the New Plug--With final preparations for the plug removal completed, the initial retraction of the plug was begun early on the 4-12 shift, July 19. As the plug was retracted, using two "come-alongs" anchored to building columns and attached to the front of the removal dolly, radiation readings were made. The radiation level did not increase significantly until the plug was almost completely out of the hole (see Figures 1.9 and 1.10). As the end of the plug emerged from the hole, the radiation level in the pit increased sharply;

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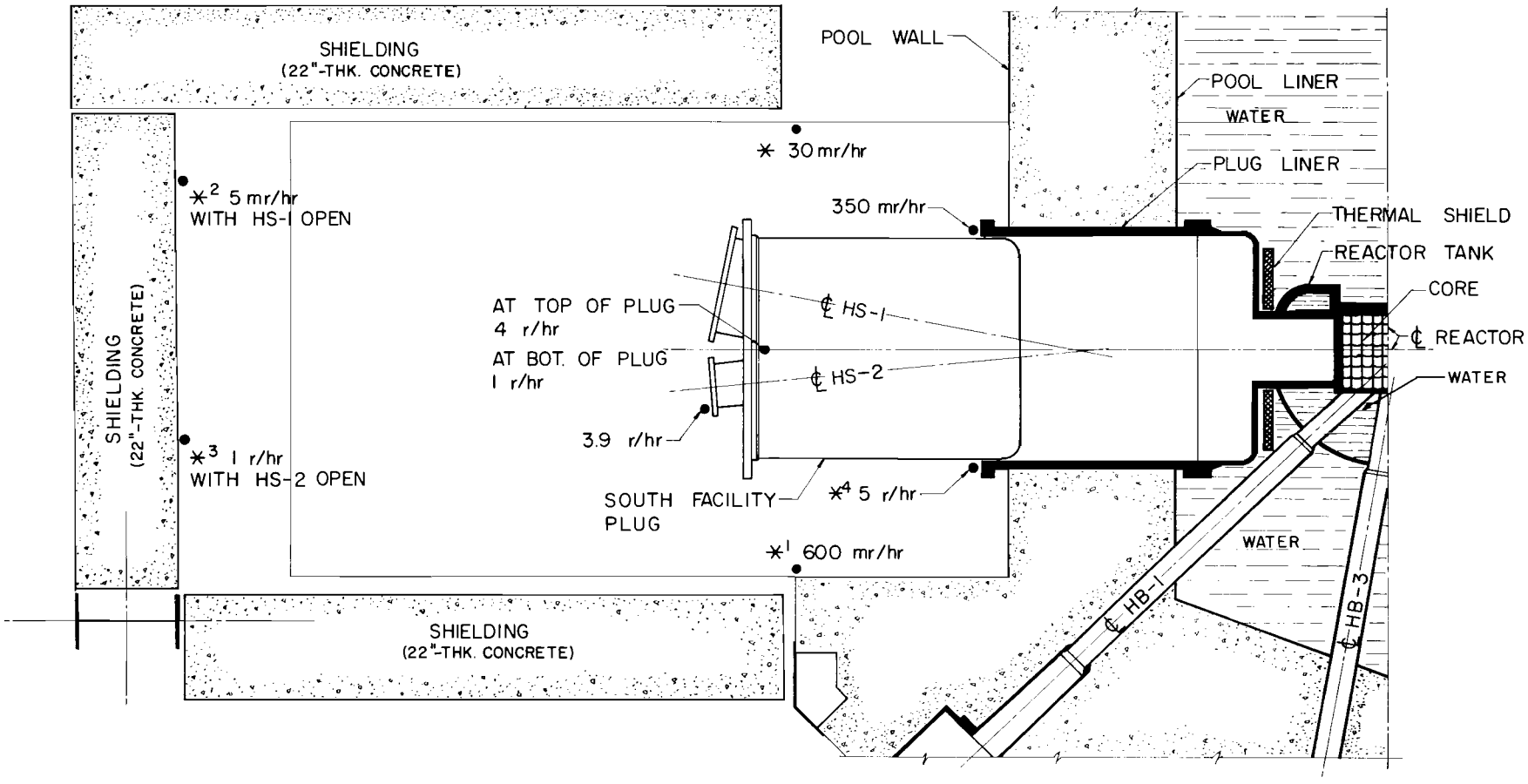

CONDITION: PLUG 65" OUT OF LINER; CORE AS SHOWN IN FIG. 1.8, COND. 2

POINTS: * & *1 SAME DISTANCE FROM PLUG AND FACILITY FACE
*2 ℄ OF HS-1
*3 ℄ OF HS-2

FIG. 1.9 GAMMA MEASUREMENTS DURING REMOVAL OF SOUTH ENGINEERING TEST FACILITY PLUG

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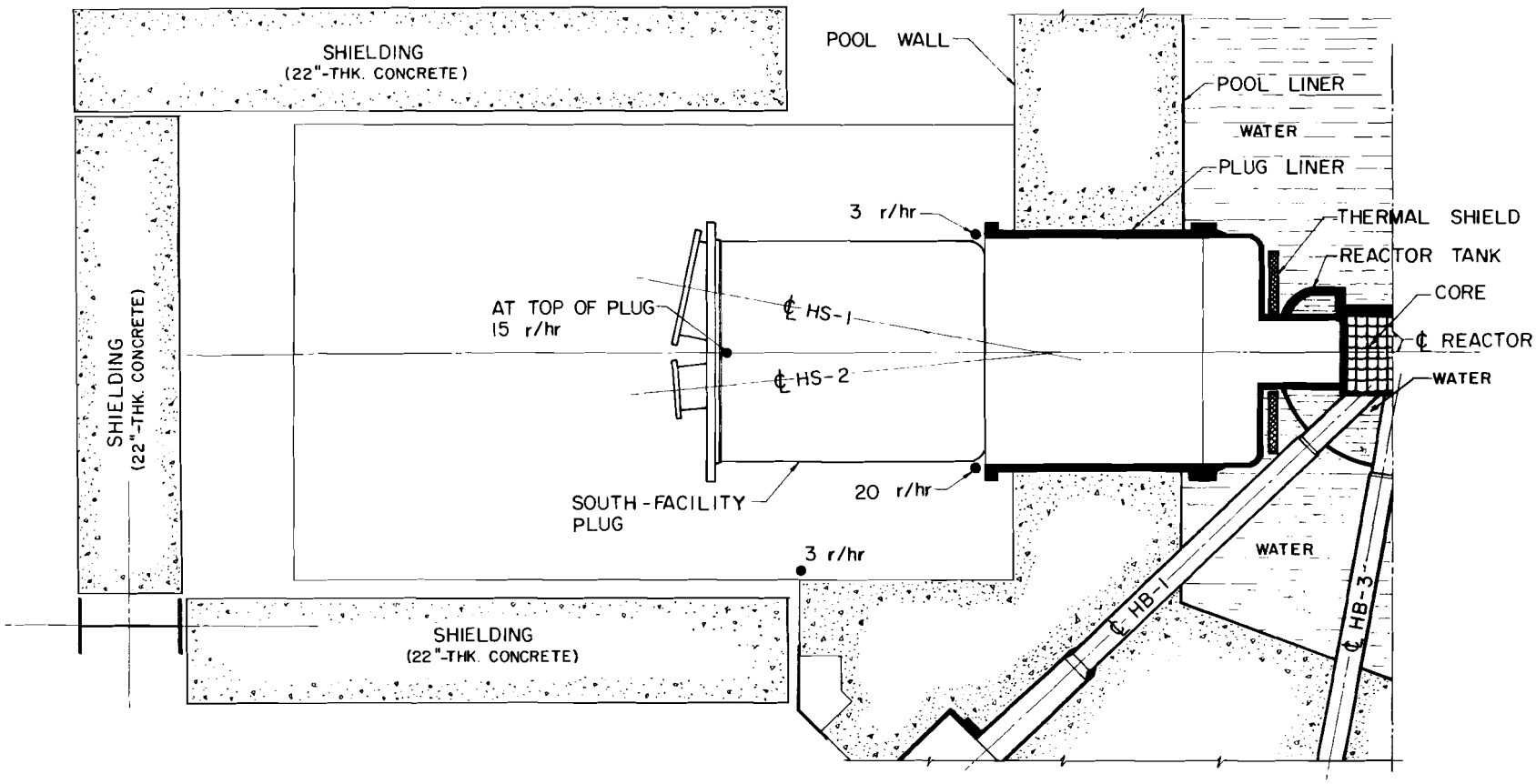

CONDITION: PLUG EVEN WITH LINER FLANGE
CORE AS SHOWN IN FIG. 1.8, COND. 2

FIG. 1.10 GAMMA MEASUREMENTS DURING REMOVAL OF SOUTH ENGINEERING TEST FACILITY PLUG

however, the floor slabs placed around the pit provided more than adequate shielding for personnel. When the plug was fully retracted, the steel shutter was closed, reducing the radiation to a tolerable level, as shown in Figure 1.11.

The two Al pipes which directed the inlet water flow into the obround section read 10 r/hr at a distance of 2 in. from the end of the pipe. These pipes were removed directly with a wrench by unscrewing them at the coupling near the end of the plug rather than sawing them remotely as was originally planned. After removing the pipe, the end of the plug read 200 mr/hr at contact. The shield cap was placed over the end of the plug because it was available, although it was not really needed. The plug was removed from the building and stored outside temporarily until it was determined that the new plug was satisfactory.

The new plug was then placed on the removal dolly and checked for alignment. The shutter was opened and the plug was manually pushed into the hole by personnel who stood behind the plug which provided adequate shielding against the radiation from the hole.

Radiation readings under various conditions during interchange of plugs are given in Figure 1.12.

The entire operation of removing the original plug and inserting the new plug was accomplished without any unusual incident. The maximum exposure of personnel to radiation was 40 mr which is quite low considering the nature of the job.

Radiation measurements with the new plug installed are shown in Figures 1.13 and 1.14.

Facility Assignment

Table 1.5 outlines usage of the ORR during the quarter.

TABLE 1.5. ORR FACILITY ASSIGNMENT

Facility	Access Flange	Nature of Experiment	Division Sponsor
A-1, A-2	V-11	Pressurized water loop, MSR	Reactor Projects
A-3, A-7 C-2, D-9 F-5		Radioisotope production	Isotopes
B-1, B-2	V-10	Gas-cooled loop No. 1	Reactor Projects
B-8, E-9 C-3	V-1, V-3	Radiation damage studies	Solid State
B-9	V-2	Gas-cooled loop	Solid State

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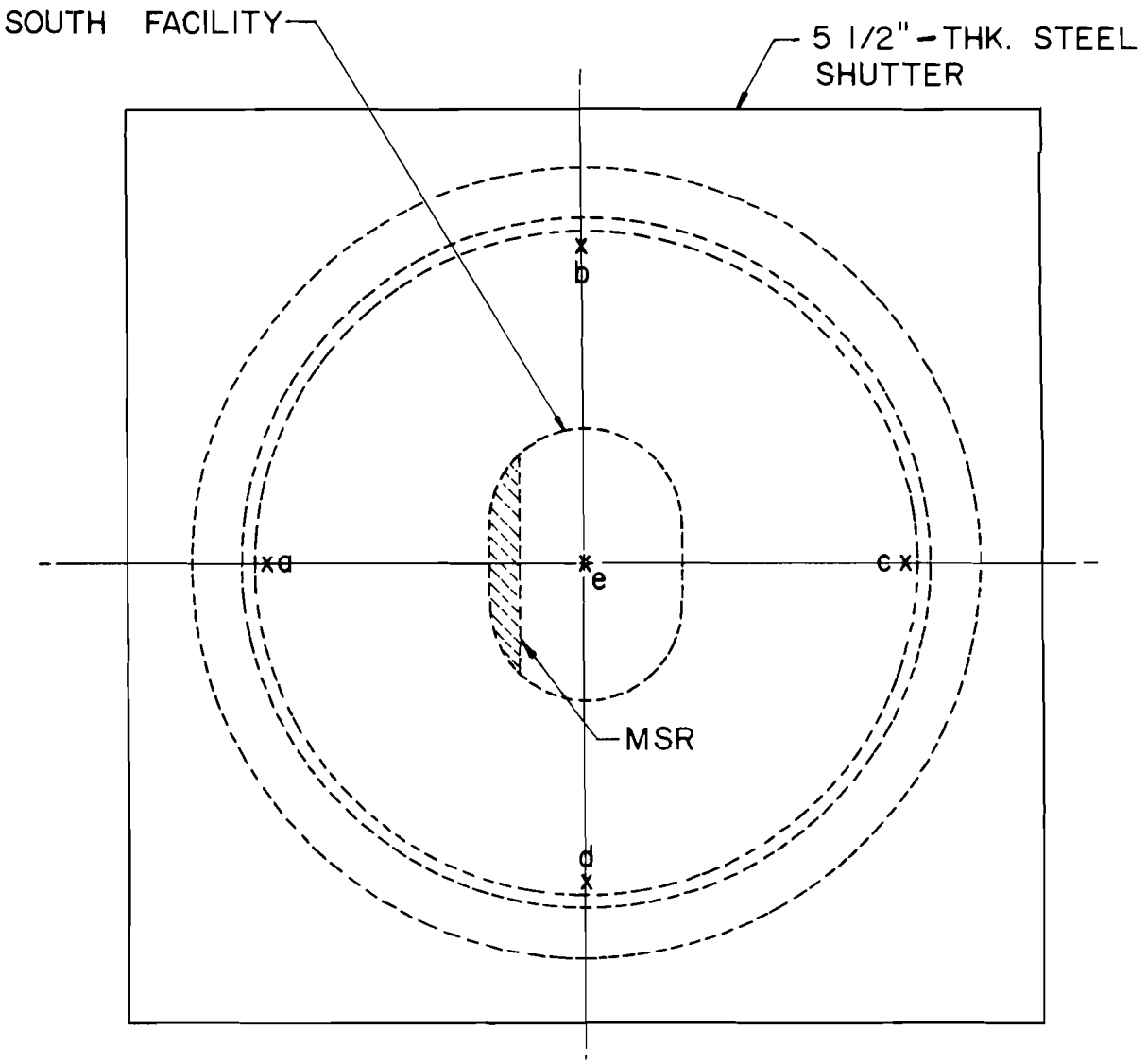

CONDITIONS: FACILITY PLUG REMOVED
STEEL SHUTTER CLOSED
CORE AS SHOWN IN FIG. 1.8, COND. 2
READINGS MADE ON 7/19/60

POSITION	RADIATION READINGS - mr/hr
a	70
b	150
c	220
d	80
e	200

FIG. 1.11 RADIATION READINGS AT SOUTH ENGINEERING TEST FACILITY

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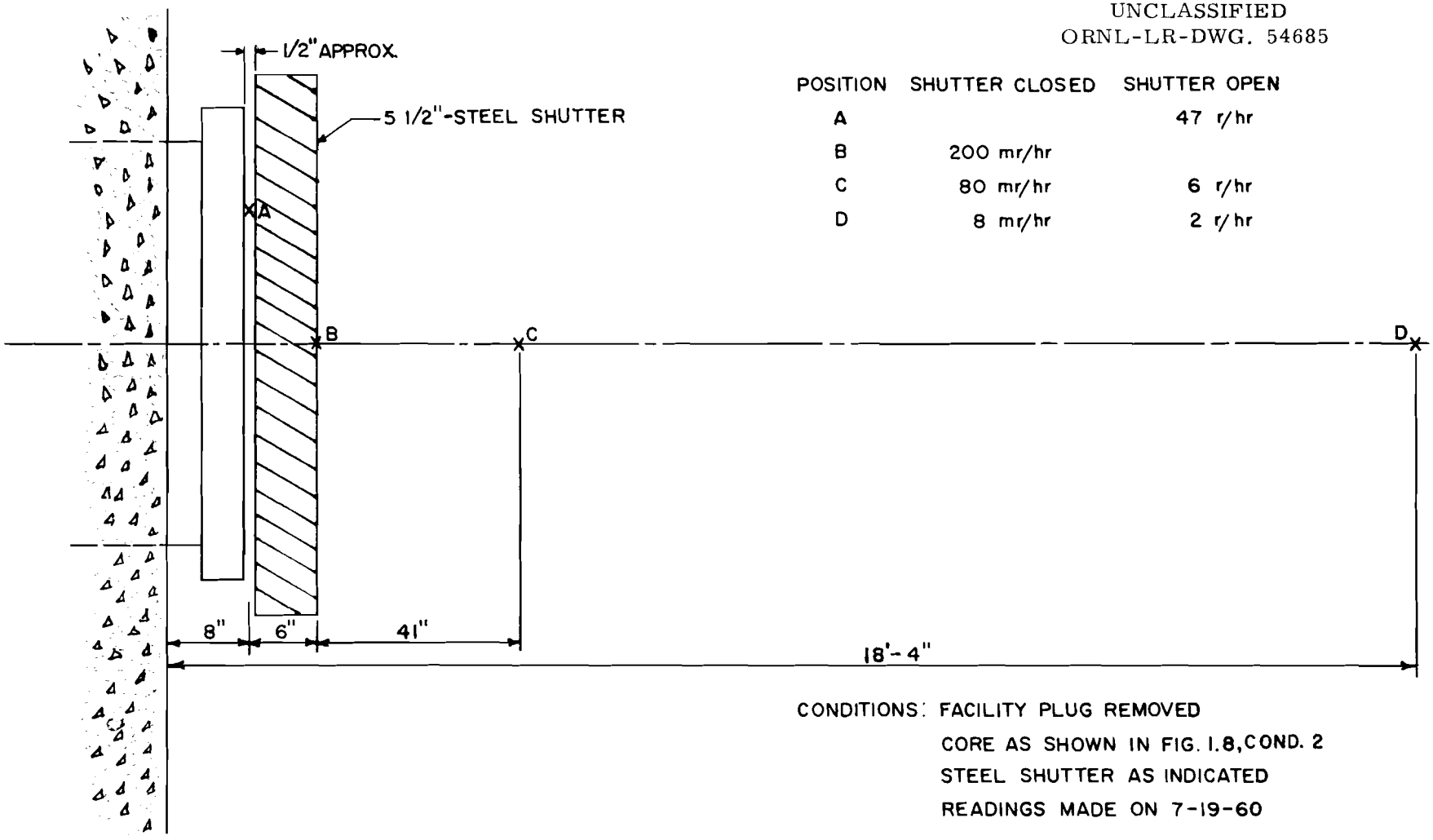

POSITION	SHUTTER CLOSED	SHUTTER OPEN
A		47 r/hr
B	200 mr/hr	
C	80 mr/hr	6 r/hr
D	8 mr/hr	2 r/hr

CONDITIONS: FACILITY PLUG REMOVED
CORE AS SHOWN IN FIG. 1.8, COND. 2
STEEL SHUTTER AS INDICATED
READINGS MADE ON 7-19-60

FIG. 1.12 RADIATION READINGS AT SOUTH ENGINEERING TEST FACILITY

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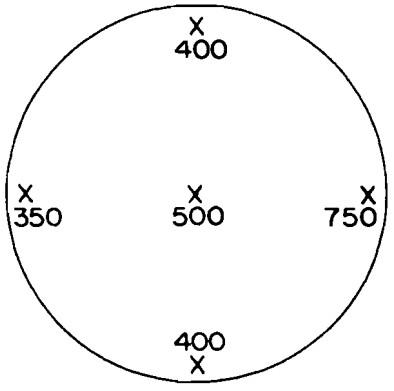
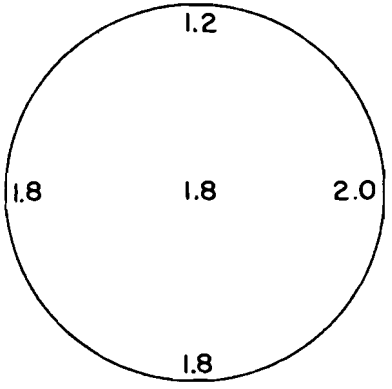


24"-DIAMETER EXTENSION LINER
MEASUREMENTS IN mr/hr DATE: 7-20-60
CONDITIONS: CORE SAME AS FIG.1.8 CONDITION 2
24"-DIAMETER HOLE EMPTY
1"-THICK STEEL BLIND FLANGE
BOLTED TO THE EXTENSION LINER



24"-DIAMETER EXTENSION LINER
MEASUREMENTS IN r/hr DATE: 7-20-60
CONDITIONS: CORE SAME AS FIG.1.8 CONDITION 2
24"-DIAMETER HOLE EMPTY
1"-THICK STEEL BLIND FLANGE REMOVED
NOTE: GAMMA MEASUREMENT 28' FROM
FACE OF PLUG FLANGE 60 mr/hr

FIG. 1.13 GAMMA MEASUREMENTS WITH NEW SOUTH ENGINEERING TEST FACILITY PLUG INSTALLED

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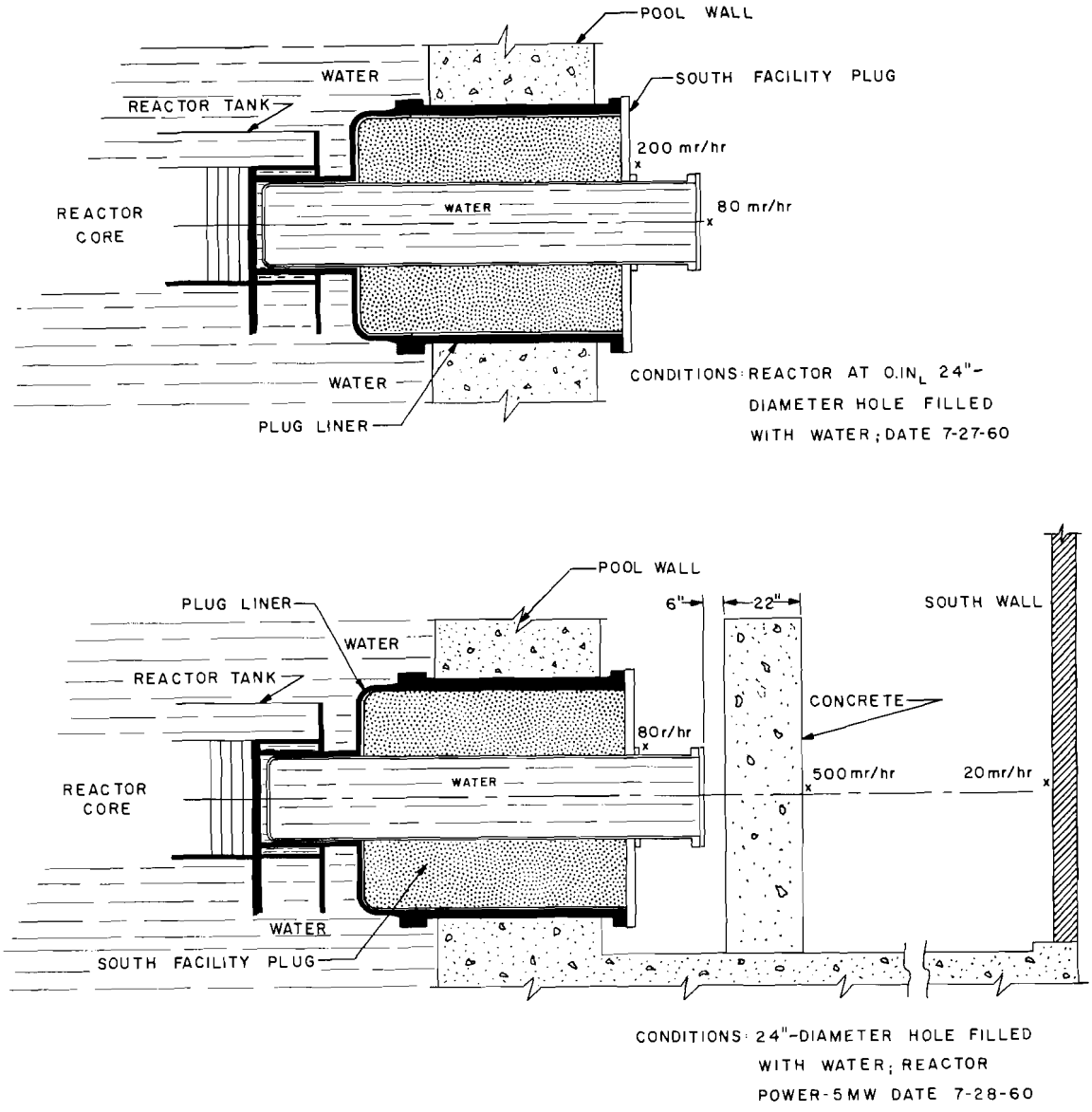

FIG. 1.14 GAMMA MEASUREMENTS WITH NEW SOUTH ENGINEERING TEST FACILITY PLUG INSTALLED

TABLE 1.5. (Continued)

Facility	Access Flange	Nature of Experiment	Division Sponsor
C-1	V-9	Fuel tests	Solid State
F-1	V-8	Solid fuel studies	Reactor Projects
F-2	V-6	Fuel tests	Reactor Projects (GE)
F-3	V-7	Ne^{23} studies	Physics
F-8	V-4	Hydraulic rabbit	Isotopes-Solid State
F-9	V-5	Fused-salt loop	Reactor Chemistry
P-1, 2, 3, 7, 8, and 9		EGCR capsule irradiations	Reactor Projects
P-4, P-5		Radiation damage	Solid State
P-6		He^6 studies	Physics
HN-1		Homogeneous fuel loop	REED
HN-3		Pneumatic rabbit for activation analyses	Chemistry-Analytical Chemistry
HN-2, HN-4			Operations
HS		Gas-cooled loop No. 2	Reactor Projects
HB-1		Magnetic analysis of fission fragments	Physics
HB-2		Neutron spectrometer	Solid State
HB-3		Neutron spectrometer	Physics
HB-4		Neutron spectrometer	Chemistry
HB-5		Neutron spectrometer	Physics
HB-6		Time-of-flight spectrometer	Physics

Information on new experiments in the ORR is given in Table 1.6.

TABLE 1.6. NEW ORR EXPERIMENTS INSTALLED OR OPERATED

Date Installed	Division Sponsor	Expected Duration	Facility	Experiment Description
8-14-60	Reactor	Indefinite	B-1	GCRP Loop No. 1*
9-8-60	Reactor Chemistry	Indefinite	F-9	Fuel meltdown*

*No sample, experiment facility equipment only.

1.2. Beryllium Reflector Pieces

J. F. Wett

The final assembly of the beryllium reflector pieces for the Poolside Critical Facility has been completed. The mechanism for removal and replacement, under water, of the end boxes on the radioactive beryllium has been tested and found acceptable.

1.3. Local Flux Distributions in ORR Fuel Elements

A. L. Colomb and J. F. Wett

The detailed study of the thermal neutron flux distribution in the ORR has been continued.[1] Results to date have indicated that rather large flux gradients exist radially across the MTR-type fuel element employed in this reactor and that these gradients are strongly dependent on the fuel concentration in the element being investigated, as well as that of the adjacent elements.

Figure 1.15 shows the geometrical pattern of the standard ORR core, and Table 1.7 presents the complete set of fuel weights loaded in the core for each experiment represented by the subsequent figures. Because of the operating schedule of the ORR and the time lapse between data gathering and analysis, loading of identical cores was impossible. A flux traverse along the center plane of the "4" column at a distance of 16 inches from the top of the fuel plates is shown in Figure 1.16. The traverse is shown at 16 inches because the peak axial flux occurs at approximately 16 inches from the top of the fuel plates. Fluxes have been normalized to the highest measured value in the "4" column at the 16-inch level.

It must be pointed out that 131 g of U^{235} in the shim rod gives the same fuel density in its fuel plates as that for a 200-g fuel element. However, due to the structure of the shim rod, the metal-to-water ratio of the fuel follower is not the same as it is for a fuel element.

It is interesting to note that the ratio of maximum extrapolated flux to minimum measured flux along the center plane is 2.3 for A-4 and 1.3 for E-4. It is perhaps more interesting to observe that the ratio of maximum extrapolated flux to center flux is 1.4 for A-4, 1.3 for C-4, and 1.1 for E-4. For routine core flux measurement in the ORR, it is common practice to measure fluxes in the geometric center of each fuel element. However, one sees that such a measurement gives a value far below the maximum flux in certain cases. The implications of such a situation for hot spot analyses and fuel consumption calculations are evident. The validity of the flux interpolation between elements, and of the flux shape in the shim rod is shown in Figures 1.17 and 1.18. In order to check the validity of the

[1] J. A. Cox, Reactor Operations and Radioactive Waste Operations Quarterly Report, January - March 1960, CF-60-3-148 (May 24, 1960).

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	1	2	3	4	5	6	7	8	9
A	Be	Be	Be	F	F	F	Be	Be	Be
B	Be	Be	F	S	F	S	F	Be	Be
C	Be	Be	F	F	F	F	F	F	Be
D	Be	F	F	S	F	S	F	F	Be
E	Be	F	F	F	F	F	F	F	Be
F	Be	Be	Be	Be	Be	Be	F	Be	Be
G	Be	Be	Be	Be	Be	Be	Be	Be	Be

F – FUEL
S – SHIM ROD
Be – BERYLLIUM REFLECTOR

Fig. 1.15. Core Loading Pattern of ORR.

TABLE 1.7. FUEL WEIGHT LOADED IN ORR FOR VARIOUS FLUX MEASUREMENTS (IN GRAMS)

Position	Figures 1.16 and 1.17	Figure 1.18	Figure 1.19
A-4	163	176	169
A-5	169	161	169
A-6	166	168	167
B-3	193	192	192
B-4	142	46	132
B-5	153	140	156
B-6	110	120	102
B-7	189	189	188
C-3	131	112	148
C-4	148	151	147
C-5	163	140	163
C-6	146	200	180
C-7	157	147	157
C-8	161	157	200
D-2	159	179	159
D-3	189	173	175
D-4	91	102	82
D-5	161	138	160
D-6	69	131	60
D-7	188	157	157
D-8	142	170	121
E-2	160	183	157
E-3	189	189	172
E-4	188	188	200
E-5	158	152	179
E-6	159	173	175
E-7	187	156	158
E-8	162	142	200
F-7	148	158	148

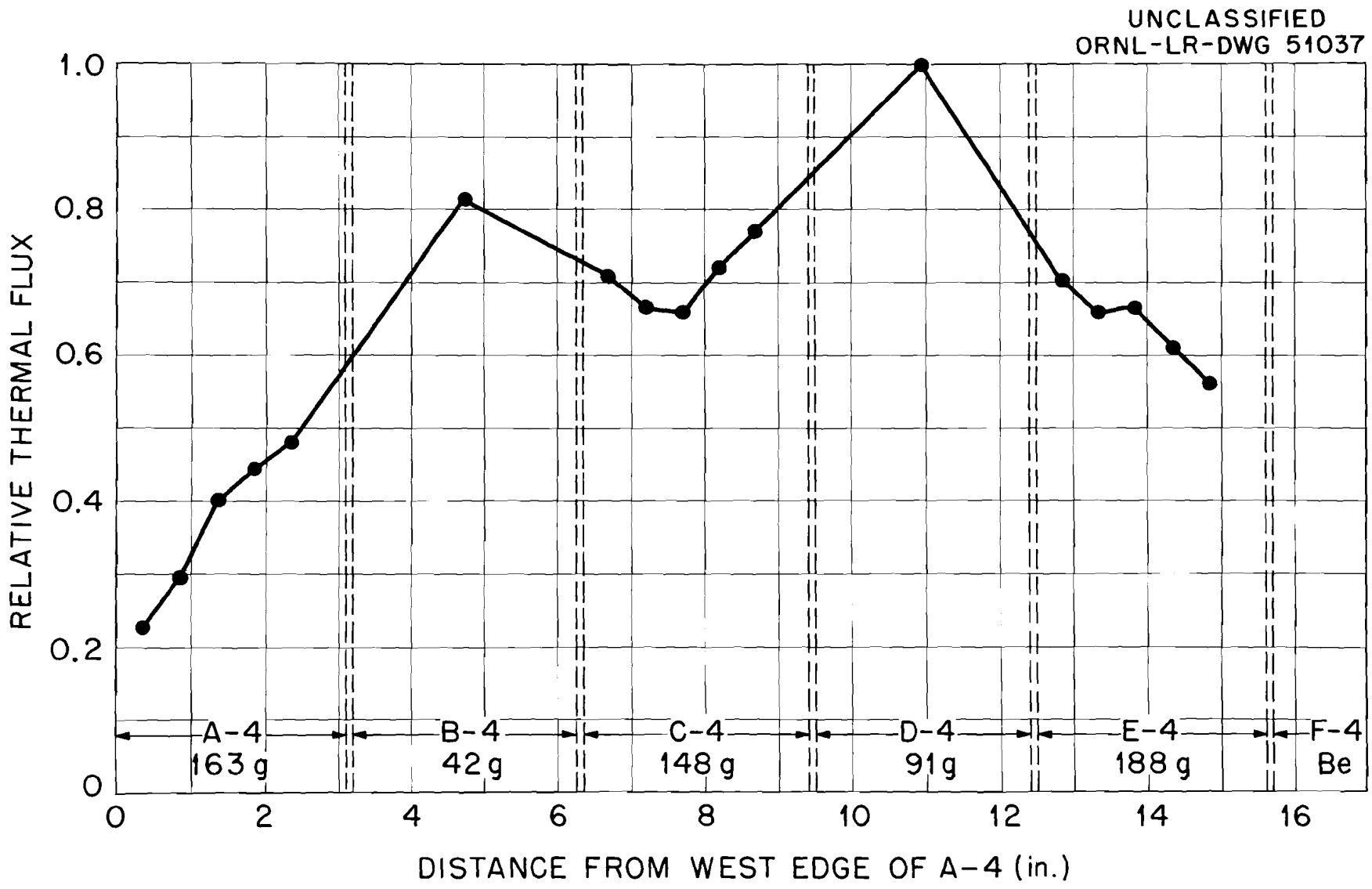

Fig. 1.16. Flux Traverse Along Center Plane of "4" Column.

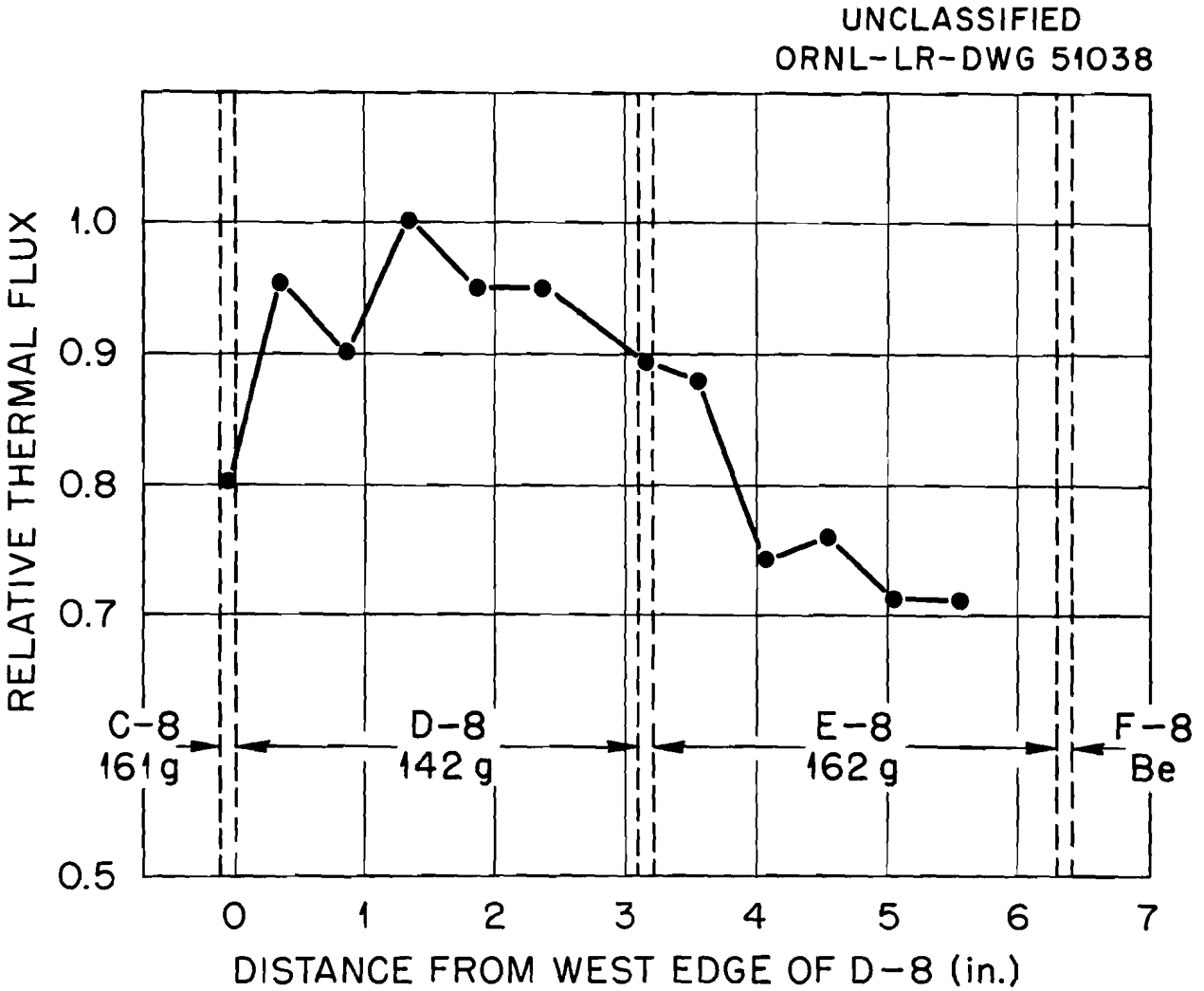

Fig. 1.17. Flux Traverse for D-8 and E-8 12 in. from Top of Fuel.

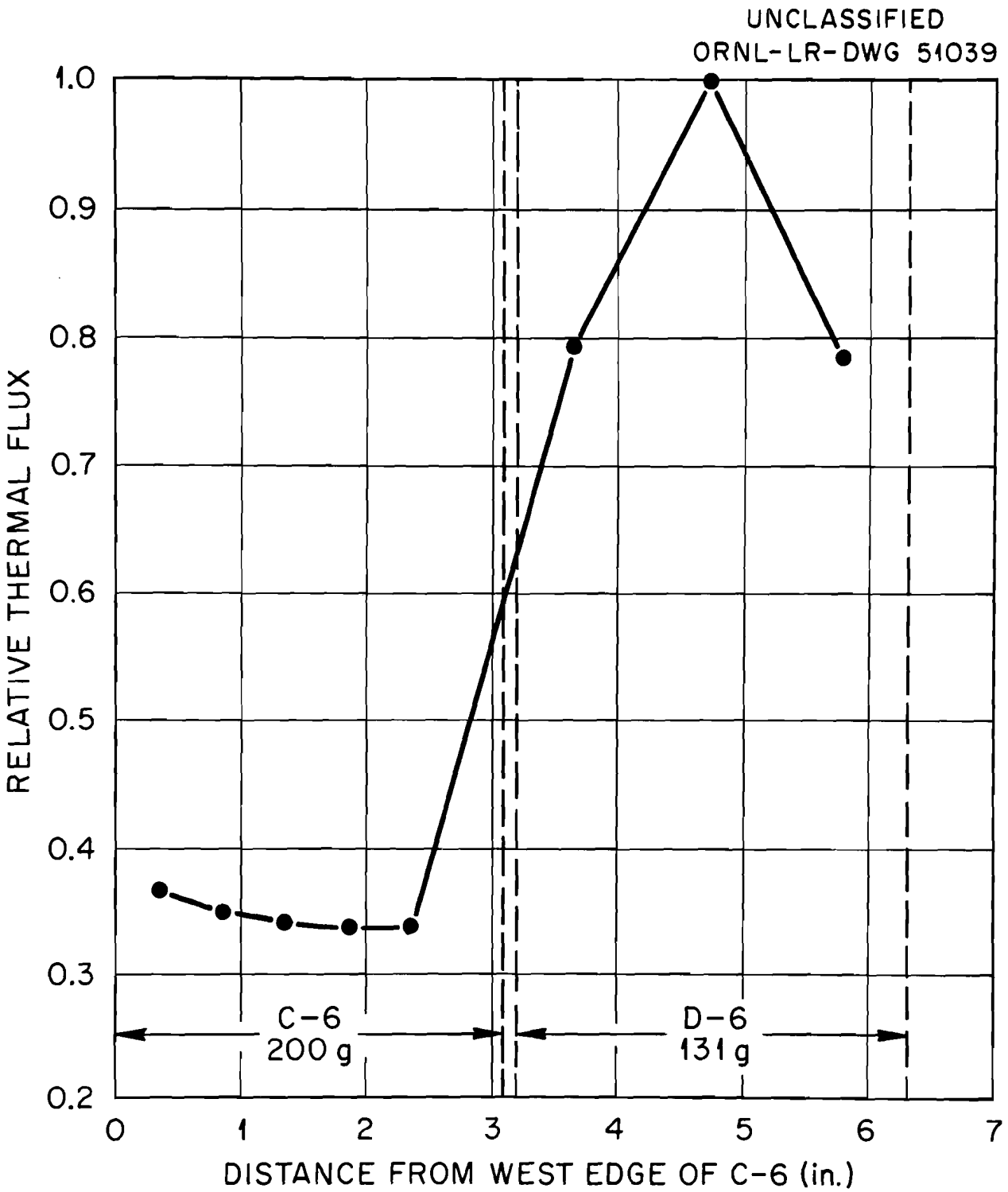

Fig. 1.18. Flux Traverse for C-6 and D-6 at Water Gap in Shim Rod.

interpolation, flux monitors were placed in core positions D-8 and E-8, between elements in C-8 and D-8, and between D-8 and E-8. Results are shown in Figure 1.17 and indicate a smooth flux transition between elements.

Due to the construction of the upper portion of the shim rod, only one wire could be accurately placed in an irradiated rod. However, it was possible to place three wires in a new shim rod.

A flux traverse taken through the 131-g, shim-rod fuel section and a 200-g adjacent element showed only a small ripple, indicating that the difference in metal-to-water ratio existing between a normal fuel element and a shim-rod fuel section does not have a drastic effect on flux distribution. This result, however, did not settle the problem of interpolation between a central flux value in the fuel section of a burned shim rod and the flux values in the adjacent elements. Figure 1.18 shows a flux traverse through the two-inch water gap located between the fuel and the poison sections of the shim rod. The flux has the same general shape as that assumed on Figure 1.16. It is felt that the results shown in Figures 1.17 and 1.18 validate the smooth flux traverse between elements and the general pattern of the peaking in the shim rods.

A measurement of the flux distribution from side plate to side plate was also made. Four wires were placed at equal distances in a polyethylene holder. Four of these holders were placed in coolant channels in each of two new fuel elements. The two elements were then placed in positions C-8 and E-8. Five wires were placed in the element located in position D-8. From the 37 flux values thus measured, an iso-flux pattern for the three elements C-8, D-8, and E-8 could be plotted. Such a pattern is shown in Figure 1.19 for a cut 16 inches below the top of the fuel. The iso-flux lines are normalized to the highest flux measured in position E-8. The fluxes shown as greater than one were extrapolated from plots of flux across the channels.

The difficulty in choosing the proper single point at which to measure flux is obvious. If one should choose the geometric center, physically the easiest point at which to make measurements, one measures only 0.91 times the highest flux in D-8, 0.74 times the highest flux in E-8, and 0.61 times the highest flux in C-8. The situation concerning the average flux is even more uncertain. It is interesting to note the effect of the beryllium reflector. One sees that the reflection very nearly makes the iso-flux lines symmetric about the center line of column "8".

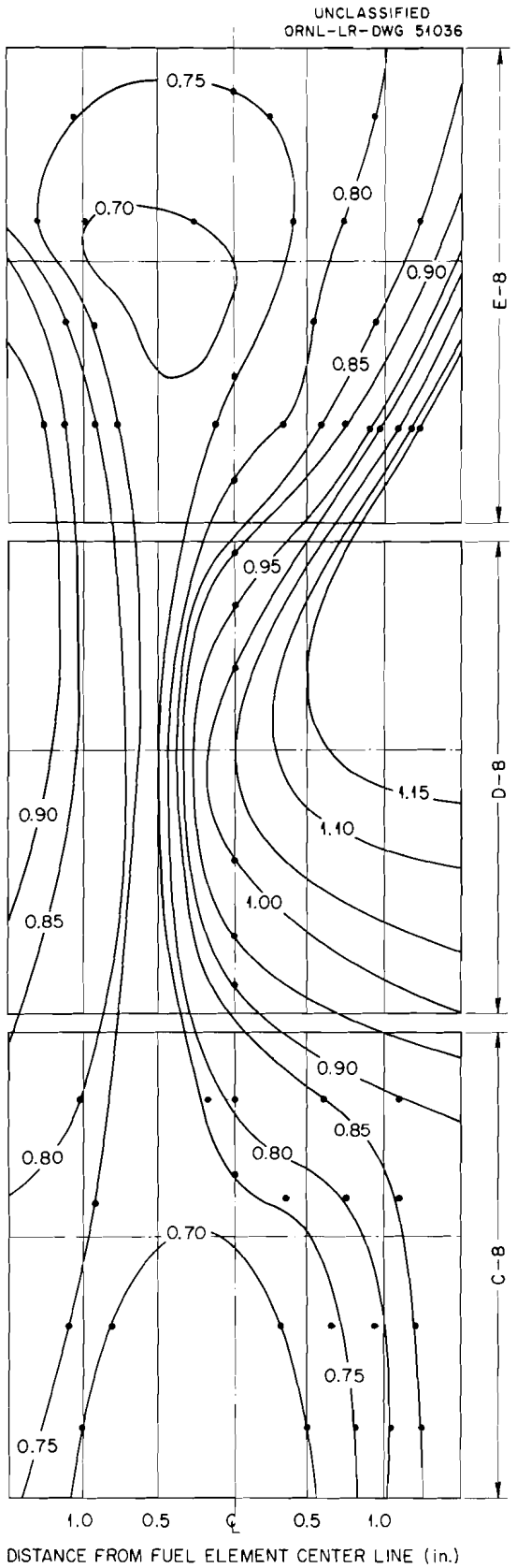

Fig. 1.19. Iso-Flux for Core Positions C-8, D-8, E-8 Normalized to Highest Measured Value in E-8.

At this point there are several conclusions which can be drawn. The first is that when a heavily burned element (low fuel density) is placed next to a new element (high fuel density) the flux will peak in the burned element and will show a depression in the new element. Such a condition is not unexpected since, in the first approximation, local flux varies as the inverse of the local macroscopic absorption cross section $\sum_a$, and the burned element will have a lower $\sum_a$. For the cases measured here, the magnitude of the peak-to-center ratio in the new element was as high as 1.6. The second conclusion is that the placing of large water gaps, such as that which exists between the fuel and the cadmium sections in the shim rod, can cause large peaks in the adjacent element. If these peaks raise the flux in a high-density fuel region, high power density or, in other words, hot spots have to be expected. The case of a new element is clear because the fuel concentration is uniform. Thus, one may infer that placing new elements next to heavily burned ones or next to water gaps should be done with care being given to the subsequent flux peaks and power-density peaks. The case of burned elements is more difficult. It is evident that the geometrical variation of fuel density will be a function of the prior flux history. It is also evident that the high-density regions will locally suppress the flux. However, it is conceivable that a power-density peak of unexpected proportion may be found at various spots.

PART III

Taken from OPERATIONS DIVISION QUARTERLY REPORT

October - December, 1960, ORNL CF-60-12-122

REACTOR OPERATIONS
RADIOACTIVE WASTES OPERATIONS
AND HOT CELLS OPERATIONS
QUARTERLY REPORT

Summary

The operating time at the ORR increased to 82% this quarter--the highest on-stream time to date. Mechanical trouble was encountered with the ball-latch mechanism on the ORR control-rod drives. Some of the rods failed to function properly during prestartup checks, and the drives had to be replaced. A study is being made of the causes of the failures.

Studies of 40-Mw operation show that it would be more economical to use the existing air coolers than provide coolers of a different type. However, since these coolers would contain primary water, they would be very radioactive in event of a fuel meltdown.

1. OAK RIDGE RESEARCH REACTOR

1.1. Operations

W. R. Casto

Operations

The ORR was operated during this period at a power level of 30 Mw. Total operating time for the quarter was 1810.1 hr. Because of the eight-week cycle adopted with 30-Mw operation, the operating time was increased to 82%--the highest since the beginning of operation.

TABLE 1.1. ORR OPERATIONS

Period October 1, through December 31, 1960

	This Quarter	Last Quarter	Year to Date
Total energy, Mwd	2246.3	1075.9	5997.5
Average power, Mw/operating hr	29.8	24.1	22.7
Time operating, %	82.0	48.5	72.6
Reactor water radioactivity, c/m/ml (av)	42,644	29,687	27,436
Pool water radioactivity, c/m/ml (av)	913	721	658
Reactor water resistivity, ohm-cm (av)	444,000	547,000	550,000
Pool water resistivity, ohm-cm (av)	663,000	699,000	736,000
Research samples	6	4	53
Radioisotope samples	104	124	664

The core configuration at the end of the quarter is unchanged from that of 6-30-60 and is indicated in Figure 1.1.

Cycles of operation during this period are shown in Table 1.2.

TABLE 1.2. ORR CYCLES OF OPERATION

Cycle No.	Date Begun	Date Ended	Accumulated Energy (Mw)
30	October 4	November 20	1,354.2
31	December 1	In Progress	892.1

Figures 1.2 and 1.3 indicate shim-rod positions versus the operating

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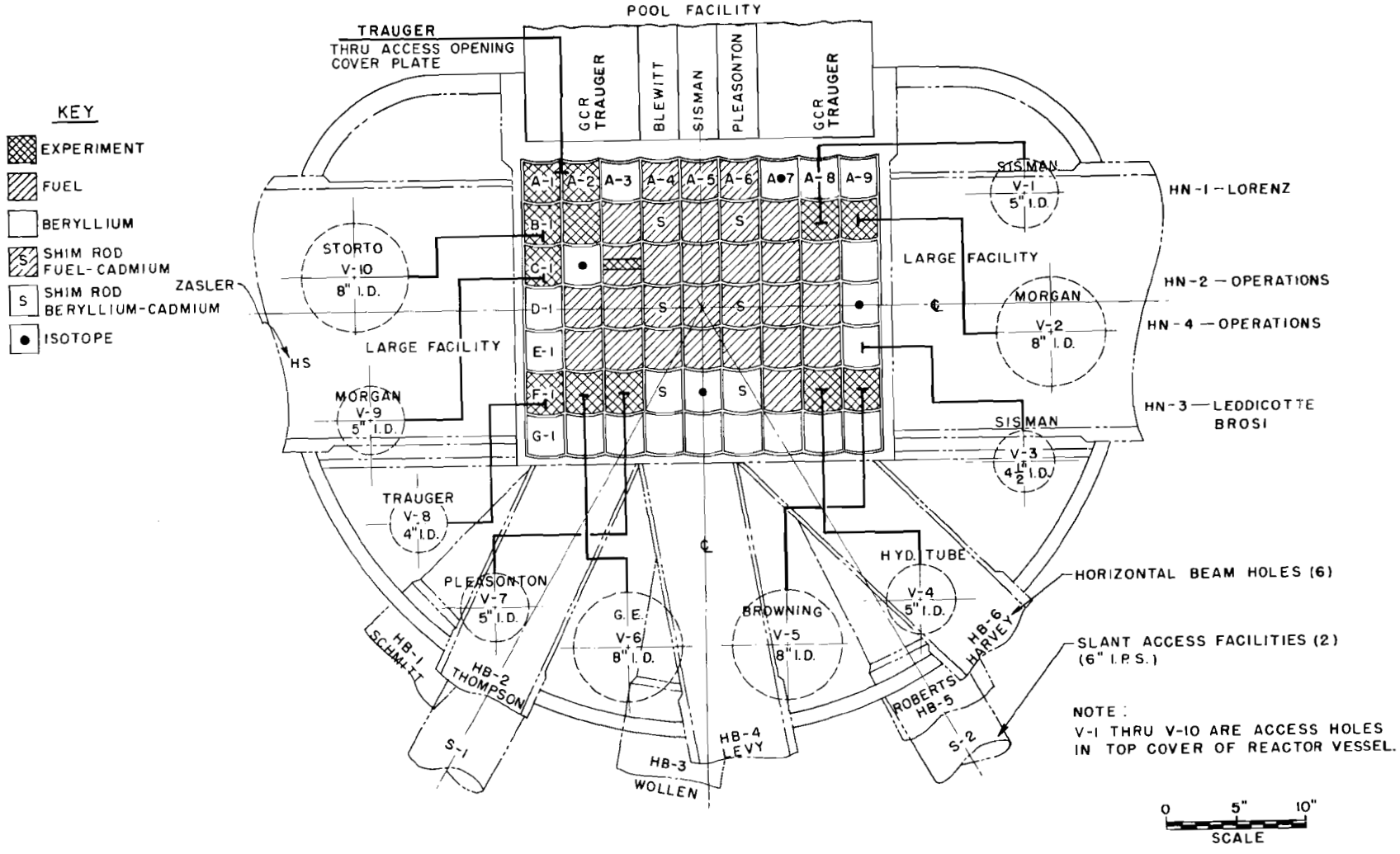

FIG. 1.1

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

RESEARCH ASSIGNMENTS & FUEL LOADING ON 12-31-60

C-33561

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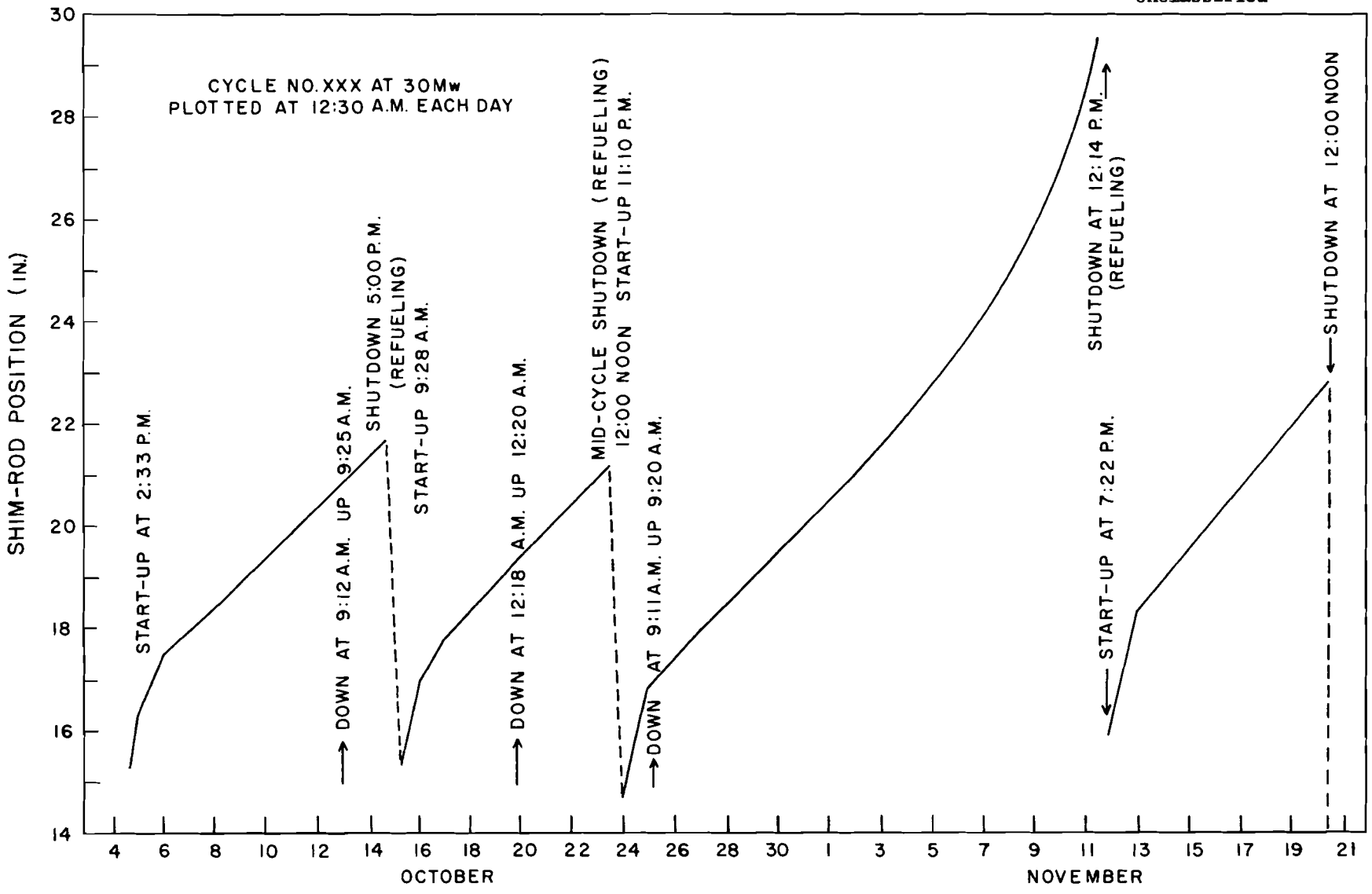

FIG. 1.2 - SHIM ROD POSITION VS. TIME

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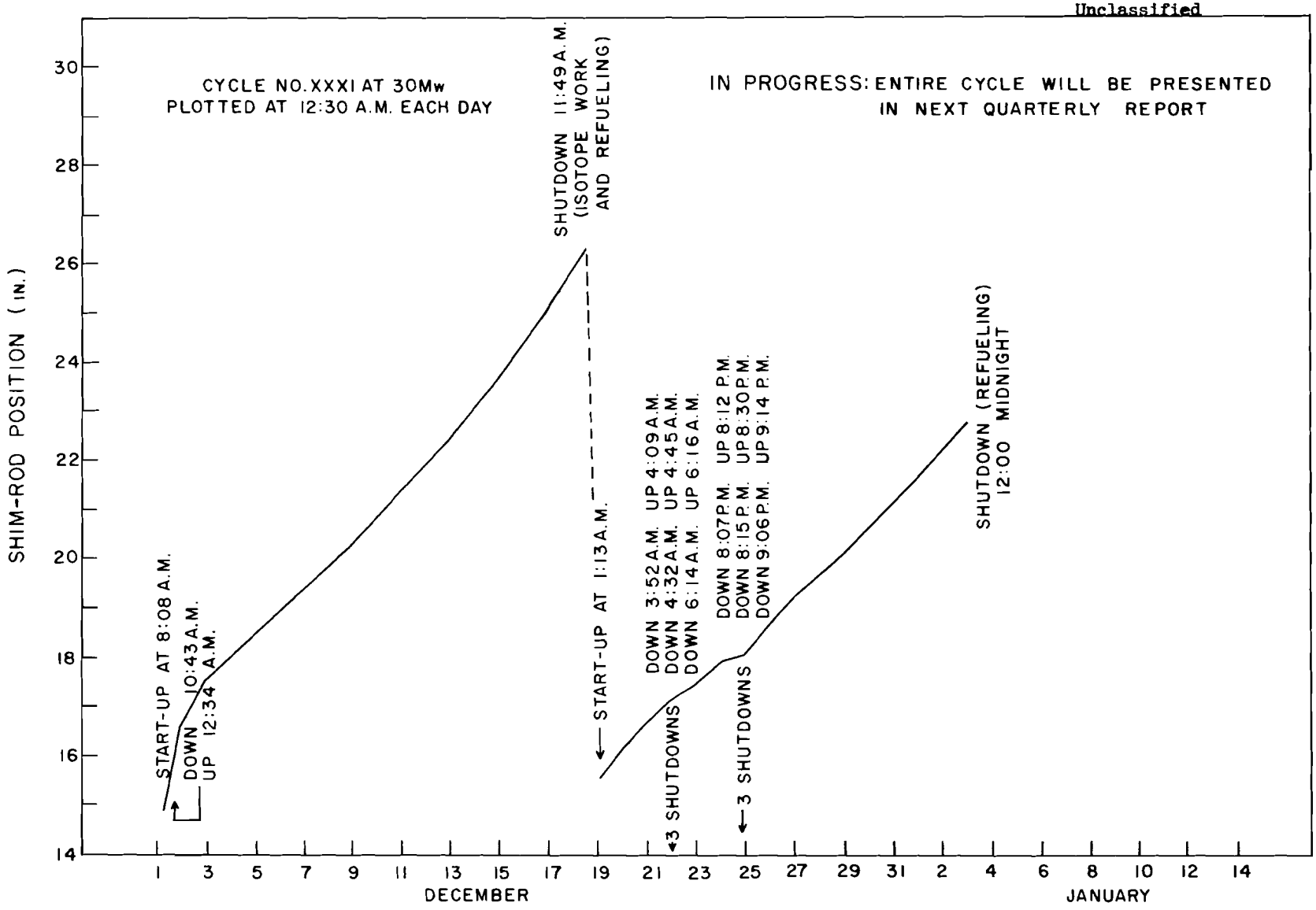

FIG. 1.3 - SHIM ROD POSITION VS. TIME

time during cycles 30 and 31 (in progress), respectively.

Shutdowns

Two major shutdowns occurred during the period.

In Progress through October 4, 1960. The installation of lead shielding at the south facility for GCRP Loop No. 2 continued from last quarter. This was the major work done during this shutdown.

November 20 through December 1. Activities during this period involved: inspection, repair, and leak checking of several slip-joints in GCR Loop No. 1; reinstallation of the repaired "meltdown experiment" facility tube and associated equipment; replacement of five other experiments, one of which (core position B-3) was subsequently removed due to improper alignment.

At the end of the scheduled shutdown period, extensive difficulties were experienced with the shim-rod drives. This prolonged the shutdown four days (see Reactor Controls).

Table 1.3 lists the unscheduled shutdowns which occurred this quarter.

TABLE 1.3. UNSCHEDULED SHUTDOWNS AT THE ORR

Date	Duration (hr)	Remarks
10-13-60	0.217	Scram due to human error. The No. 1 Log-N chamber was adjusted without switching to channel No. 2. The chamber slipped in, giving a false, fast-period scram.
10-19-60	0.033	Setback and reverse from MSI experiment. The recorder on thermocouple TR-12 failed intermittently. The standard cell was replaced. The recorder will be replaced during the next end-of-cycle shutdown.
10-24-60	0.150	Setback from core position F-2 experiment. Thermocouple TC-7 on TR-5 (recorder) opened and resulted in upscale "burnout" from the recorder. The thermocouple was replaced with a spare.
12-22-60	0.283	Setback from EGCR capsule No. 8. Recorder TR-81 drove upscale due to a standardization switch malfunction and stuck the recorder switches. The recorder switches were released and the standardization switch adjusted.

TABLE 1.3. (continued)

Date	Duration (hr)	Remarks
12-22-60	0.217	Setback and reverse from core position F-2 experiment. Recorder TR-11 drove upscale due to electronic tube failure. During the start-up after the shutdown, shim rod No. 4 dropped, reason unknown.
12-22-60	0.033	Shim rod No. 1. dropped, reason unknown.
12-24-60	0.083	Setback and reverse from EGCR capsule No. 8. Recorder TR-81 drove upscale due to standardization switch malfunction and the backup reverse recorder switch stuck. The recorder switches were released and standardization switch adjusted.
12-24-60	0.250	Setback from EGCR capsule No. 8. Recorder TR-81 drove upscale again due to further standardization switch malfunction. The switch was replaced.
12-24-60	0.133	Shim rod No. 5 dropped, reason unknown.

There were no shutdowns due to real cause; i.e., a condition existed which was such that without reactor power reduction an experiment and/or the reactor could be damaged.

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

TABLE 1.4. ANALYSIS OF ORR SHUTDOWNS

Description	Number	Down Time (hr)
Scheduled Shutdowns		
Regular, end-of-cycle	1	346.466*
Regular, midcycle and isotope work	2	24.567
Regular, refueling	1	7.134
Experiment removal	2	18.317
Subtotal	6	396.484

*Including 86.550 hrs during the shutdown in progress at the beginning of this quarter.

TABLE 1.4. (continued)

Description	Number	Down Time (hr)
Unscheduled Shutdowns		
Instrument failure, reactor controls	0	
Instrument failure, experiments	6	1.016
Rod drops	2	0.166
Human error	1	0.217
Subtotal	9	1.399
Total	15	397.883

Reactor Controls

During the shutdown following cycle 30, considerable difficulty was experienced with the drive mechanism on shim rods No. 3, 4, 5, and 6 (see Table 1.5). All of these rods had functioned properly during the shutdown at the end of the cycle, but about one week later many difficulties were encountered. Three of the four rods failed to drop during prestartup tests, and the fourth gave some indication of trouble. Inspection of the faulty drive units indicated excessive wear and indentations on all plungers[1] of the ball-latch mechanism and the presence of foreign matter, similar to lubricant, on the body of one of the plungers.

During the month of December, unexplained rod drops were experienced. A special design group from the Reactor Division has been assigned to work on the problems with rod drives.

An alarm was provided to warn of low water level in the reactor cooling-tower basin. This alarm was installed on a temporary basis until the next end-of-cycle shutdown.

[1] T. E. Cole and J. P. Gill, The Oak Ridge Research Reactor (ORR) A General Description, ORNL-2240 (January 21, 1957).

TABLE 1.5. MALFUNCTION OF REACTOR CONTROLS--ORR

Date	Description
10-12-60	The control system transferred from the servo to the manual mode of operation apparently due to the momentary opening of a shim-rod clutch switch.
11-28-60	Drive mechanisms were replaced on shim rods No. 4 and 6 after the rods failed to drop during instrument checks on separate occasions.
11-29-60	The drive mechanism on No. 3 shim rod was replaced when the "push rod" unit was checked and did not operate freely. The drive mechanism on No. 5 rod was replaced after the rod failed to drop during a prestartup test.
12-8-60	While attempting to reposition No. 2 safety chamber, it was noted that after inserting two notches on the positioning device the second move resulted in a fourfold increase as compared to the first move. Upon withdrawing three notches, no change in reading (102%) was obtained. Withdrawing an additional notch resulted in a large decrease to (87%). The chamber was then reinserted three notches, resulting in a final reading of 94%. The above indicates that the chamber was sticking in the guide and that the positioning wire was dragging. This situation is to be examined during the next end-of-cycle shutdown.
12-20-60	The northeast gamma-chamber channel was found to be spiking upscale concurrently with downscale spiking of the southeast gamma-chamber channel. These chambers had a common power supply. After separate power supplies were provided the northeast channel operated properly, but the southeast channel continued to spike downscale. Because a thorough check of its associated instrumentation revealed no fault, it is assumed that the southeast gamma chamber failed. This channel was shut off and the chamber will be examined during the next end-of-cycle shutdown.
12-22-60	Two shim rods (No. 1 and 4) dropped, reason unknown.
12-24-60	During two "backup reverses" from experiments, the reactor control system did not switch from servo to the manual mode of operation. This is being investigated.
12-24-60	Shim rod No. 5 dropped, reason unknown.

Facility Assignment

Table 1.6 outlines usage of the ORR during the quarter.

TABLE 1.6. ORR FACILITY ASSIGNMENT

Facility	Access Flange	Nature of Experiment	Division Sponsor
A-1 and 2	V-11	Pressurized water loop, MSR	Reactor
A-3 and 7, C-2, D-9, and F-5		Radioisotope production	Isotopes
B-1 and 2	V-10	Gas-cooled loop No. 1	Reactor
B-8, E-9, and C-3	V-1 and 3	Irradiation damage studies	Solid State
B-9	V-2	Gas-cooled loop	Solid State
C-1	V-9	Fuel tests	Solid State
F-1	V-8	Solid fuel studies	Reactor
F-2	V-6	Fuel tests	Reactor (GE)
F-3	V-7	Ne^{23}	Physics
F-8	V-4	Hydraulic rabbit	Isotopes--Solid State
F-9	V-5	Fuel meltdown loop	Reactor Chemistry
P-1, 2, 3, 7, 8, and 9		EGCR capsule irradiations	Reactor
P-4 and 5		Radiation damage	Solid State
P-6		He^6	Physics
HN-1		Homogeneous fuel loop	Reactor
HN-3		Pneumatic rabbit for activation analysis	Chemistry--Analytical Chemistry
HN-2 and 4			Operations
HS		Gas-cooled loop No. 2	Reactor
HB-1		Magnetic analysis of fission fragments	Physics
HB-2		Neutron spectrometer	Solid State
HB-3		Neutron spectrometer	Physics
HB-4		Neutron spectrometer	Chemistry
HB-5		Neutron spectrometer	Physics
HB-6		Time-of-flight spectrometer	Physics

A list of new experiments operated during the quarter is given in Table 1.7.

TABLE 1.7. NEW ORR EXPERIMENTS INSTALLED OR OPERATED

Date Installed	Division Sponsor	Expected Duration	Facility	Experiment Description
10-3-60	Reactor	One cycle	B-1	"Cold finger" to provide cooling in absence of sample
10-3-60	Reactor Chemistry	One cycle	F-9	Temperature monitor installed in experiment tube[a]
11-23-60	Solid State	One cycle	P-5	"Columbium tube burst" experiment
11-24-60	Solid State	One cycle	B-8	"Be tube burst" experiment
11-24-60	Solid State	One cycle	P-4	"Be tube burst" experiment
11-24-60	Reactor Chemistry	Indefinite	F-9	Replace experiment tube
11-25-60	Reactor	One cycle	B-1	Installed "Charpy test" sample[b]

[a] The experiment tube was removed on 10-15-60 due to failure of a weld where a 1/2-in. stainless steel tube was welded into a 1-in. stainless steel pipe. The latter pipe was also broken off just under the top-of-tank access flange due to hydraulic forces.

[b] During the approach to power for the following cycle, it developed that the loop cooling would not maintain the desired sample temperatures above about 13 Mw. The reactor was shut down and the sample retracted.

1.2 Investigation of 40-Mw Operation of the ORR

J. F. Wett, Jr., and A. L. Colomb

An investigation is under way as to the feasibility of increasing the power of the ORR to 40 Mw. Most of the work so far has assumed the use of the Trane coolers since they are available. Certain difficulties have become apparent and further investigations are under way.

Maximum Power at Which the Present System can be Operated

Investigation of the daily temperatures occurring during the summer of 1960 reveals that between April 1 and September 30 the wet-bulb temperature will rise above 70°F on 68% of the days, above 80°F on 19% of the days, and above 85°F on 8% of the days. A maximum wet-bulb temperature of ~90°F was recorded on 1% of the days.

A study of the characteristics of the present tower and shell-and-tube combination indicates a maximum power removal capability of 31 Mw at 90°F, 34 Mw at 85°F, 36 Mw at 80°F, and 38 Mw at 70°F. All temperatures are ambient wet-bulb temperatures. This indicates that the reactor cannot be run continuously above 38 Mw from about April 15 to about September 30, continuously above 36 Mw from about May 15 to about September 15, or continuously above 34 Mw from about June 15 to about September 15. In the period June 15 to September 15, there would be several days at random where the power would have to be reduced to 30 Mw. It is evident that peak temperatures occur only for a few hours in each day.

The maximum wet-bulb temperature at which the reactor can maintain 40 Mw is ~67°F. This means that continuous operation at 40 Mw cannot be assured during the period April 1 to September 30. Therefore, one can conclude that, to avoid daily power fluctuations, the reactor could be run at 40 Mw for six months and 30 Mw for six months. However, certain experiments cannot be operated satisfactorily with such a power variation.

Use of Trane Coolers

The capability of a system which includes the Trane coolers in parallel with the shell-and-tube heat exchangers has been studied. Use of the Trane coolers presents certain hydraulic and control problems. At the present, the main cooling-system control is performed by actuating

a valve in the by-pass which, in turn, regulates the flow through the shell-and-tube heat exchangers. The flow distribution during operation of the two heat-exchanger systems in parallel is such that the by-pass valve must be operated closed or nearly so. The effect of such operation on the control system is under study at the present time. The problem is being set up for solution on the analog computer.

Using data taken on the two heat-exchanger systems during operation a rough estimate of flow conditions and thermal capacity have been made. The conditions selected were (1) dry-bulb temperature = 100°F; (2) wet-bulb temperature = 90°F; (3) flow in secondary of shell-and-tube heat exchangers = 10,000 gpm; and (4) reactor exit temperature = 135°F. The table below lists results for operation of all eight Trane coolers in parallel with the shell-and-tube heat exchangers. The results are certainly correct to no better than ±5%.

By-Pass Valve Position (% open)	Flow in S & T (gpm)	Flow in Trane (gpm)	Flow in By-Pass (gpm)	Maximum Capacity of S & T (Mw)	Maximum Capacity of Trane (Mw)	Total Maximum Capacity (Mw)
0	10,600	8,000	0	29.8	12.8	42.6
10	9,700	7,200	1,000	28.2	12.4	40.6
20	8,700	6,400	3,000	26.6	11.9	38.5
30	7,800	5,800	4,500	24.6	11.2	35.8
40	7,000	5,200	5,300	22.6	10.4	33.0

Heat Transfer in the Core

Analyses of the maximum temperatures to be found in the core for both nominal and hot-spot, hot-channel conditions have been made. These analyses have been based on gross flux measurements and do not consider the flux and power distributions throughout an element. At 18,000-gpm flow and 40 Mw the maximum nominal surface temperature of a fuel element is 212°F; the maximum hot-spot, hot-channel surface temperature of a fuel element is 250°F; the maximum nominal surface temperature of a shim rod is 230°F: and the maximum hot-spot, hot-channel surface temperature of a shim rod is 265°F. The saturation temperature in the core is 250°F, but

local boiling does not begin until the surface is 20°F above the saturation temperature or 270°F. Thus, one sees that local boiling should not exist for 40-Mw operation at a flow of 18,000 gpm.

A study has been made to determine the temperature which exists on the side of the plate opposite an occlusion which completely insulates the opposite side. Based on this study the allowable occlusion in a shim rod is one with a diameter of ~4 mils and that for a fuel element is ~10 mils. Such occlusions will not cause local boiling on the opposite side of the plate.

Further studies of the heat-transfer characteristics of the core are contemplated.

Safety Considerations with Respect to Trane Coolers

It is shown in the previous section that, if the reactor has to be operated at 40 Mw all year, the Trane coolers or other additional cooling will have to be used at least during six months. The Trane coolers, being operated with primary cooling water, can represent a radioactive hazard in the case of a reactor meltdown. An evaluation of this hazard has been done and the possibility of cleaning the primary cooling system analyzed.

Starting with an average ORR core at the end of an average fuel cycle and assuming that 1% of the core total fission-product contents (~1 gm) will get into solution in the primary cooling system, the concentration of fission products will be:

0.0062 curies/cm^3 at the time of the meltdown
0.0053 curies/cm^3 10 min after meltdown
0.0039 curies/cm^3 1 hr after meltdown
0.0016 curies/cm^3 1 day after meltdown
0.00052 curies/cm^3 12 days after meltdown

It is interesting to notice the slow decay of this mixture of fission products which is due to the fact that an average ORR core contains a large amount of "old" fission products.

The dose rates produced by these fission products in the vicinity of the unshielded portions of the primary cooling system are:

1. Trane Coolers

   Calculated as a plane source, the dose rate calculated for a point located at 1 meter from the center of the plane is 830 r/hr at the time of the meltdown.

2. Main Pump

   Spherical source with 1-ft concrete shielding and 10-ft distance: The dose rate at the time of the meltdown is 2.5 r/hr.

3. Decay Tank

   Cylindrical source 5 ft underground: The dose rate calculated for a point 3 ft above ground level is 0.015 r/hr.

The Trane coolers are the main source of radiations. With an accident of this type, it is very likely that the Bulk Shielding Facility, the Rolling Mill, and perhaps the LITR, the water processing building, and the public road, would have to be evacuated.

In order to avoid having these facilities evacuated too long a time, the system would have to be cleaned. A calculation shows that access to the demineralizers would be impossible a few minutes after the accident and that the resin would be damaged by radiation approximately 5 days after the accident. During this time, nearly all the fission products in the water will have been removed by the resin. However, an undetermined amount would plate out in the Trane coolers making access to the immediate area difficult for a considerable time. A method of isolating the demineralizer units after 5 days should be found in order to avoid a recontamination of the primary system by the damaged resin.

1.3. Biology Experiment--ORR

F. T. Binford and A. L. Colomb

Thermal and fast neutron fluxes were measured in a shielded container located near the ORR poolside facility in order to determine the feasibility of a genetic experiment proposed by R. C. von Borstel, of the Biology Division. It was found that the thermal neutron flux requirement can be met. It is not yet clear that the fast neutron intensity can be reduced to a satisfactory level. Further experiments to determine the acceptable fast neutron doses are planned.

PART IV

Taken from OPERATIONS DIVISION QUARTERLY REPORT

January - March, 1961, ORNL CF-61-3-138

REACTOR OPERATIONS
RADIOACTIVE WASTES OPERATIONS
AND HOT CELLS OPERATIONS
QUARTERLY REPORT

Summary

The operating time at the ORR decreased to 80% due to several shutdowns for repairing the ball-latch mechanism on the shim rods and due to the fact that there were two, major, bimonthly shutdowns in the quarter. New components of harder material have been fabricated for the ball-latch mechanisms, and a redesigned mechanism is being tested outside the reactor. If this performs satisfactorily, it will be tested on one of the control rods in the reactor.

1. OAK RIDGE RESEARCH REACTOR

1.1. Operations

W. R. Casto

Operations

The ORR was operated during this period at a power level of 30 Mw. Total operating time for the quarter was 1728.2 hours. The operating data are given in Table 1.1.

Table 1.1. ORR Operations

Period January 1, through March 31, 1961

	This Quarter	Last Quarter	Year to Date
Total energy, Mwd	2136.7	2246.3	2136.7
Average power, Mw/operating hour	29.7	29.8	29.7
Time operating, %	80.0	82.0	80.0
Reactor water radioactivity, c/m/ml (av)	38,622	42,644	38,622
Pool water radioactivity, c/m/ml (av)	900	913	900
Reactor water resistivity, ohm-cm (av)	501,000	444,000	501,000
Pool water resistivity, ohm-cm (av)	669,000	663,000	669,000
Research samples	9	6	9
Radioisotope samples	109	104	109

The core configuration at the end of the quarter is indicated in Figure 1.1.

The last three cycles of operation are shown in Table 1.2.

Table 1.2. ORR Cycles of Operation

Cycle No.	Date Begun	Date Ended	Accumulated Energy (Mwd)
31	December 1, 1960	January 15, 1961	1290.5
32	January 21, 1961	March 10, 1961	1329.7
33	March 17, 1961	In Progress	408.7

Figures 1.2, 1.3, and 1.4 indicate the positions of the shim rods during cycles 31, 32, and 33, respectively.

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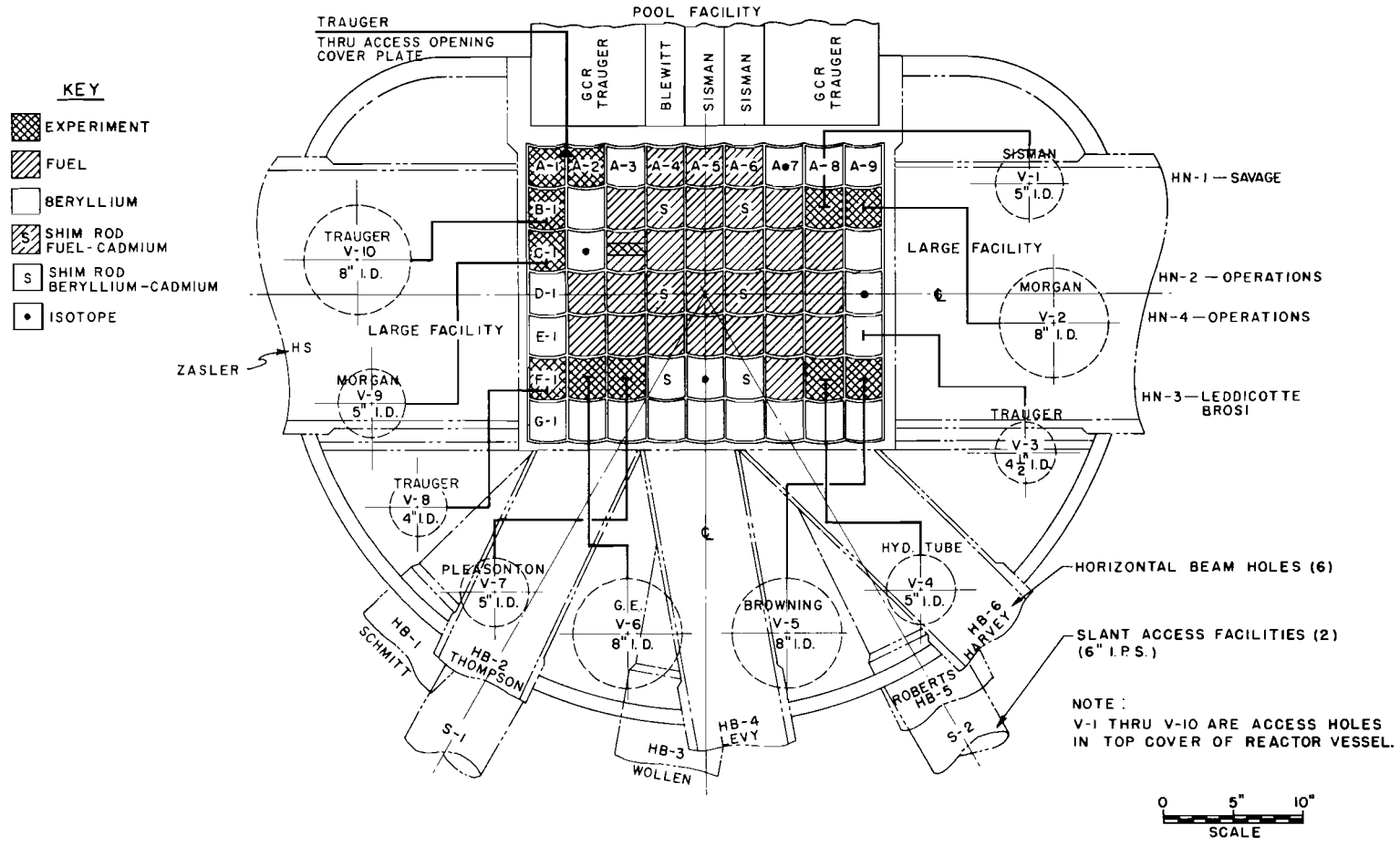

Fig. 1.1.
O.R.N.L. RESEARCH REACTOR
LATTICE PATTERN AND EXPERIMENT LOCATIONS

RESEARCH ASSIGNMENTS & FUEL LOADING ON 3-31-61

C-33561

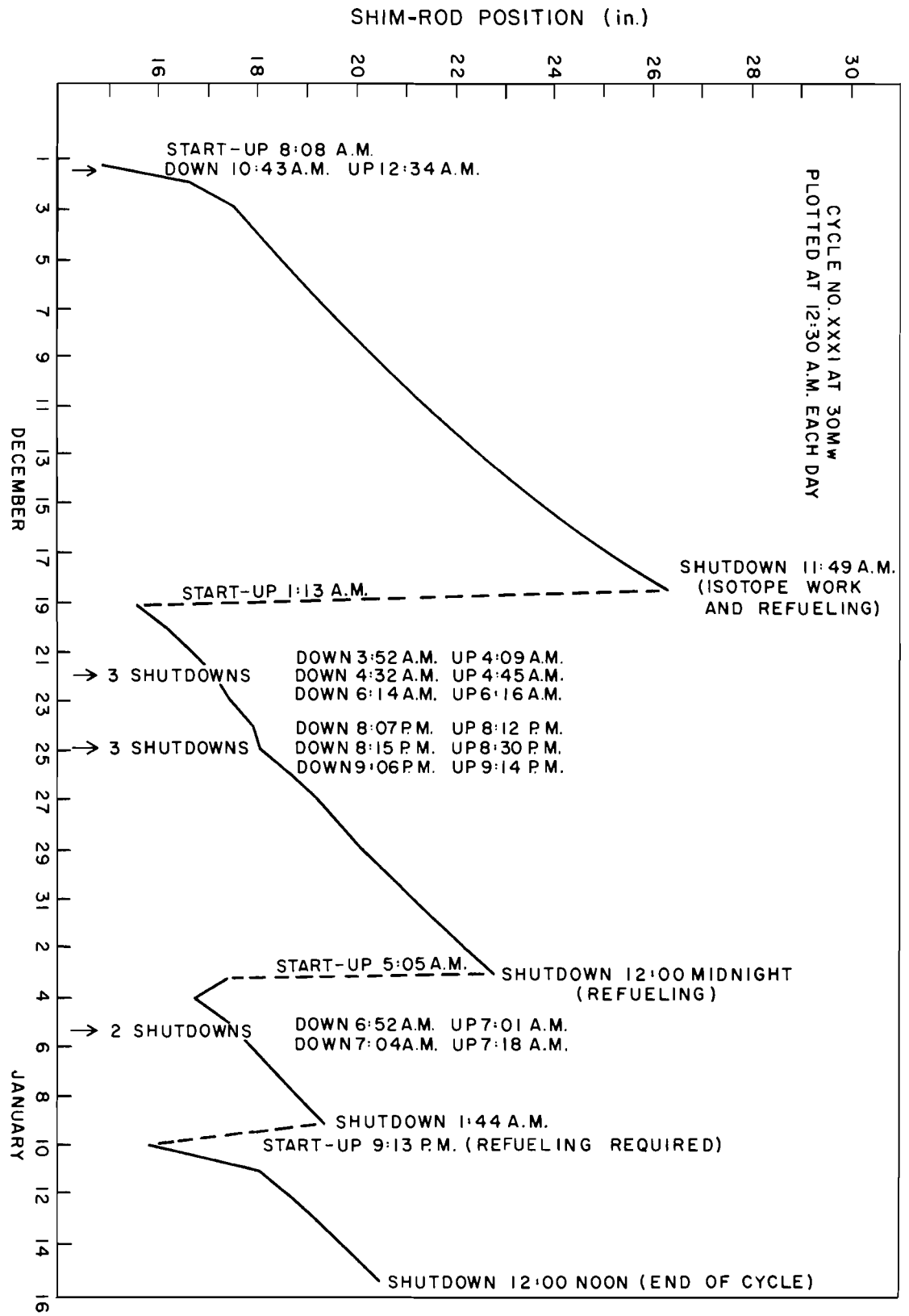

Fig. 1.2. SHIM-ROD POSITION VS. TIME

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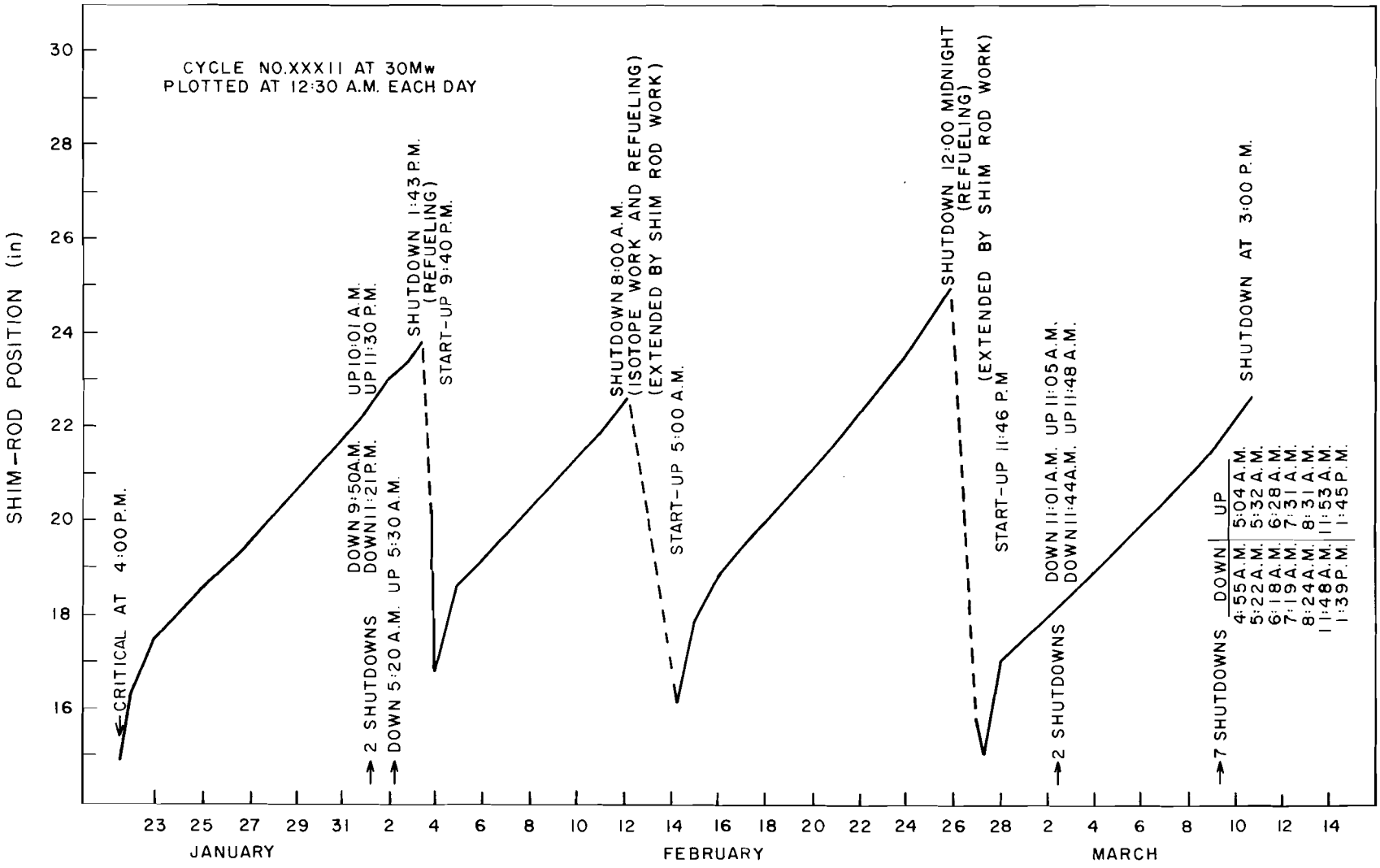

Fig. 1.3. SHIM-ROD POSITION VS. TIME

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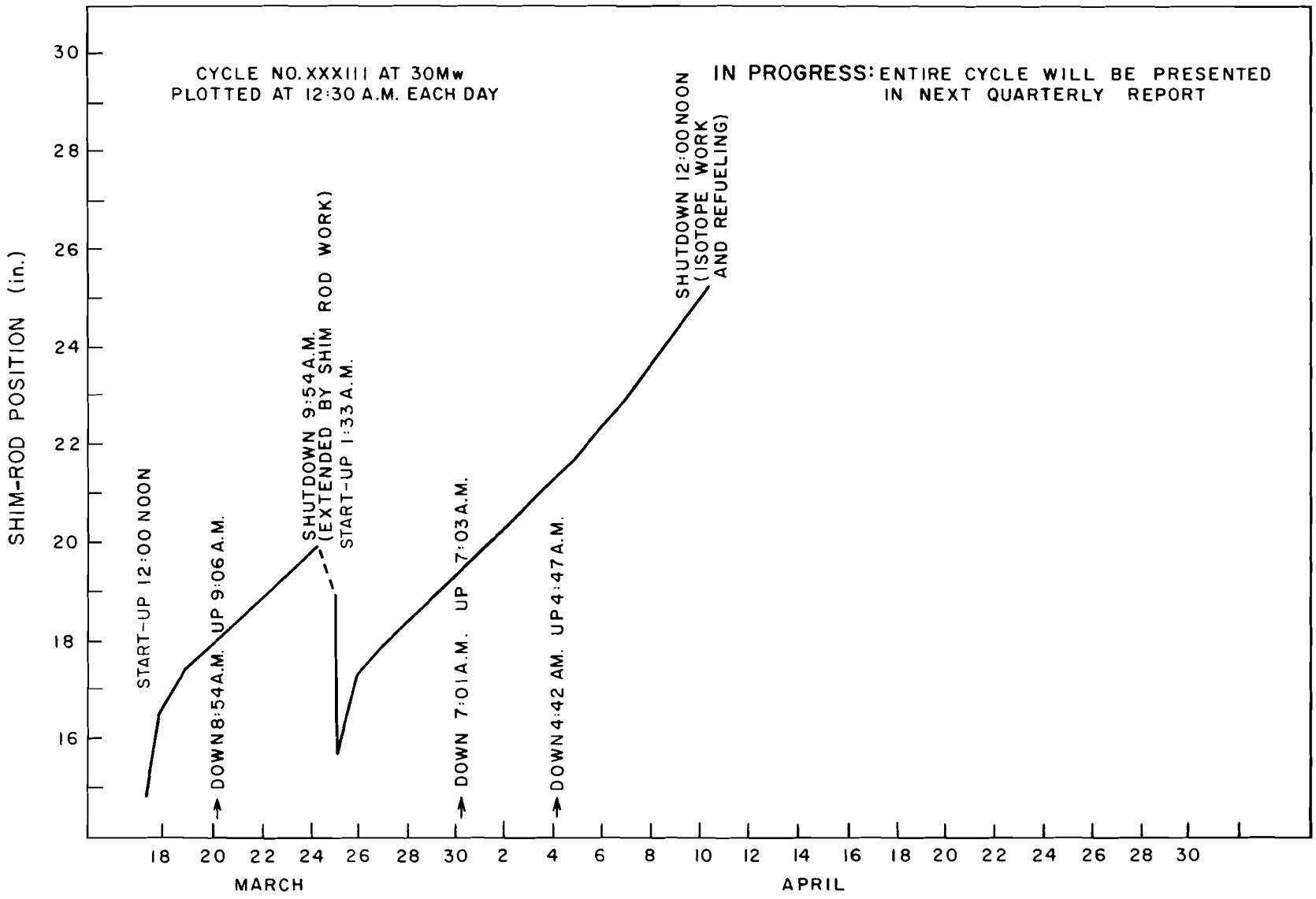

Fig. 1.4. SHIM-ROD POSITION VS. TIME

Shutdowns

Two major shutdowns occurred during this quarter.

January 15 through January 21, 1961. Activities during this period included modifications at the south facility in preparation for the GCR gas-cooled loop No. 2, removal of five experiments, and installation of six experiments.

March 10 through March 17, 1961. Activities during the period included removal of "in-reactor" and "in-pool" components of GCR gas-cooled loop No. 1; replacing the charcoal trap and associated piping of the experiment in CP-F2; an attempt to repair the fission-chamber drive unit (see section on reactor controls); and removal and installation of six experiments.

Table 1.3 lists the unscheduled shutdowns which occurred this quarter.

Table 1.3. Unscheduled Shutdowns at the ORR

Date	Duration (hr)	Remarks
1-5-61	0.150	Shim rod No. 4 dropped, reason unknown.
1-5-61	0.233	Shim rod No. 5 dropped, reason unknown.
1-9-61	19.484	Shim rod No. 4 dropped. Water had leaked through a bellows seal and shorted out the magnet. The drive mechanism was replaced and the reactor reloaded.
2-1-61	0.183	Shim rod No. 3 dropped, reason unknown.
2-1-61	0.150	Shim rod No. 3 dropped, reason unknown.
2-2-61	0.167	Shim rod No. 3 dropped, reason unknown.
2-3-61	7.917	Scram from either GCR loop No. 1 or MSR (both alarmed). This may have resulted from a momentary indication of loss of instrument power; but extensive investigation failed to indicate either the experiment or the primary cause. Refueling was necessary due to xenon concentration increase.

Table 1.3. (Continued)

Date	Duration (hr)	Remarks
3-2-61	0.067	Shim rod No. 5 dropped.*
3-2-61	0.066	Shim rod No. 5 dropped.*
3-9-61	0.150	Shim rod No. 5 dropped.*
3-9-61	0.167	Shim rod No. 5 dropped.*
3-9-61	0.166	Shim rod No. 5 dropped.*
3-9-61	0.200	Shim rod No. 5 dropped.*
3-9-61	0.117	Shim rod No. 5 dropped.*
3-9-61	0.083	Shim rod No. 5 dropped.*
3-9-61	0.100	Shim rod No. 5 dropped.*
3-20-61	0.200	Electrical power outage (human error). The wrong transfer switch at the K-25 substation was thrown.
3-24-61	15.650	Electrical power outage (human error). The wrong switch was thrown during a test of a transfer switch at the substation. Power was not restored for about 15 minutes, and refueling was necessary.
3-30-61	0.033	Shim rod No. 1 dropped, reason unknown.

*During the end-of-cycle shutdown, which began on 3-10-61, it was found that the No. 5 shim rod magnet insulation was breaking down.

There were no shutdowns for real cause; i.e., where such a condition existed that without reactor power reduction, an experiment and/or the reactor could be damaged.

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

Table 1.4. Analysis of ORR Shutdowns

Description	Number	Total Downtime (hr)
Scheduled Shutdowns		
Regular, end-of-cycle	2	313.833
Regular, midcycle and isotope work	1	9.667
Regular, refueling	2	25.033
Supplementary, refueling	1	3.549
Control-rod drive repair	1	34.483
Subtotal	7	386.565
Unscheduled Shutdowns		
Instrument failure, reactor controls	0	0
Instrument failure, experiments	1	7.917
Rod drops, reason unknown	7	20.400
Rod drops, magnet failure	9	1.116
Human error (resulting in electrical power failure)	2	15.850
Subtotal	19	45.283
TOTAL	26	431.848

Reactor Controls

Maintenance and Modifications. During the shutdown ending cycle 31, the temporary circuit to warn of low water level in the reactor cooling tower basin was removed and a permanent circuit installed. At the same time, a change was made in the gamma-chamber installation to provide separate power supplies for the two chambers and to provide a method of compensating for the increase in chamber current during a reactor operating cycle.

When the reactor is at 30 Mw, the initial load resistance for each channel is determined to give a reading of 100 on a 0-150 scale with the scram switch just below full scale. Since the chamber current is expected to increase slowly throughout the cycle due to withdrawal of the shim rods, a switch is provided which inserts a shunt, reducing the recorder voltage about 25%. Thus, if either recorder reading has drifted upward

to a scale reading of 135, throwing the switch will reduce the reading to about 100. The low-sensitivity position is never used unless it has been established that the high-sensitivity position gives a reading greater than 135 at a reactor power of 30 Mw, as determined by a heat balance. The high-sensitivity position is always used during reactor startup.

The major objectives of the gamma-chamber installation are: (1) to obtain information regarding the performance of the chambers, especially the variation of chamber current during a normal reactor operating cycle; and (2) to provide a slow scram for protection against an accident caused by the flooding of one or more beam holes during operation which would make the neutron-sensitive channels unreliable.

Prior to the shutdown in which this work was done, the fission-chamber drive assembly had been observed to stick frequently between 20 in. and 30 in. withdrawn. As the shutdown progressed, it became apparent that the repair would require a more extensive replacement of parts than was possible at that time. Since preparation for repairing the drive was estimated to require about one month, it was decided to install a temporary fission chamber and preamplifier for use with the permanent channel. The installation of a fission chamber in the ORR pool had previously been investigated.[1] A "Procedure for Checkout and Operation of Temporary ORR Fission Chamber" was written by members of the Reactor Controls Department, Instrument and Controls Division. This procedure was followed in detail to establish the adequacy of the temporary channel.

Repair of the permanent fission-chamber drive assembly began during the shutdown ending cycle 32 (March 1961). It was planned to retain the temporary installation as an installed spare which could be used if necessary. During the repair operation, it was found that the new bearing unit was not interchangeable with the installed one; and repair was rescheduled for the shutdown ending cycle 33 (May 1961). Use of the temporary channel was continued.

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[1] D. P. Roux and A. L. Colomb, Experimental Determination of an Adequate Fission Chamber Location in the ORR Pool, CF-60-11-75 (November 4, 1960).

Due to the construction of a shielded cell in the basement for GCR loop No. 2, a panelboard containing the reactor ΔP, facility-cooling ΔP, and off-gas ΔP transmitters was installed southeast of the entrance to the pipe-chase. The nitrogen-16 activity recorder will also be mounted in this panel to centralize all reactor water-system instruments in this area and make maintenance easier.

The difficulties continued with the shim-rod drive mechanism (see Table 1.5., Malfunction of Reactor Controls). Design and testing to eliminate the problem continues.

Procedures. The four most important ORR Procedure Memoranda issued during the period were for the following:

1. ORR Procedure Memorandum No. 160 - To restate and revise the procedure covering operations involving the fuel-cadmium shim rods from initial insertion into the reactor to final shipment for fuel processing. Safety aspects covered are both mechanical and nuclear.
2. ORR Procedure Memorandum No. 165 - To provide rules for the use of the new sensitivity switches on the gamma-chamber channels as outlined above.
3. ORR Procedure Memorandum No. 170 - To define the criteria of acceptability for control-rod drive unit assemblies and auxiliary components. This memorandum not only contained revisions but restated criteria previously written. The memorandum also included procedures for routine safety system adjustments and tests.
4. ORR Procedure Memorandum No. 172 - To restate and revise the procedure involving the positioning of ion chambers in order to compensate for changes in the neutron flux at the chamber location.

Tests. During removal of a fuel-cadmium shim rod, the four fuel elements immediately adjacent to the rod are removed first in order to prevent the reactor from going critical as the rod is being removed. To determine the effect on reactivity caused by changing shim rods, a critical test was planned in which the four fuel elements adjacent to a shim rod would be removed. The effect on the positions of the remaining rods with the reactor critical could then be observed. Since the temporary fission

chamber was in use, the neutron source was relocated from CP-A8 to CP-F1 for this test. When the test was performed, however, it was found that the reactor was subcritical with all shim rods at their upper limits. Since only one shim rod is removed at a time, the test demonstrated that the reactor is subcritical with all shim rods withdrawn although a quantitative measurement could not be made as desired.

Critical tests were performed after the core was fully loaded for the next operating cycle. In each case, the No. 1 and No. 2 rods (Be-Cd) were at their upper limit; and the reactor was critical at the indicated position of the other four rods. These tests were made to determine how far various combinations of shim rods would have to be withdrawn to make the reactor critical with the remaining rods inserted.

Rods Inserted to Seat	Rods Withdrawn	Inches Withdrawn
None	3, 4, 5, and 6	15.00
3	4, 5, and 6	16.57
4	3, 5, and 6	19.77
5	3, 4, and 6	16.48
6	3, 4, and 5	21.04
3 and 4	5 and 6	22.91
5 and 6	3 and 4	25.56
3 and 5	4 and 6	18.40
4	3 and 5 6	Fully 16.52

Further tests will be performed as required by changes in operating conditions.

Table 1.5. Malfunction of Reactor Controls--ORR

Date	Description
1-5-61	Shim rod No. 4 dropped, reason unknown.
1-5-61	Shim rod No. 5 dropped, reason unknown.
1-9-61	The magnet burned out on shim rod No. 4, resulting in a rod drop and reactor shutdown. Refueling was necessary. The magnet was found to be wet, and it was decided to change out the drive tube since investigation indicated that the leak was inside the tube rather than around it. Both magnet amplifiers had blown fuses, and several resistors had failed as a result of the power surge. After the drive tube was removed, the leak was found in the bellows seal located above the magnet in the magnet housing. In addition, during preliminary checks one of the leads of the Thyrite shunt was found to be loose.
1-18-61	The No. 2 (southeast) gamma chamber was found to have a hole in the Tygon tubing containing the leads--probably due to a combination of damage by water and by radiation. This was found during routine replacement of the No. 1 (northeast) gamma chamber, the servo chamber, and the No. 3 safety chamber. The shutdown ending cycle 31 was in progress.
1-20-61	During startup tests, the No. 6 shim rod would not drop with water flowing, and the drive tube was replaced. A routine replacement of the drive tubes for shim rods No. 1 and No. 2 was also performed during this shutdown.
1-21-61	The reactor startup for cycle 32 was made with the temporary fission chamber as discussed above.
1-23-61	The power supply for the reactor and pool water activity monitors was replaced due to the failure of a transformer.
2-1-61	Shim rod No. 3 dropped twice, reason unknown.
2-2-61	Shim rod No. 3 dropped, reason unknown.
2-9-61	The log count rate meter in the fission chamber channel was replaced due to drifting of the calibration circuit.
2-12-61	The drive tube for No. 6 shim rod did not permit the rod to drop when the reactor was scrammed prior to reloading. The tube was replaced with a unit containing a new head, a new plunger, and new balls.
2-13-61	The unit installed on No. 6 shim rod contained a magnet which had a short. The magnet was replaced.
	Following the work on No. 6 shim rod, tests showed No. 4 shim rod would not drop with water flowing (No. 4 shim rod had performed properly during all previous tests). The spare used for the latter position included a new

Table 1.5. (Continued)

Date	Description
	plunger and an old head.
	During completion of the replacement, a leak was observed in the drive tube on No. 3 shim rod. A spare was installed, including a reworked (replated) plunger, new head, and new balls.
2-26-61	During startup checks following a regular refueling shutdown, No. 6 shim rod drive tube was found to be defective. The shim rod could be withdrawn while testing the drive with no magnet current; i.e., using the "raise" circuit. The rod was then picked up using the magnet; and, although the rod scrammed properly several times, it was decided to change the drive tube. When removal of the drive tube was begun, it was found that the new head unit lacked a chamfer on the lower end. This prevented its removal without first removing the wiper-bearing unit. The absence of the chamfer had not prevented insertion of the tube on 2-12-61 due to its location.
	After a spare tube had been installed, the faulty tube was inspected. A 6° taper on the new plunger was found to be longer than specified.
3-2-61	Shim rod No. 5 dropped twice.
3-9-61	Shim rod No. 5 dropped seven times.
3-13-61	During the shutdown at the end of cycle 32, the drive tubes for No. 5 and 6 shim rods were replaced. The magnet on No. 5 shim rod drive tube was found to break down under high voltage. It is felt that this caused the rod drops on 3-2-61 and 3-9-61. Considerable difficulty was experienced in removing the permanent fission chamber drive tube for repair due to galling of the tube.
3-14-61	The fission chamber drive tube and housing were removed with the intention of replacing the bearing unit, but the replacement unit was not interchangeable. The assembly was replaced, and the temporary fission chamber was used for the next cycle. A routine replacement of the No. 2 safety chamber and the No. 1 log-N chamber was also made.
3-24-61	Following an unscheduled scram, the No. 4 shim rod failed to cock after automatic rundown. The drive tube was replaced with a spare.
3-30-61	Shim rod No. 1 dropped, reason unknown.

Mechanical Control Redesign

A redesign of the ball-latch release mechanism has been completed by personnel of the Reactor Division. Following the fabrication of a test unit, a comprehensive series of tests will be performed to determine the reliability and integrity of the new design. Out-of-reactor tests will be conducted first; and, if performance is acceptable, tests under simulated operating conditions will be preformed in the ORR in one of the Be-Cd shim-rod positions.

To reduce the malfunctions of the release mechanism during the interim period until the new design is accepted, the old plungers have been resurfaced with a harder surface using stellite No. 1; and new stellite balls and new head assemblies have been installed. Operation of the control-drive unit with the new parts has been satisfactory.

Fuel Handling

During the quarter, the inventory of spent fuel elements continued to increase. A total of 43 fuel elements and 4 shim rods reached depleted weight during the quarter. The use of the underwater saw in the ORR pool improved handling of these elements. However, only 15 fuel elements and 11 shim rods were shipped for reprocessing, resulting in a total increase, in inventory, of 21 units. Although a portion of the increase was due to shipment of elements from other reactors, the fact remains that the previously large inventory of spent fuel elements was increased.

This inventory growth resulted from increasing the ORR power level and lengthening the ORR operating cycles. Increasing the power level to 30 Mw from the previous 20-Mw level (16 Mw during the summer months) has actually brought about an increase in the average operating power from 18.3 Mw for 1959[1] to about 29.7 Mw at present. The increase in the length of the ORR operating cycle has resulted in an increase in operating time from 75.4% (average for 1959)[1] to about 81%. The two factors indicate an increase in fuel consumption by a factor of about 1.7 and has resulted in a need for a second fuel shipping carrier. This is expected to be available for use during the third quarter of this year.

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[1] J. A. Cox, Operations Division Quarterly Report, October - December, 1959, ORNL-CF-59-12-102 (March 16, 1960).

Facility Assignment

Table 1.6 outlines usage of the ORR during the quarter.

Table 1.6. ORR Facility Assignment

Facility	Access Flange	Nature of Experiment	Division Sponsor
A-1 and 2	V-11	Pressurized water loop, MSR	Reactor
A-3 and 7, C-2, D-9, and F-5		Radioisotope production	Isotopes
B-1	V-10	Gas-cooled loop No. 1	Reactor
B-8 and C-3	V-1 and 3	Radiation damage studies	Solid State
B-9	V-2	Gas-cooled loop	Solid State
C-1	V-9	Fuel tests	Solid State
F-1 and E-9	V-8 and 3	Solid fuel studies	Reactor
F-2	V-6	Fuel tests	Reactor (GE)
F-3	V-7	Ne^{23} studies	Physics
F-8	V-4	Hydraulic rabbit	Isotopes--Solid State
F-9	V-5	Fuel meltdown	Reactor Chemistry
P-1, 2, 3, 7, 8, and 9		GCR capsule irradiations	Reactor
P-4, 5, and 6		Radiation damage	Solid State
HN-1		Homogeneous fuel loop	Reactor Chemistry
HN-3		Pneumatic rabbit for activation analysis	Chemistry--Analytical Chemistry
HN-2 and 4			Operations
HS		Gas-cooled loop No. 2	Reactor
HB-1		Magnet analyses of fission fragments	Physics
HB-2		Neutron spectrometer	Solid State
HB-3		Neutron spectrometer	Physics
HB-4		Neutron spectrometer	Chemistry
HB-5		Neutron spectrometer	Physics
HB-6		Time-of-flight spectrometer	Physics

A list of new experiments operated during the quarter is given in Table 1.7.

Table 1.7. New ORR Experiments Installed or Operated

Date Installed	Division Sponsor	Expected Duration	Facility	Experiment Description
1-17-61	Solid State	2 months	P-4	Be tube-burst
1-17-61	Solid State	2 months	P-5	Columbium tube-burst
1-18-61	Solid State	2 months	P-6	Zr II tube-burst
1-17-61	Solid State	2 months	P-4 Piggy Back	Impact and tensile specimen
1-18-61	Reactor (GE)	2 months	F-2	Air-cooled fuel test
1-16-61*	Solid State	Indefinite	B-9	N_2-cooled fuel test
1-18-61	Solid State	2 months	B-8	Be tube-burst
3-15-61	Solid State	2 months	P-5 Piggy Back	Impact and tensile Specimen
3-15-61	Solid State	2 months	B-8	Be tube-burst
3-15-61	Solid State	2 months	B-1	Irradiation tube
3-15-61	Reactor (GE)	2 months	F-2	"Charpy" metal specimens
3-29-61	Reactor (GE)	20 hours	F-9	Fuel test

*The capsule was removed from flux on 1-30-61 due to leaking specimen.

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