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HIGH FLUX ISOTOPE REACTOR QUARTERLY REPORT

JANUARY, FEBRUARY, AND MARCH OF 1967

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SUMMARY

The HFIR encountered two major problems this quarter; one was a recurrence of excessive bearing wear and failure, and the other was the cracking of some target rods. Despite the downtime entailed in the investigation of these incidents, the operating-time percentage increased to 75.8%. Only six scheduled shutdowns occurred this quarter, and no unscheduled shutdowns were experienced.

Each fuel element continues to produce in excess of 2300 Mwd of power. A hydraulic-rabbit facility, which can insert and remove samples from the center of the target bundle during reactor operation, was placed in service this quarter. The spent fuel element shipping cask was tested with an irradiated element and is ready to be used to transport spent elements to the reprocessing plant.

OPERATIONS

Three fuel cycles were completed this quarter, and a fourth is in progress at its end. Cycle 7 produced 2361 Mwd of power, cycle 8 produced 2360 Mwd of power, and cycle 9 produced 2362 Mwd of power. Cycle 10 is in progress at the end of the quarter and has accumulated 1346 Mwd.

Basic operating data for the quarter are listed in Table 1.

Table I. HFIR Basic Operating Data
(January 1 through March 31, 1967)

	This Quarter	Last Quarter	Year To Date
Total energy, Mwd	6795.8	6213.0	6795.8
Average power, Mw/operating hr	99.6	97.1	99.6
Time operating, %	75.8	69.7	75.8
Reactor water radioactivity, $\frac{\text{c/min}}{\text{ml}}$ (av)	359,000	346,000	
Pool water radioactivity, $\frac{\text{c/min}}{\text{ml}}$ (av)	106	48	
Reactor water resistivity, ohm-cm (av)	0.315×10^6	0.268×10^6	
Pool water resistivity, ohm-cm (av)	2.09×10^6	1.82×10^6	

The starting and ending dates and the accumulated power for cycles 7, 8, 9, and 10 are presented in Table 2. Figure 1 is a plot of the symmetric plate positions versus accumulated megawatt days for cycles 7, 8, 9, and 10.

Table 2. HFIR Cycles of Operation

Cycle No.	Date Started	Date Ended	Accumulated Power (Mwd)
7	12-15-66	1-8-67	2361
8	1-8-67	2-1-67	2360
9	2-17-67	3-12-67	2362
10	3-13-67	In progress	

Fig. 1. Symmetric Plate Positions vs Accumulated Megawatt Days --
Cycles 7, 8, 9, and 10

SHUTDOWNS

A summary of the HFIR shutdowns for the quarter is given in Table 3. Table 4 gives further details of the shutdowns. There were no unscheduled shutdowns this quarter.

Table 3. Summary of HFIR Shutdowns

Reason	Number	Downtime (hr)
End of cycle	3	396.682
Tests	1	10.867
Leaking target rods	2	<u>115.949</u>
Total		523.498

Table 4. Description of HFIR Shutdowns

Date	Downtime (hr)	Remarks
1-8-67	15.516	Fuel cycle 7 was completed at 6:34 a.m. A total power generation of 2361 Mwd was obtained on elements 6-0 and 6-I.
2-1-67	361.416	Fuel cycle 8 was completed at 12:57 p.m. A total power generation of 2360 Mwd was obtained on elements 7-0 and 7-I.
2-16-67	10.867	The reactor was operated at ~12 Mw for dynamic reactivity measurements on the rabbit tube. Since the rabbit-tube facility was not scheduled for permanent installation during cycle 9, it was necessary to shut down the reactor and remove it.
3-12-67	19.750	Fuel cycle 9 was completed at 7:15 p.m. A total power generation of 2362 Mwd was obtained on elements 18-0 and 18-I.
3-21-67	82.616	The reactor was shut down to locate and remove a leaking target rod.
3-30-67	33.333	The reactor was shut down to locate and remove additional leaking target rods.

INSTRUMENTATION AND CONTROLS - MAINTENANCE AND CHANGES

The more significant changes and maintenance performed on the various instrumentation subsystems are described below.

Control System

An additional position, "air-motor insert", was added to control-plate actuating switch S-7. This new position causes the air motors to insert control plates 1, 2, 3, and 4 at high speed. The rod selector switch is bypassed, as individual plates cannot be selected for air-motor insertion. In effect, the new switch position duplicates the action of the "reverse" mode on the quadrant plates but inserts them with the air motors.

Safety Channels.

During routine safety system tests of the rate trip, it was discovered that the rate and level trips occurred almost simultaneously. An investigation revealed that the output signal from the rate test module was just barely sufficient to cause a rate trip before the level trip occurred. To clearly differentiate between the trips, the rate test modules were modified to supply a 30 Mw/sec ramp instead of the original 25 Mw/sec signal.

The work described in HFIR instrumentation change memo No. 1 was completed this quarter. This change involves the installation of remotely operated valves to simulate a change in flow by reducing the pressure differential across the main flow D/P cells. Thus, an additional on-line safety system test is provided to simulate a loss of flow in the flux-to-flow ratio signal. A routine check of the trip capability of each channel upon loss-of-flow signal will be made once per day, the current frequency of the on-line safety system tests.

Safety and servo flux amplifiers on channels 1 and 2 were modified in accordance with HFIR instrumentation change memo No. 10. This modification was made to protect the input transistor in the flux amplifier

from damage caused by excessively high input currents. If the modified flux amplifiers in channels 1 and 2 continue to perform satisfactorily, the modification will be extended to the channel 3 amplifiers.

It was necessary to move all three ionization chambers closer to the core this quarter. A small, but continuous, decrease in the chamber output signals has been apparent since the reactor reached full power. When the output of the servo portion of the chambers decreased to the point where the maximum reset gain was required to equalize the flux and heat-power signals, the chambers were inserted. Various parameters measured during the chamber repositioning are tabulated in Table 5.

A tabulation of spurious single-channel trips has been made for this quarter and is presented in Table 6. All three safety channels were in service each time a trip occurred, so no actual reactor scrams resulted from the spurious trips.

Table 5. Ionization Chamber Repositioning

Channel and/or Chamber	Reset Gain		Chamber Position (in. withdrawn)		Signal Output After Repositioning (amps)	
	Before	After	Before	After	Add-On Chamber	Gamma Chamber
Number 1			2	1 5/8	5.0×10^{-6}	1.39×10^{-5}
Safety	1.29	1.15				
Servo	1.35 (max)	1.25				
Number 2					4.9×10^{-6}	1.28×10^{-5}
Safety	1.29	1.15	2 1/16	1 3/4		
Servo	1.35 (max)	1.21				
Number 3			2 1/2	2 3/16	5.15×10^{-6}	1.48×10^{-5}
Safety	1.21	1.10				
Servo	1.35 (max)	1.25				

Table 6. Spurious Single-Channel Trips in the HFIR Safety System

Date	Remarks
1-21-67	Momentary flux-to-flow and rate trips were received in channel 3. No other abnormality was observed. The cause of the spurious trips was not determined.
2-27-67	Momentary flux-to-flow and rate trips were received in channel 3. Sheet metal workers were modifying the cabinet housing this channel at the time of the trips.
3-13-67	Momentary flux-to-flow and rate trips were received in channel 2. No other abnormality was observed. The cause of the spurious trips was not determined.

Wide-Range Counting Channels

Two fission-chamber assemblies were installed in the No. 3 position and one was installed in the No. 2 position this quarter. These failures appeared to be caused by the metallic sheath fraying in the flexible portion of the chamber assembly.

The channel 3 fission-chamber drive motor and its servo amplifier failed shortly after the end-of-cycle 8 shutdown. The failure was caused by the fission chamber hitting its mechanical insert limit before the insert limit switch was actuated. This condition required the drive motor to run continuously which overloaded its servo amplifier. The motor and servo amplifier were replaced, and the limit-switch position was adjusted to its correct setting.

PROCESS SYSTEMS

Maintenance and changes in the various process systems are listed in Table 7.

Table 7. Process Systems, Maintenance, and Changes

Date	Component	Remarks
Primary System		
1-21-67	Pressurizer pump PU-4B	The magnetic coupling (speed reducer) on pressurizer pump PU-4B failed. It started vibrating excessively and leaking water at the seals. It was necessary to send the unit back to the manufacturer for bearing replacement and dynamic balancing.
2-1-67	Hot water injection valves	Hot water injection valves HCV-100-1A and HCV-100-3A, which admit hot water to the reactor inlet temperature bulbs during the safety system tests, were removed from the system, repaired, and replaced.
2-15-67	Pressurizer pump PU-4A	The magnetic coupling of pressurizer pump PU-4A was cleaned with a scale-removing solution. When it was put into operation, it was discovered that the tachometer had failed. This prevented proper operation of the pump. A dummy signal was substituted for the tachometer cutput until a new tachometer could be procured from the manufacturer.
Primary Cleanup System		
2-7-67	Demineralizer prefilter vent lines	Vent lines from the two demineralizer prefilters were modified to include a ball-float trap to the off-gas system from each filter. Also, a remotely operated valve was installed in each vent line so that entry into the cell while cleaning the filters is unnecessary.
Miscellaneous		
2-8-67	Air compressor C-1B	Instrument air compressor C-1B was overhauled after a defective exhaust valve broke and fell above the piston, causing it to crack.

FUEL

The status of the HFIR fuel, target, and control-plate inventory is indicated in Table 8.

Table 8. HFIR Material Inventory

Item	This Quarter	Last Quarter
New fuel elements placed in service	3	3
New fuel elements available for use	17	13
Spent fuel elements on hand	9	6
New sets of shim plates placed in service	1	1
New sets of shim plates available for use	0	1
Plutonium target rods ready for use	21	22
Plutonium target rods inserted in reactor	1	30

The accumulated number of tensioning cycles on the reactor vessel head studs is presented in Table 9. These studs were designed for a fatigue life of 40 cycles loading due to tensioning of the bolts and 730 full-pressure cycles.

Table 9. Vessel Head Stud Tensioning Cycles

Type Cycle	This Quarter	Last Quarter	Total To Date
Head bolts tensioned			10
1500 psig			10
950 psig		2	198
650 psig	10	13	<u>228</u>
Total			446

REVISIONS TO THE HFIR OPERATING MANUAL

The revisions and additions to the HFIR operating manual which have been made this quarter are tabulated in Table 10.

Table 10. HFIR Manual Revisions

Date	Section	Title	Reason
2-14-67	6.1	Primary coolant system	The procedure for shutting down and depressurizing the primary coolant system was revised and simplified.
2-16-67	6.2	Primary cleanup system	The procedure for cleaning the primary demineralizer inlet filters was revised to include treatment with acid, caustic, and steam.
2-23-67	8.6	Poison injection system	The procedure for testing the poison injection system was revised to make the test simpler and more meaningful in terms of component operability.

OPERATIONAL NOTES AND SPECIAL TESTS

Control-Plate Guide Bearings

During the shutdown at the end of cycle 8, an inspection of the primary system inlet strainer revealed two dowel pins $\sim 1/8$ in. in diameter by $3/4$ in. long. These pins were identified as bearing shaft retaining pins from the outer control plates. The control plates were removed to make sure the bearings were still attached and to determine the exact source of the pins.

A close inspection of the control plates after their removal from the reactor confirmed that the shaft retaining pins were missing from two of the lower bearings. These pins could have been easily replaced, but an inspection of the bearings revealed that some of the races could be moved up and down ~ 0.012 inches. Since the race movement on the bearings when they were installed was only 0.002 in. and since it was desired to study the condition of the bearings, it was decided to install new control plates in the reactor. The bearings on the set of plates which was removed will be replaced, and this set will be reinserted into the reactor when required.

During the removal of the control plates from the reactor, a roller from one of the upper track roller assemblies was found on the No. 1 control-rod access plug. The pin on which this roller was mounted was found on top of the removable beryllium. After recovering the roller and pin, the upper track assembly was removed from the reactor for a closer inspection of its bearings and rollers. This inspection revealed that the bearings had worn a slight amount but, in general, were in satisfactory condition. Of the four track rollers which position the track assembly and hold it in proper alignment, one was in good condition; two were slightly damaged but still serviceable; and the fourth had fallen off the track assembly and was found in the reactor. It was decided to replace the missing roller, since it could be done remotely, and reinstall this set of tracks in the reactor. While reactor operation continues, the spare set of tracks will be modified so that the bearings can be replaced remotely.

While the control plates and upper tracks were removed from the reactor vessel, the lower tracks were inspected in place with an underwater periscope. All the inner control cylinder bearings appeared to be in good condition. Most of the lower track bearings which position the outer control plates showed a slight amount of wear, but they still appeared serviceable and in no imminent danger of failure; therefore, it was decided to leave the lower tracks in place and to modify the spare set of tracks so that the bearings can be changed remotely when required.

Depleted Fuel Element Shipping Cask

A cask for shipping depleted HFIR fuel elements to a reprocessing plant has been designed and constructed. When the cask was designed, the expected life of a HFIR fuel assembly was 15 days; so the heat-transfer and shielding calculations were based on a 1500-Mwd element which would be shipped after 9 months' decay. Since the fuel assemblies actually produced 2200 to 2300 Mwd of power, it was decided to check the adequacy of the shipping cask.

The fuel assembly which was operated at a maximum power of 50 Mw and produced 2229 Mwd of power was loaded into the shipping cask in the HFIR pool. At the time of this test, the calculated heat production of this element was 3.2 kw. It had been out of the reactor for about 8 months and contained $\sim 1.2 \times 10^6$ curies of fission-product radioactivity. Although this heat generation rate and radioactivity content exceeds the cask design criteria, it is desirable to ship the depleted elements when these conditions exist.

After the fuel assembly had been loaded into the cask, thermocouples were inserted into the coolant gaps of both the inner and outer elements. Three thermocouples were located in a coolant channel of each element; one at the midplane, one 4 in. above the midplane, and one 4 in. below the midplane. The thermocouples had a diameter of ~ 0.045 in. and were assumed to be in physical contact with at least one of the fuel plates adjacent to the 0.050-in. coolant gap. The loaded shipping cask was removed from the pool and allowed to come to temperature equilibrium with

water still inside the fuel cavity. After ~19 hours an equilibrium temperature of 198°F was reached in the inner element and 191°F in the outer element while the outside surface temperature of the cask was 124°F.

Water was then blown out of the cask and the temperatures monitored until equilibrium was again established, about 34 hours later. The maximum inner element fuel-plate temperature was 440°F, the maximum outer element plate temperature was 348°F, and the surface temperature remained constant at ~124°F. Radiation levels at the surface of the cask did not exceed 50 mr/hr. These temperatures and radiation levels are acceptable for shipping depleted HFIR fuel elements to the reprocessing plant.

Hydraulic-Rabbit Tube

A hydraulic-rabbit tube was installed in the reactor this quarter. The in-core section of this facility occupies the center position of the target bundle. Reactor primary coolant serves to insert, cool, and withdraw the rabbits while the reactor is in operation. A failure of the primary coolant flow causes the rabbits to be automatically ejected from the reactor.

Before the facility was placed in operation, a series of reactivity tests was made to determine the magnitude of reactivity changes which might be encountered. A number of "single rod mockups" of various rabbit configurations was fabricated; i.e., one rod simulated nine cadmium (black) rabbits, one rod simulated nine "white" (essentially transparent to neutrons) rabbits, and other rods simulated various combinations of black-and-white rabbits. Static reactivity measurements were made by inserting these rods into the position occupied by the in-core section of the rabbit tube, making the reactor critical at low power and noting the control-plate position changes caused by the different rods. The results of this series of tests are listed in Table 11.

Table 11. Static Reactivity Measurements
on the Hydraulic-Rabbit Facility

Rabbit Configuration*	Reactivity** (cents)
Nine black	-48
Six black	-41
Three black	-26
Two black	-18
One black	-10
Nine white	+08
Maximum void in hydraulic tube	+10

* Nine rabbits are the maximum which can be loaded into the facility. Black rabbits were approximately centered axially about the reactor horizontal midplane.

** Reactivity compared to the in-core section of the hydraulic tube filled with water.

After the results of the static reactivity measurements had provided assurance that unusually large reactivity changes would not be encountered, dynamic reactivity tests were run in which various rabbit combinations were inserted and ejected while the reactor was operating at ~12 Mw. Symmetric critical plate positions during these tests were ~17.5 in. withdrawn. High speed recorders were used to measure the reset flux and rate network transients as the rabbits were inserted and ejected. Table 12 summarizes the results of these dynamic reactivity measurements.

Table 12. Dynamic Reactivity Measurements on the Hydraulic-Rabbit Facility

Hydraulic Tube Loading*	Load Reactivity Worth (cents)	$R_{\max}$, Peak Rate Network Output (Mw/sec)	$\Delta P_{\max} = P_{\max} - P_0$ ($P_0 \approx 12$ Mw) (Mw)	dP/dt (max) (Mw/sec)
4W-1/3B-4W	-0.8	0.078	0.23	2.4
4W-2/3B-4W	-3.5	0.156	0.45	4.2
4W-1B-4W	-6.1	0.178	0.52	4.7
4W-2/3B	-5.4	0.192	0.52	5.4
2/3B	-1.1	0.246	0.52	10.1

*W = white rabbit; B = black rabbit; and 1/3B, 2/3B = partial black rabbits. The loadings listed represent the contents of the hydraulic tube starting at the bottom; i.e., "4W-1B-4W" refers to a tube load of four white rabbits at the bottom of the tube followed by one black rabbit and four white rabbits; "2/3B" represents a load consisting of one partial (2/3) black rabbit at the bottom of the tube.

Since the results tabulated in Table 12 were obtained with the reactor control system in operation, the measured power and rate transients also reflect the operation of the servo system. The servo control system operates to resist any reactivity change and tries to hold the power level constant. This tends to decrease the rate and power transients observed in some cases and magnify them in others. The values listed as load worths in column 2 of Table 12 were determined by net rod movement. Attempts to correlate these values with rate and power transients can give misleading results because the reactivity change does not necessarily correspond to a simple step or ramp function. For example, upon ejection of the 2/3B load, reactivity at first decreases as the rabbit travels toward the core horizontal midplane. This initial decrease is compensated to some extent by the servo system. Further movement of the rabbit above the horizontal midplane then causes a reactivity increase. The resultant rate and power transients are thus larger than would be expected from the insertion of 1.1¢ in a simple manner.

Target Rod Rupture

A full loading of target rods containing ^{242}Pu was put in the HFIR for its second 100-Mw cycle, which started on October 21, 1966. This target loading consisted of 17 rods which had been irradiated at Savannah River and 14 virgin ^{242}Pu rods. The fabrication techniques used were identical for all rods. The only difference was that the Savannah River rods initially contained 10 g of ^{242}Pu , while only 8 g were loaded into the other rods. The Savannah River rods were irradiated for ~1 year in a Savannah River reactor before being sent to the HFIR. Two of the virgin ^{242}Pu rods were subsequently removed and shipped to TRU for evaluation. They were both eventually replaced with virgin ^{242}Pu rods; but a flux monitor was run in the center target position during cycle 8, which ended on February 1, 1967. The flux monitor was replaced with the second virgin ^{242}Pu rod for cycle 9, which began on February 17, 1967.

The original complement of water-monitoring instrumentation installed at the HFIR did not include any alpha detectors but did include delayed neutron and beta-gamma sensors. An in-line alpha monitor was considered but rejected because this type of instrument is unreliable in high gamma backgrounds. A bench-type alpha proportional counter was obtained, and a procedure was established to manually sample and count primary coolant water for alpha activity. It was felt that any gross target rupture would be detected by the in-line delayed neutron or beta-gamma detectors and that the manual alpha counter would serve to detect pinhole leaks or surface contamination on the target rods.

The in-line delayed neutron detector has proven to be an extremely sensitive monitor of fission products from surface contamination on fuel elements. A continuous water sample passes through the delayed neutron detector about 18 sec after it has left the reactor core. Delayed neutrons released by fission products, primarily ^{137}I , are monitored by a BF_3 detector. Excellent correlation has been observed between the delayed neutron detector reading and the ^{235}U content of fuel-element surfaces as measured by smears and activation analysis techniques. Fission-product gases evolved in the primary cleanup system deaerator also give a good indication of the quantity of exposed uranium in the reactor. A good

correlation has also been observed between the deaerator off-gas activity level and the delayed neutrons detected by the delayed neutron detector. The detector output signal varies by a factor of ~ 8 , depending upon whether an element is "clean" or "dirty". It was expected that fission products or neutron-emitting elements escaping from a ruptured target would be detected by the in-line delayed neutron detector. This did not occur.

No alpha activity was detected in the primary water until February 22, 1967, about 6 days after the start of cycle 9, when 2^* counts/min were obtained from a 1-ml sample. (It should be noted that a new virgin rod was inserted in the target at the start of cycle 9.) For the next 9 days the alpha activity fluctuated between 0 and 2 counts $\text{min}^{-1} \text{ml}^{-1}$. During the last 6 days of cycle 9, the alpha activity increased slightly and averaged 9 counts $\text{min}^{-1} \text{ml}^{-1}$. Comparing the alpha activity of 9 counts $\text{min}^{-1} \text{ml}^{-1}$ to the normal system β - γ activity of $\sim 400,000$ counts $\text{min}^{-1} \text{ml}^{-1}$ after a 20-min decay, it seemed almost insignificant. At the end of cycle 9, a target inspection was considered but rejected because it was felt that a leak, if it existed, would be too small to locate by any reasonable underwater inspection.

During the first few days of cycle 10, the system alpha activity more than doubled to ~ 25 counts $\text{min}^{-1} \text{ml}^{-1}$. No increase was observed on any of the in-line water monitoring instruments. The gamma spectrum of the primary system water, which is routinely run each day, did not disclose any abnormalities. An inspection of the vessel quick-opening hatch storage pedestal, where the quick-opening hatch was stored during the end-of-cycle 9 shutdown, showed alpha contamination of ~ 100 counts $\text{min}^{-1} \text{ml}^{-1}$. An alpha spectrum run on this contamination indicated that the alpha activity was primarily ^{244}Cm . The contaminated storage pedestal indicated that the interior of the primary system was contaminated with ^{244}Cm at the end of cycle 9.

The personnel who were responsible for the construction of the target rods were apprised of the presence of the alpha activity. Initially, it was their consensus that the source of the activity might be surface

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* Counter geometry: 2.6 dis/min per count

contamination from the new target rod which was installed at the beginning of cycle 9. They also recommended obtaining a larger sample of the alpha activity for a more detailed analysis, which, it was hoped, would determine which group (i.e., Savannah River targets, virgin ^{242}Pu target installed October 21, 1966, or new ^{242}Pu rods) of target rods was leaking. This sample was obtained, and the analysis indicated that one of the Savannah River rods was leaking. (It was estimated that each of the Savannah River rods contained 3.9 g ^{244}Cm , 3.3 g ^{242}Pu , and 200 μg ^{252}Cf ; each virgin rod inserted on October 21, 1966, contained 1.4 g ^{244}Cm , 4.8 g ^{242}Pu , and 5 μg ^{252}Cf ; the last virgin rod inserted contained 0.1 g ^{244}Cm , 7.1 g ^{242}Pu , and 10^{-10} g ^{252}Cf .) The alpha activity continued to increase slowly while the above analysis was being made. No other water-monitoring instruments indicated any increase in activity; in fact, it appeared to be one of the "cleanest" runs in terms of total system radioactivity. When the alpha activity reached 85 counts $\text{min}^{-1} \text{ml}^{-1}$ on March 21, 1967, the reactor was shut down to identify and remove the leaking target rod.

After a cleanup period of ~48 hours, during which the alpha level dropped to ~30 counts $\text{min}^{-1} \text{ml}^{-1}$, the primary system was opened and the target bundle was removed. A remote, visual inspection of the target rods and a rather lengthy smearing procedure of each rod did not reveal any anomalies. It was necessary to place each target rod in a small recirculating system containing a particulate filter and a demineralizer before the defective rod was found. A continual radiation increase of ~1 mr/hr β - γ per minute on the demineralizer was noted when the defective target rod was in the recirculating loop. No alpha activity was detected in the loop water. None of the other target rods showed any significant radiation buildup when they were run in the recirculating loop. The leaking target rod which was located in target position C-1, a peripheral position, was replaced with a flux monitor; and the reactor was restarted on March 24, 1967. Figure 2 is a picture of the crack found in this rod after the outer sheath was removed.

Fig. 2. Cracked ^{242}Pu Target Rod

The alpha activity in the primary water averaged ~ 30 counts $\text{min}^{-1} \text{ml}^{-1}$ for 6 days after the reactor was restarted. Although the demineralizers were not very effective in removing the alpha contamination, its level did not increase. On the seventh day there was a small, but definite increase in the alpha level to ~ 35 counts $\text{min}^{-1} \text{ml}^{-1}$. It was decided to shut down the reactor again and search for additional leaking target rods.

After the shutdown the target bundle was removed, and the entire assembly was placed in a semiclosed recirculating loop which included a bed of demineralizer resin. A buildup of β - γ radiation on the resin occurred, but the rate of buildup was much slower than when the target bundle containing the original leaking target was subjected to the same treatment.

Each target rod was run individually in a smaller recirculating loop which also contained a bed of demineralizer resin. The resin was changed after each target rod was run. A gamma spectrum analysis was run on the 30 resin samples which represented the radioactivity collected from the individual rods. Twelve of these gamma spectra showed the presence of enough fission products to suspect that the corresponding target rods were leaking. All of the suspected leaking rods will be rechecked. Table 13 lists the rods which have already been transferred to TRU and some of the results of their inspection.

The alpha activity was contained quite well during the shutdown work. No activity was detected outside the poolside contamination zone except on the tools which were wrapped in plastic as they were removed from the water. After the shutdown, the tools were easily cleaned by wiping them with a damp cloth. The pools did not become contaminated with alpha activity, as indicated by the numerous measurements made on the pool water.

Thus far, almost all of the activity released by the leaking target rods has been confined to the primary water system. It has not created any operating problems. The only interior surface which has been smeared, the bottom of the reactor vessel quick-opening hatch, was contaminated to ~ 400 counts $\text{min}^{-1} \text{cm}^{-2}$ alpha. If the entire primary system is contaminated to this level, it only represents ~ 0.25 mg of ^{244}Cm . It is estimated that the primary demineralizers collected ~ 7 mg of ^{244}Cm .

Table 13. Results of Target Rod Inspection

Rod No.	Target Position	Remarks
56-A	C-1	This was the first target rod which was determined to be leaking. The crack found in this rod is shown in Figure 2.
34-A	G-5	The gamma spectrum of the demineralizer resin showed a large amount of fission products. A physical examination in the hot cell disclosed cracks in the rod.
6-A	F-3	Same as rod 34-A (see above).
42-A	C-6	Gamma spectrum analysis indicated that this rod was not leaking. However, it was examined because it was a Savannah River rod and was located on the periphery of the target bundle. No cracks were found in the rod.
35-A	B-1	This rod was a suspected leaker. Two very small cracks were found in it.
18-D	D-5	This was the only virgin ^{242}Pu rod which was suspected of leaking. Physical examination did not disclose any cracks.

The primary system alpha activity is slowly coming down, but the demineralizers are not too effective. They seem to be acting more as filters. It is essential to get the system activity down to practically zero if future target leaks are to be detected at their onset.

Several different means of cleaning up the reactor system are being considered. The primary demineralizers, although they continue to do a very effective job of removing the ionic impurities normally present in the system, do not seem to be effective in removing the ^{244}Cm . It is therefore assumed that the curium is present in a particulate form which is not hydrolyzed. Further indications of the particulate nature of the circulating alpha activity were furnished by the installation of a small filter with a 5-micron-pore size on a sample stream. A decontamination factor of ~6 was obtained across the filter. Therefore, it is planned to install a 200-gpm filter in the demineralizer effluent line during the next reactor shutdown. This filter will be equipped with media that contain 5-micron pores.

Various suggestions have been received on how best to remove the estimated 0.25 mg ^{244}Cm which is plated on the interior of the primary system. One procedure, which some transplutonic chemists feel might be effective, is to lower the primary system pH from the normal 5 to ~ 2 by the addition of nitric acid. It is hoped that this would put the curium into solution, and it could then be removed by the demineralizers. This procedure would be relatively easy and quite straightforward, but the HFIR corrosion consultants have expressed strong reservations about exposing the primary system to this treatment. Other suggestions concerning the use of various complexing agents and detergents have been received. It appears that some further study will be required before any foreign agent could be introduced into the HFIR system with confidence.

Xenon Transients

Due to the leaking target rods, it was necessary to shut down the reactor twice during cycle 10. These shutdowns were utilized to gain some information on the xenon transients which occur in the HFIR after a power reduction. Instead of scrambling the reactor, the power was reduced from 100 Mw to 10 Mw, the control plates were kept balanced, and their withdrawal rate was recorded as the xenon concentration increased. Runs were made after 777 Mwd and 1346 Mwd of reactor operation. The results of these tests are plotted in Figure 3.

WATER SYSTEMS

Operation of the HFIR demineralizers during this quarter is summarized in Table 14. Results of various water analyses performed by the analytical laboratories are tabulated in Table 15.

Fig. 3. Xenon Growth After a Power Reduction from 100 Mw to 10 Mw

Table 14. Demineralizer Data: January 1 - March 31, 1967

Column	Run No.	Starting Date	Termination Date	Throughput Gallons	Specific Resistance (ohms-cm)		pH		Gross Activity (counts min ⁻¹ ml ⁻¹)	
					Influent	Effluent	Influent	Effluent	Influent	Effluent
Pool System										
Cation	3	12-15-66		27,878,000	2.09 x 10 ⁶		5.9		106	
Anion	3	12-15-66		27,878,000		3.25 x 10 ⁶		6.2		13
Reactor System										
East Cation	2	12-15-66	2-3-67	13,222,000	0.281 x 10 ⁶		5.0		563,000	
East Anion	2	12-15-66	2-3-67	13,222,000		2.56 x 10 ⁶		6.1		6580
East Cation	3	2-3-57	3-23-67	8,203,000	0.257 x 10 ⁶		5.0		267,000	
East Anion	3	2-3-57	3-23-67	8,203,000		2.89 x 10 ⁶		6.2		1350
West Cation	3	3-23-67		2,755,000	1.06 x 10 ⁶		5.2		186,000	
West Anion	3	3-23-67		2,755,000		3.09 x 10 ⁶		6.2		3720
Plant Demineralizer										
Monobed	126	12-22-66	1-6-67	14,970						
Monobed	127	1-6-67	2-3-67	15,340						
Monobed	128	2-3-67	2-3-67	21,300						
Monobed	129	2-4-67	2-7-67	18,170						
Monobed	130	2-7-67	2-8-67	26,570						
Monobed	131	2-8-67	2-12-67	17,860						
Monobed	132	2-12-67	2-17-67	18,490						
Monobed	133	2-17-67	2-19-67	18,500						
Monobed	134	2-20-67	3-11-67	15,410						
Monobed	135	3-11-67	3-25-67	15,840						
Monobed	136	3-25-67	3-31-67	18,680						
Monobed	137	3-31-67								

Table 15. Water Analysis Results

Date	Total Solids (ppm)	Nonvolatile Material (ppm)	Si (ppm)	Cl (ppm)	Cu (ppm)	Hg (ppm)	Na (ppm)	Ca (ppm)	Al (ppm)	Conductivity (mhos)	pH	CaCO ₃ (ppm)	CrO ₄ ⁼ (ppm)	O ₂ (ppm)	H ₂ O ₂ (ppm)	NO ₃ (ppm)	H ₂ (ppm)	NO ₂ (ppm)	³ H (dis min ⁻¹ ml ⁻¹)
Primary Water																			
1-26-67	1.2	0.2	<1.0	<1.0	<0.1	<1.0	<0.2		0.7	3.1 x 10 ⁻⁶				11.5	2.8	0.28	0.3	0.2	3.05 x 10 ⁵
2-23-67	5.0	2.0	1.0	1.0	<0.3	<1.0	<0.2		4.5	6.2 x 10 ⁻⁶				32.0*	10.8	<1.0	1.3*	<0.2	1.12 x 10 ⁵
Pool Water																			
1-26-67	1.2	0.4	<1.0	<1.0	<0.1		<0.2	<0.3		6.8 x 10 ⁻⁷									
2-23-67	1.6	0.2	1.0	<1.0	<0.3		<0.2	<0.1		9.8 x 10 ⁻⁷									
Secondary Water																			
1-26-67				8.0							6.75	428	16						
2-23-67				14.0							6.93	375	27						

* Sample possibly contaminated by air during analysis.

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