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HIGH FLUX ISOTOPE REACTOR QUARTERLY REPORT

OCTOBER, NOVEMBER, AND DECEMBER OF 1966

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SUMMARY

Two 100-Mw fuel cycles were completed this quarter, and a third was in progress at its end. The fuel elements are producing in excess of 2200 Mwd of power during each cycle.

Only six shutdowns occurred this quarter, and two of these were "end-of-cycle" shutdowns. However, the operating-time percentage dropped because of the extended shutdown required to investigate the control-plate bearing failure. New control plates with modified bearings were installed in the reactor after the bearings on the original set incurred excessive wear.

OPERATIONS

Two fuel cycles were completed this quarter, and a third was in progress at its end. Cycle 5 produced 2266 Mwd of power, and cycle 6 produced 2326 Mwd of power. Cycle 7 was in progress at the end of the quarter and had accumulated 1633 Mwd.

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

Table 1. HFIR Basic Operating Data
(October 1 through December 31, 1966)

	This Quarter	Last Quarter	Year to Date
Total energy, Mwd	6,213.0	6,699.3	15,161.2
Average power, Mw/operating hr	97.1	86.0	63.1
Time operating, %	69.7	84.7	65.9
Reactor water radioactivity, counts min ⁻¹ ml ⁻¹ (avg)	346,000	297,000	
Pool water radioactivity, counts min ⁻¹ ml ⁻¹ (avg)	48	1,755	
Reactor water resistivity, ohm-cm (avg)	0.268 x 10 ⁶	0.468 x 10 ⁶	
Pool water resistivity, ohm-cm (avg)	1.82 x 10 ⁶	1.39 x 10 ⁶	

The starting and ending dates and the accumulated power for cycles 5, 6, and 7 are presented in Table 2. Figure 1 is a plot of the symmetric plate positions versus accumulated megawatt days for cycles 5, 6, and 7.

Table 2. HFIR Cycles of Operation

Cycle No.	Date Started	Date Ended	Accumulated Power (Mwd)
5	10-21-66	11-15-66	2266
6	11-17-66	12-9-66	2326
7	12-15-66	In progress	

SHUTDOWNS

A summary of the HFIR shutdowns for the quarter is given in Table 3. Table 4 gives further details of the scheduled and unscheduled shutdowns, respectively.

Table 3. Summary of HFIR Shutdowns

Reason	Number	Downtime (hr)
Scheduled		
Maintenance	2	2,567
Tests	1	0.150
End of Cycle	2	174.049
Unscheduled		
Human error	1	0.117

Fig. 1. Symmetric Plate Position vs Accumulated Megawatt Days -
Cycles 5, 6, and 7.

Table 4. Description of HFIR Shutdowns

Date	Downtime (hr)	Remarks
Scheduled		
10-21-66	0.150	After reaching 100 Mw in cycle 5, the reactor was scrammed to obtain time-of-flight data on the No. 2 control plate. The control plate time-of-flight was normal.
11-15-66	36.933	Fuel cycle 5 was completed at 2:06 a.m. A total power generation of 2266 Mwd was obtained on elements 1-0 and 1-I.
11-16-66	2.567	Two shutdowns were required to repair the No. 1 Failed Fuel Element Detector (FFED) ionization chamber cable. During the shutdown at the end of cycle 5, a vent valve vibrated open in the pipe tunnel and sprayed water on the FFED ionization chambers. Drying the chamber cable thoroughly enough for reliable operation proved difficult.
12-9-66	137.116	Fuel cycle 6 was completed at 9:58 p.m. A total power generation of 2326 Mwd was obtained on elements 3-0 and 2-I.
Unscheduled		
11-22-66	0.117	The reactor was shut down by the accidental manipulation of the scram switch.

INSTRUMENTATION AND CONTROLS MAINTENANCE AND CHANGES

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

Control System

The auto-process start system was modified to permit one pressurizer, one secondary, and two primary circulating pumps to start in a timed sequence after a power failure. The two primary pumps start simultaneously.

This simultaneous start differs from the original concept of the auto-process start, but tests indicate that reactor scrams following a flow coastdown will be minimized if the revised starting sequence is followed.

The positions of the "raise-test" and "computer bypass" switches on the reactor console were interchanged with each other. This was done to group together at the side of the console all of the switches which will scram the reactor and locate the switches normally used by the operator at the front of the console.

Safety Channels

Some magnet current fluctuations were noticed when the automatic block and drain valves in the hot-water injection system were actuated. Further investigation revealed that the switch which operates these valves actually introduced a trip signal into all channels. However, the duration of the trip signal was so short that the magnet currents did not drop low enough to release the safety plates, and the scram latch lights were not actuated. The trouble was traced to noise pickup from the solenoids which control the block and drain valves in the hot-water injection system. When contact protectors (diode noise reducers) were installed on these solenoids, the magnet current fluctuations disappeared.

The power supply to the operational amplifiers in safety channel 2 was changed from the square wave power source of the original design to a sine wave power source. It is hoped that this change will provide better operational stability and reduce the number of amplifier failures. If this proves to be the case, the other two channels will be similarly modified.

A tabulation of spurious single-channel trips has been made for this quarter and is presented in Table 5. All three safety channels were in service each time a trip occurred so no actual reactor scrams resulted from the spurious trips.

Table 5. Spurious Single-Channel Trips in the HFIR Safety System

Date	Remarks
10-25-66	Channel 1 heat power tripped several times. Loose connector pins were discovered on the heat-power fast trip comparator.
11-10-66	Momentary heat-power trips occurred in channel 1. The reset flux-heat power operational amplifier was replaced to correct the trouble.
12-18-66	A rate trip and a level trip occurred in channel 3. The trips cleared immediately. (The cause was not determined until December 23, 1966.)
12-23-66	Momentary rate and level trips again occurred in channel 3. The reset flux-heat power operational amplifier was replaced.

Wide-Range Counting Channels

Three fission chamber assemblies were installed in the No. 3 position this quarter. The first chamber assembly installed replaced a unit which failed at the end of last quarter. However, it did not function properly; so it was removed and replaced with another spare. This second unit lasted ~60 days before it failed. The third chamber assembly was installed at the end of cycle 6. It was still operating at the end of the quarter, although its output signals were becoming erratic.

PROCESS SYSTEMS

Maintenance and changes in the various process systems are listed in Table 6.

Table 6. Process Systems, Maintenance and Changes

Date	Component	Remarks
Primary System		
11-15-66	Pressure safety valve PSV-154	Pressure safety valve PSV-154 developed a small leak during cycle 4. Since the leaking water was being contained and returned to the system, the valve was not changed out until the end of cycle 5.
11-22-66	Pressure safety valve PSV-150	A leak of ~2 gpm was discovered coming through the seat of pressure safety valve PSV-150. The leaking water was contained and returned to the system. The valve was replaced at the end of cycle 6.
12-11-66	Reactor vessel vent and vacuum break valve assembly	The reactor vessel vent valve and vacuum break check valve assembly was replaced. A modified assembly consisting of two 2-in. ball valves in series and a new check valve was installed to prevent primary water leaks into the pool.
Ventilation Systems		
10-24-66	SBHE fan No. 3	The special building hot exhaust (SBHE) fan No. 3 was shut down because of a noisy motor bearing. The motor was removed and sent to the shop for repairs.
11-19-66 to 11-22-66	HOG charcoal filters	New 1 1/8-in.-thick charcoal filters, identical to those in the SBHE system, were installed in the center and east hot off-gas (HOG) filter pits.
Pool System		
10-4-66	Control plate seal housing water supply	The water supply to the control plate seal housings was changed from the demineralized water system to the pool cleanup system. Individual flow indicators were installed for each seal water line. After passing through each seal housing, the water is routed into a common header which discharges into the reactor vessel extension purge line and thus returns to the pool.

Table 6. (Continued)

Date	Component	Remarks
11-11-66	Pool coolant pump PU-9A	The inboard mechanical seal of pool coolant pump PU-9A was replaced because of a water leak.

FUEL

The status of the HFIR fuel, target, and control-plate inventory is indicated in Table 7.

Table 7. HFIR Material Inventory

Item	This Quarter (No.)	Last Quarter (No.)
New fuel elements placed in service	3	3
New fuel elements available for use	13	9
Spent fuel elements on hand	6	4
New sets of shim plates placed in service	1	0
New sets of shim plates available for use	1	2
Plutonium target rods ready for use	22	52
Plutonium target rods inserted in reactor	30	2

A summary of the more significant criticality tests which have been run to date is presented in Table 8.

The accumulated number of reactor vessel head stud-tensioning cycles 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 8. Symmetric Control-Plate Positions and Core Conditions

Element	Reactivity* in Infinite Water Reflector (\$)	Symmetric Critical Position of Plates (in. withdrawn)	Target Status	Beryllium (Mwd)	Control Plate	
					Type	Mwd
1-O and 1-I	-2.49	17.605	31 Dummy**	0	Set No. 1	0
1-O and 1-I	-2.49	18.670	31 Dummy**	4540	Set No. 1	4540
1-O and 1-I	-2.49	18.530	31 Dummy	4540	Set No. 1	4540
1-O and 1-I	-2.49	18.527	29 Dummy; 2 ²⁴² Pu	4540	Set No. 1	4540
1-O and 1-I	-2.49	17.600	31 Dummy	8948	Set No. 2	0
1-O and 1-I	-2.49	17.802	31 ²⁴² Pu	8948	Set No. 2	0
3-O and 2-I	-1.93	18.320	29 Dummy; 2 ²⁴² Pu	4540	Set No. 1	4540
3-O and 2-I	-1.93	18.539	31 ²⁴² Pu	11,214	Set No. 2	2266
6-O and 6-I	-1.96	18.300	31 ²⁴² Pu	13,540	Set No. 2	4592

*Data taken from tests run in the Critical Facility.

**Indicates original model target holder which contained less metal than new model.

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	28	198
650 psig	13	20	<u>218</u>
			436

REVISIONS TO THE HFIR PROCEDURE AND DESCRIPTIVE MANUALS

A number of revisions have been made this year to the HFIR operating manuals. Since most of these revisions were actually published this quarter, all manual revisions made this year are tabulated in Table 10.

Table 10. HFIR Manual Revisions

Date	Section	Title	Reason
HFIR Descriptive Manual			
1-10-66	3.3	Primary Coolant System	This revision reflects changes made in the primary coolant system process instrumentation.
1-10-66	3.3	Primary Coolant System - Auxiliaries	This revision describes a modification of the instrumentation controlling the vessel-vent valve.
6-9-66	7.5	Special Building Hot Exhaust System	This section was revised to reflect changes made during the prestartup testing program and to include measured parameters and setpoints.

Table 10. (Continued)

Date	Section	Title	Reason
8-1-66	3.3	Primary Coolant System - Auxiliary	This manual addition describes a new primary coolant temperature control system.
11-4-66	8.9	Poison Injection System	This manual addition describes the poison injection system.
11-9-66	6.3	Secondary Coolant Pumps	This revised pump characteristic curve includes the minimum pump submergence required.
HFIR Operating Procedure Manual			
4-21-66	5.2	Slant Engineering Facilities	This manual revision details the slightly changed procedure for determining the high pressure coolant water flow to the slant engineering facilities.
7-22-66	6.1	pH Control System	This manual addition details the operation of the newly installed primary coolant pH control system.
7-26-66	8.3	Maintenance Policy for Building Evacuation Equipment	This manual addition describes the procedures followed for testing and repairing building evacuation equipment.
8-1-66	7.1	SBHE System	This manual revision details the operating procedures and set-points for the SBHE system.
8-4-66	3.2	Process Controllers	This manual addition details the operating procedures required for the new primary coolant temperature control system.
8-25-66	5.1	Beam Tubes	This manual revision details the altered procedures required to establish and monitor beam tube coolant flow.

Table 10. (Continued)

Date	Section	Title	Reason
9-15-66	4	Reactor Components	This revised section describes in detail the tools and procedures required to remove and replace all reactor components.
10-4-66	8.6	Poison Injection System	This manual addition describes in detail the methods for actuating and testing the poison injection system.
10-20-66	4.3	Miscellaneous Maintenance Procedures	This manual addition describes in detail the procedures to be followed when replacing a fission chamber, an ionization chamber and drive assembly, and a control-plate drive.
11-1-66	2.1	Reactor Startup	This manual revision describes the changes incorporated into the "auto process start" circuit and adds a section on the programming of a reactor restart after operation at 100 Mw.
11-1-66	8.7	Emergency Cooling to Primary Heat Exchangers	This manual addition describes the procedures to be followed to supply emergency cooling to the primary heat exchangers in the event of total failure of the secondary system.

OPERATIONAL NOTES AND SPECIAL TESTS

Control-Plate Bearing Failure

During the shutdown terminating cycle 4, ten 3/16-in.-diam balls were found in the primary system strainer. Since the balls appeared to have come from a ball bearing and at least one of them had been exposed to an appreciable neutron flux (it read 75 r/hr through 5 in. of water),

a thorough inspection of the accessible bearings in the reactor vessel was initiated. Upon inspecting the outer control-plate bearings with a periscope, it was obvious that the source of the balls was one of the upper bearings of the No. 4 control plate. It was also apparent that some of the other control-plate bearings had worn excessively.

All four control plates and the inner control cylinder were removed from the reactor. The race on the failed bearing was retrieved as the control plate was removed. Using an underwater periscope, a detailed investigation of all the control-plate bearings was made. It was obvious that considerable wear had occurred on all of the upper bearings of the control plates; and, in fact, a race and its companion balls were missing from an upper bearing of the No. 3 plate. This race and three of the balls were found in the pool, indicating that the bearing came apart while being removed from the reactor. There was some evidence of wear on the lower control-plate bearings but to a much lesser degree than on the upper bearings. The bearings attached to the track assemblies were inspected and found to be in good condition.

After the primary coolant was circulated at full flow for ~1 hour, the strainer was inspected again. Six additional balls were found in the strainer. Of the 26 balls missing from the two bearings, 19 have been accounted for--16 recovered from the strainer and three found in the pool. The missing balls are of no real concern, as it has been demonstrated that they are small enough to pass through the control region. It is improbable that they can cause any trouble.

A routine time-of-flight check, which was made on all the control plates immediately after terminating cycle 4 and before discovering the failed bearings, gave normal results. This indicates that the scram response of the safety plates was not affected, even though some of the bearings had failed completely.

The excessive wear of the control-plate bearings was probably caused by fretting corrosion. Although the wear rate of these bearings was greater than anticipated, it is significant that these plates were in the reactor almost twice as long as their design life. They were used during

the extensive hydraulic and low-power tests; so, although the accumulated reactor power was less than the amount which would result from operation at full power during the design life of the plates, their exposure to the reactor flow environment was approximately twice their design life.

To prevent further bearing failures in the reactor, a new set of control plates was installed with modified bearings which provide retainers for both the balls and the race. Time-of-flight tests of the new plates with the modified bearings gave results similar to those obtained with the original bearings. While this change does not alleviate the wear problem, it does prevent the bearings from coming apart. More frequent inspections of the bearings will be made to observe the rate of wear, and plates will be changed before the wear becomes excessive. For the longer term, work is under way to develop better bearings and to investigate the mechanism of the wearing process.

Coolant Flow Anomalies

It has been observed that the total primary coolant flow can vary markedly during a fuel cycle. This flow variation appears to be related to the treatment the new fuel elements receive before they are inserted into the reactor. On some elements the flow curve is relatively flat through a cycle, not varying more than ~300 gpm. On other elements the flow rate starts at a lower value, increases by ~1000 gpm, and then decreases to near the original rate. Figure 2, a plot of flow versus accumulated power, shows flow curves which are typical of each type of behavior. Water activity versus accumulated power is also plotted on Figure 2, since there seems to be some correlation between the anomalous flow behavior and the water activity.

Thus far all fuel elements which have been used in the HFIR have had an oxide film built up on their surfaces by soaking in 95°C water for 72 hours. Both fuel elements 3-0 2-I and 6-0 6-I had this treatment. Fuel element 3-0 2-I, which exhibited a flat-flow curve, was stored under water in the HFIR storage pool for ~3 months before it was used in the

Fig. 2. Flow Versus Accumulated Power.

reactor. Fuel element 6-0 6-I, which exhibited a humped flow curve, was moved directly from the dry fuel storage to the reactor vessel. One other fuel element, 1-0 1-I, which was stored under water for ~4 months, also exhibited a flat flow curve. All five elements, of which 6-0 6-I is typical, that have been moved directly from dry fuel storage to the reactor vessel have had humped flow curves.

As can be seen from Figure 2, the primary system water activity is much lower when a fuel element with a flat flow curve is in the reactor than when a fuel element with a humped flow curve is being used. Gamma spectrum analyses of the water system activity (after a 20-minute decay) indicate that it is almost all ^{24}Na and ^{27}Mg . The shape of the gamma spectrum does not change appreciably throughout a fuel cycle or from one fuel cycle to another. Since both ^{24}Na and ^{27}Mg are the result of neutron reactions with aluminum, there is probably more free aluminum or aluminum oxide in the coolant system during periods of high water activity. Other factors, such as the rate of filter plugging, also indicate an increase in system particulates during this time.

No satisfactory explanation has yet been advanced to account for the difference in flow characteristics between fuel elements. Further study of this problem is planned, since it is desirable from an operational standpoint to have a flat flow curve. Plans have been made to run an element in the reactor that has not had any surface pretreatment. Also, oxidized elements will be soaked in the pool for varying amounts of time before being run to determine the parameters involved in this type of treatment.

Corrosion Specimens

Corrosion specimens were removed from the upper plenum coolant water inlet nozzles 1 and 2. The specimen-strainer combinations in these positions were replaced with strainers only. The specimens were examined; and in general, little corrosion was found. Complete results of the examination will be tabulated in another report.

WATER SYSTEMS

Operation of the HFIR demineralizers during this quarter is summarized in Table 11. Results of various water analyses performed by the analytical laboratories are tabulated in Table 12.

Table 11. Demineralizer Data: October 1 - December 31, 1966

Column	Run No.	Starting Date	Termination Date	Throughput Gallons	Specific Resistance (ohms-cm)		pH		Gross Activity (counts/min/ml)	
					Influent	Effluent	Influent	Effluent	Influent	Effluent
Pool System										
Cation	2	8-5-66	12-11-66	34,142,000	1.50 x 10 ⁶		5.79		38	
Anion	2	8-5-66	12-11-66	34,142,000		1.615 x 10 ⁶		5.79		10
Cation	3	12-15-66		4,964,000	2.322 x 10 ⁶		6.13		73	
Anion	3	12-15-66		4,964,000		2.991 x 10 ⁶		6.29		24
Reactor System										
West Cation	2	8-25-66	12-11-66	21,059,000	0.262 x 10 ⁶		4.96		314,000	
West Anion	2	8-25-66	12-11-66	21,059,000		1.384 x 10 ⁶		5.75		3020
East Cation	2	12-15-66		4,720,000	0.285 x 10 ⁶		5.01		432,700	
East Anion	2	12-15-66		4,720,000		2.656 x 10 ⁶		6.29		6660
Plant Demineralizer										
Monobed	113	9-24-66	10-7-66	21,710						
Monobed	114	10-7-66	10-7-66	21,030						
Monobed	115	10-7-66	10-8-66	23,230						
Monobed	116	10-8-66	10-14-66	18,820						
Monobed	117	10-14-66	10-17-66	21,040						
Monobed	118	10-17-66	10-21-66	19,760						
Monobed	119	10-21-66	10-23-66	22,920						
Monobed	120	10-23-66	11-15-66	17,050						
Monobed	121	11-15-66	11-19-66	18,130						
Monobed	122	11-19-66	12-10-66	15,310						
Monobed	123	12-10-66	12-12-66	19,480						
Monobed	124	12-12-66	12-15-66	21,180						
Monobed	125	12-15-66	12-22-66	22,290						
Monobed	126	12-22-66								

Table 12. Water Analysis Results

Date	Total Solids (ppm)	Non-Volatile Material (ppm)	Si (ppm)	Cl (ppm)	Cr (ppm)	Hg (ppm)	Na (ppm)	Ca (ppm)	Conductivity (mhos)	pH	CaCO ₃ (ppm)	CrO ₄ ²⁻ (ppm)	O ₂ (ppm)	H ₂ O ₂ (ppm)	NO ₃ (ppm)	H ₂ (ppm)	NO ₂ (ppm)	³ H (d/min/ml)
Primary Water																		
10-25-66	2.0	<1.0	<1.0	<1.0	<0.4	<2.0	0.8		3.1 x 10 ⁻⁶				4.1	7.4	0.4	0.1	<1.0	5.81 x 10 ⁴
11-11-66													4.0	8.6	0.5	0.4	0.19	1.47 x 10 ⁵
11-29-66	7.0	5.6	1.0	<0.5	<0.2	<0.2	<1.0		3.13 x 10 ⁻⁶				9.0	10.5	0.3	0.6		1.58 x 10 ⁵
12-27-66	0.4	<0.2	<1.0	<0.1	<1.0	<1.0	<0.2		3.2 x 10 ⁻⁶				24.0	10.9	0.62	2.4	24.0	1.69 x 10 ⁵
Pool Water																		
10-25-66	1.2	<1.0	<1.0	<1.0	<0.4		1.0	1.20	7.4 x 10 ⁻⁷									1.78 x 10 ⁴
11-29-66	8.8	7.2	1.0	<0.5	<0.2		<1.0	<0.1	7.3 x 10 ⁻⁷									
12-27-66	0.4	<0.2	<1.0	<0.1	<1.0		<0.2	0.034	9.0 x 10 ⁻⁷									
Secondary Water																		
10-25-66				<1.0						6.6	298	27						
11-29-66				21.0						6.57	417	17						
12-27-66				10.0						6.2	430	18						

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