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HIGH FLUX ISOTOPE REACTOR QUARTERLY REPORT

JULY, AUGUST, AND SEPTEMBER of 1966

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RELEASED FOR ANNOUNCEMENT
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SUMMARY

Following the startup program of operating at progressively higher power, the full reactor design power level of 100 Mw was reached on September 9, 1966, at the start of cycle 4. Operation of the reactor has been quite good with no major problems occurring. The approach of routine operation is indicated by the fact that the reactor operated at power levels of 10 Mw or above 84.7% of the time this quarter.

Major maintenance jobs this quarter consisted of repairing a leaking primary heat-exchanger tube, reinforcing the foundations of the secondary coolant circulating pumps, and slightly modifying the reactor control system.

OPERATIONS

Three fuel cycles were completed this quarter at progressively higher powers. Cycle 2, which was run at 75 Mw, produced 2310 Mwd of power. Cycle 3, which was run at 90 Mw, produced 2349 Mwd of power. Cycle 4, the first operation at 100 Mw, produced only 2047 Mwd of power because of a shutdown caused by a laboratory-wide power outage.

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

Table 1. HFIR Basic Operating Data
(July 1 through September 30, 1966)

	This Quarter	Last Quarter	Year- to Date
Total energy, Mwd	6699.3	1580.1	8948.2
Average power, Mw/operating hr	86.0	26.7	50.8
Time operating, %	84.7	65.0	64.6
Reactor water radioactivity, $\frac{\text{c/min}}{\text{ml}}$ (av)	297,000	74,140	
Pool water radioactivity, $\frac{\text{c/min}}{\text{ml}}$ (av)	1755	52	
Reactor water resistivity, ohm-cm (av)	0.468×10^6	1.20×10^6	
Pool water resistivity, ohm-cm (av)	1.39×10^6	1.88×10^6	

The starting and ending dates and the accumulated power for cycles 2, 3, and 4 are presented in Table 2. Figure 1 is a plot of the symmetric plate positions versus accumulated megawatt days for cycles 2, 3, and 4. The curve for cycle 4 is appreciably different from the other cycles because the target bundle contained target rods loaded with a uranium-tantalum mixture to simulate the heat generation properties of ^{242}Pu rods.

Fig. 1. Symmetric Plate Position vs Accumulated Megawatt Days -
Cycles 2, 3, and 4.

Table 2. HFIR Cycles of Operation

Cycle No.	Power Level	Date Started	Date Ended	Accumulated Power (Mwd)
2	75 Mw	6-30-66	7-31-66	2310
3	90 Mw	8-9-66	9-4-66	2349
4	100 Mw	9-9-66	9-30-66	2047

SHUTDOWNS

A summary of the HFIR shutdowns for the quarter is given in Table 3. Tables 4 and 5 give further details of the scheduled and unscheduled shutdowns, respectively.

Table 3. Summary of HFIR Shutdowns

Reason	Number	Downtime (hr)
Scheduled		
Maintenance	1	1.700
Tests	6	47.917
End of cycle	<u>2</u>	<u>239.734</u>
	9	289.351
Unscheduled		
Operating errors	1	0.117
Instrument failure	1	0.150
Power failure	3	8.683
Shim-safety plate drop	1	0.033
Equipment failure	<u>2</u>	<u>40.016</u>
	<u>8</u>	<u>48.999</u>
	17	338.350

Table 4. HFIR Scheduled Shutdowns

Date	Duration (hr)	Remarks
7-31-66	117.917	Fuel cycle 2 was completed at 3:33 p.m. A total power generation of 2310 Mwd was obtained on elements 2-O and 3-I.
8-7-66	8.217	The reactor was shut down to investigate the cause of increased neutron activity in the primary water and increased β - γ activity in the primary cleanup system off-gas. The only two target rods in the reactor containing ^{242}Pu were removed and replaced with dummy rods.
8-7-66	36.000	The reactor was shut down to remove fuel elements 3-O and 2-I. Surface contamination on these elements raised the primary water system activity.
8-9-66	0.133	The reactor was scrammed soon after reaching 90 Mw to check the time response of the No. 1 control plate. This was part of the procedure for power escalation to 90 Mw.
9-4-66	121.817	Fuel cycle 3 was completed at 1:18 p.m. A total power generation of 2349 Mwd was obtained on elements 4-O and 4-I.
9-9-66	0.117	The reactor was scrammed soon after reaching 100 Mw to check the time response of the No. 1 control plate. This was part of the procedure for power escalation to 100 Mw.
9-9-66	0.100	The rod-drop test was repeated because the time-of-flight was slightly high. The second test agreed closely with previous results.
9-9-66	3.350	The reactor was shut down to make a scheduled replacement of the target bundle containing dummy flow test rods with a bundle containing 30 ^{235}U and 1 ^{242}Pu target rods.
9-10-66	1.700	The reactor was shut down so the reactor pool water could be lowered to the vessel top to repair and check a primary water leak at the vessel vent valve.

Table 5. HFIR Unscheduled Shutdowns

Date	Duration (hr)	Remarks
8-5-66	0.117	The reactor scrammed because of insufficient cooling capacity during a flow-coastdown test. After the power had coasted down from 90 Mw to N_L satisfactorily, high-inlet-temperature trips were received on all channels when a primary circulating pump was restarted.
8-5-66	0.150	As the reactor power was being raised from N_L to 50 Mw, a partial scram occurred from the >20 Mw/sec rate trip. The short period was generated by an air-motor insert of the shim plates and subsequent full-speed withdrawal of the regulating cylinder. The rate trip was of such short duration that it was received only on channels 1 and 3, and only shim-safety plates 2 and 4 dropped.
8-5-66	39.833	During another flow-coastdown test from 75 Mw, the reactor scrammed when low-pressure trips were received on all three channels. The shutdown was extended to recalibrate some of the instrumentation and to repair the auxiliary pressurizer pump.
8-9-66	0.183	During a flow-coastdown test from 90 Mw, the reactor scrammed when low-pressure trips were received on all three channels.
8-19-66	0.133	An unscheduled power reduction occurred during an electrical storm when the preferred feeder tripped out. The HFIR load was transferred automatically to the alternate feeder, but the reactor power was reduced from 90 Mw to N_L because the main circulating pumps stopped briefly. After operating at N_L a few seconds, the reactor was scrammed by low-pressure trips in all channels.
8-24-66	0.117	The reactor power was automatically lowered to N_L when the HFIR preferred electrical feeder tripped out. The reactor scrammed because of high inlet temperature when the main circulating pumps were restarted.
9-20-66	0.033	Shim-safety plate 2 dropped just after completion of the routine safety system tests.

Table 5. Continued

Date	Duration (hr)	Remarks
9-30-66	8.433	The reactor was shut down by a Laboratory-wide power outage. Power was available shortly after the outage, but the reactor was so near the end of operating-cycle 4 that it was not possible to return to power; this terminated cycle 4.

INSTRUMENTATION AND CONTROLS MAINTENANCE AND CHANGES

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

Control System

The following changes were made to improve the control response during an ac power outage.

1. The control system was modified to insert plates 1 to 4 with air motors when the flux-to-flow ratio becomes larger than 1.1. The original control action, consisting of an air-motor insert when the regulating cylinder was below its intermediate limit concurrent with a servo insert error larger than 1 Mw, was removed from the system.
2. Solenoid valves which supply air to the air-motor drives were removed from the subpile room wall and mounted below the drive platform. This reduced the amount of tubing between the solenoid and the air motor. Speed of response of the air motors was increased from ~1 sec to 52 msec.
3. The automatic shim-withdraw-limit switch was adjusted closer to the upper end of the regulating cylinder servo span. This provides a larger insertion stroke to minimize the reactivity insertion required by the air motors during a power reduction. The regulating cylinder limit switches are now set as follows in the ~1-in. regulating stroke.

Insert limit	0.121 in.
Automatic shim insert	0.274 in.
Intermediate	0.614 in.
Automatic shim withdraw	0.884 in.
Withdraw limit	0.941 in.

Safety Channels

Random flux-to-flow ratio signal spikes and rate trips, which were first noticed last quarter, continued to occur in channel 3 in the early part of this quarter. The investigation into this problem apparently met with success when the "x/y, x invert" dual-operational amplifier module was replaced. The random noise spikes have stopped since this module was changed.

Automatic, air-operated pressure block and drain valves were installed in the hot-water-injection system. These valves allow the hot-water-injection system to be "armed" for testing and deactivated during nontest periods by operating a switch on the control console. When the system is not being used for testing, the pressure-supply valve is closed and the drain valve is open to the letdown system. It was necessary to install these additional block valves because the injection control and check valves in this system leak. If the hot-water-injection system is not isolated between tests, cool, high-pressure inlet water leaks to the squirt nozzles on the reactor exit water line, resulting in false temperature measurements.

Modified fast-trip comparators were installed in all three channels of the safety, servo, and count-rate systems. These modules were modified after it was discovered that a higher-than-normal voltage signal could trip the comparator, saturate it, and then cause the trip signal to clear. Although the reactor control system electronics do not normally produce a voltage signal high enough to saturate the comparators, it was felt that they should be modified to eliminate any possibility of this happening.

Servo Channels

A reset-gain span of 1 to 3 was originally provided on both the servo and safety channels to make the reset flux agree with the calculated heat power. It was thought that there would be this much variation in the neutron flux at the neutron sensitive chambers during a fuel cycle. Measurements have indicated that the actual flux variation at the chambers is only a few percent during a cycle. Therefore, the reset gain was reduced to a span of 1 to 1.33. This makes the heat power and reset flux agree more closely and reduces power oscillations introduced by the servo-reset-gain systems.

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		
7-17-66	Vessel vacuum-break block valve	A leak developed through the pressure-vessel vacuum-break block valve into the pool. A collector was installed to divert the leaking water to the pool cleanup system.
8-6-66	Emergency pressurizer pump	During a test series conducted as the reactor power was being raised to 90 Mw for the first time, the emergency pressurizer pump blew out its east packing gland. The pump was repaired, checked, and placed in normal, standby service.
8-15-66	Heat exchangers	A leak developed in one of the tubes in primary heat exchanger EX-1C. It was isolated and repaired when the reactor was shut down.

Table 6. Continued

Date	Component	Remarks
Ventilation Systems		
7-6-66	SBHE filters	The first set of absolute filters was replaced in the east compartment of the SBHE system because of poor DOP test results.
7-7-66	HOG filters	The upstream absolute filter in the center bank of the HOG filters was replaced because of poor DOP test results.
Secondary System		
7-8-66	Circulating pumps	Vibration measurements were made on each main circulating pump while operating alone and during simultaneous operation. Results indicated excessive vibration of PU-6A.
7-12-66 to 7-17-66	Fan control circuits	Three secondary tower fan control circuits failed. Fans 4A-2 and 4C-2 had control-circuit breakers burn out. A control transformer of fan 4A-2 failed during an electrical storm.
7-20-66	Pump basin screens	While cleaning the fine pump basin screens, the coarse screens were found to be corroded. The aluminum screen wire was replaced with galvanized wire.
9-28-66	Circulating pumps	Circulating pump PU-6A was removed from the pump pit for installation of a new pump base. Inspection of the pump after removal revealed slight pitting on the impeller.
9-30-66	Circulating pumps	Circulating pump PU-6B was removed from the pump pit for installation of a new pump base. Inspection after removal showed slightly more impeller pitting than was noted on PU-6A.

Table 6. Continued

Date	Component	Remarks
Miscellaneous		
9-8-66	Diesel generator	The two pressure-relief valves on the No. 2 diesel generator air receiver were replaced with valves set at 252 psi. These valve settings are consistent with the 250 psi rating of the air receiver.
9-12-66	Pool deaerator	The steam jet ejectors were inspected because of numerous "pool deaerator pressure-hi" alarms. The jets were found to be partially plugged, so they were cleaned.

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	1
New fuel elements available for use	9	10
New sets of shim plates placed in service	0	0
New sets of shim plates available for use	2	2
Plutonium target rods ready for use	54	31

A few criticality tests were run in the reactor this quarter. A summary of the symmetric control-plate positions and core conditions of the more significant tests is presented in Table 8.

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 Plates	
					Type	Mwd
Standard	-1.15	16.342	31 Dummy**	0	Set No. 1	0
ORNL Production	-4.77	18.344	31 Dummy**	0	Set No. 1	0
1-0 and 1-I	-2.49	17.605	31 Dummy**	0	Set No. 1	0
1-0 and 1-I	-2.49	18.440	31 Dummy**	1076	Set No. 1	1076
1-0 and 1-I	-2.49	18.670	31 Dummy**	4540	Set No. 1	4540
1-0 and 1-I	-2.49	18.530	31 Dummy	4540	Set No. 1	4540
1-0 and 1-I	-2.49	18.527	29 Dummy 2 ²⁴² Pu	4540	Set No. 1	4540
2-0 and 3-I	-2.02	18.265	31 Dummy**	2230	Set No. 1	2230
3-0 and 2-I	-1.93	18.320	29 Dummy 2 ²⁴² Pu	4540	Set No. 1	4540
4-0 and 4-I	-2.02	18.330	29 Dummy 2 ²⁴² Pu	4553	Set No. 1	4553
3-0 and 2-I	-1.93	18.400	31 Dummy	6902	Set No. 1	6902
5-0 and 5-I	-2.04	18.327	31 Dummy	6902	Set No. 1	6902
6-0 and 6-I	-1.96					
7-0 and 7-I	-2.01					
8-0 and 8-I	-1.90					
9-0 and 9-I	-1.91					
10-0 and 10-I	-1.82					
11-0 and 11-I	-1.86					

* Data taken from tests run in the Critical Facility.

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

The HFIR reactor vessel is one of the largest flat-headed pressure vessels in the country designed to operate at 1000 psig. A tremendous force must be applied by the 44 studs to hold down the flat top head of the vessel. These studs have a definite fatigue life and are, of course, subject to fatigue failure. The studs were designed for a fatigue life of 40 cycles loading due to tensioning of the bolts and 730 full-pressure cycles. Table 9 presents a summary of the stud-tensioning cycles accumulated to date.

Table 9. Vessel Head Stud-Tensioning Cycles

Type Cycle	This Quarter	Last Quarter	Total to January 1, 1966	Total to Date
Head bolts tensioned	0	0	10	10
1500 psig	0	0	10	10
950 psig	28	2	145	196
650 psig	20	19	145	205
TOTAL				421

OPERATIONAL NOTES AND SPECIAL TESTS

Primary Coolant System Leaks

A number of leaks from the high-pressure primary system developed this quarter. Although most of them were small and involved valves leaking through their seats, some of the more aggravating incidents were:

1. In the middle of cycle 2, the vacuum-break manual block valve (a 2-in. globe valve which is located in the reactor pool) started leaking primary coolant into the pool system. The radiation level over the reactor pool rose to ~10 mr/hr as the general radioactivity level of the pool water increased. A temporary "leak catcher" was installed under water to route the leaking primary coolant into the pool cleanup system. This reduced the radiation level in the pool water to near normal. It was also

necessary to install a connection between the pool cleanup and primary cleanup systems to return the water to the primary coolant loop. The leaking globe valve was replaced at the end of cycle 2 with a ball valve.

2. Shortly after the start of cycle 3, it was discovered that three of the four ^{16}N system sequencing valves were leaking through their seats to the letdown system. Although no water was actually being lost, these leaks constituted an undesirable and uncontrollable bleed from the high-pressure system. It was necessary to close the manual block valves associated with the leaking sequencing valves; this limited the water sample for the ^{16}N monitoring system to one quadrant of the reactor.
3. During cycle 3 routine monitoring of the secondary water system disclosed that its radioactivity level was increasing. Since the most likely source of this radioactivity was a leaking primary heat exchanger, the heat exchangers were systematically isolated. It appeared that heat exchanger EX-1C had a small leak from the primary coolant system into the secondary water system. This heat exchanger was isolated for the remainder of cycle 3, and the radioactivity level in the secondary water returned to normal.

During the shutdown at the end of cycle 3, the manhole covers were removed from the head of heat exchanger EX-1C. The water on the secondary side was displaced with air and bubbles were observed rising from a faulty tube. By manipulating the air-water interface on the secondary side, the leak was located at 20 ft 8 in. below the top of the tube sheet. This position does not coincide with the location of any of the tube baffles. The defective tube was plugged and the heat exchanger was returned to service.

Vibration of Secondary Coolant Circulating Pumps

An abnormal amount of vibration was noticed during operation of the secondary system main circulating pumps. Vibration measurements showed that excessive vibration was occurring during certain modes of operation. An analysis of the pump installation by the pump vendor and ORNL engineers indicated that the pump foundations were inadequate for the loads being imposed upon them. Accordingly, it was decided to remove the pumps and reinforce the foundations at the first opportunity. This work was started during cycle 4 and completed at its end. Subsequent operation of these pumps has been very smooth with no sign of excessive vibration.

A thorough inspection of these pumps was made while they were removed from the system. No evidence of vibration damage was found. However, both impellers had some metal erosion which was probably caused by cavitation. Before the pump foundations were reinforced, it was necessary to operate the pumps individually to minimize vibration. This resulted in operation above the rated design capacity, which probably induced some cavitation at the impellers.

Critical Tests with Used Fuel Elements

At the end of cycle 3, a short series of critical runs was made with fuel elements which had previously been run at power. Some of the results follow.

1. The first production (ORNL) fuel elements, which had been depleted at 50 Mw in cycle 1, went critical at a symmetrical plate position of 25.200 in. withdrawn. This indicates that the xenon had decayed and that insufficient poison had grown into the fuel element to prevent criticality.
2. Fuel elements 2-0 and 3-I, which had been depleted at 75 Mw in cycle 2, would not go critical. Presumably, some neutron poison--probably samarium--had grown into the element after the xenon had decayed.

WATER SYSTEMS

Operation of the HFIR demineralizers during this quarter is summarized in Table 10. Results of various water analyses performed by the analytical laboratories are tabulated in Table 11.

Table 10. Demineralizer Data: July 1 - September 30, 1966

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	1	1-24-65	7-31-66	47,043,900	1.244 x 10 ⁶		5.69		4390*	
Anion	1	1-24-65	7-31-66	47,043,900		1.523 x 10 ⁶		5.77		50
Cation	2	8-5-66		16,850,200	1.506 x 10 ⁶		5.75		97	
Anion	2	8-5-66		16,850,200		2.122 x 10 ⁶		5.95		12
Reactor System										
West Cation	1	1-26-66	7-31-66	33,321,200	0.374 x 10 ⁶		5.06		248,200	
West Anion	1	1-26-66	7-31-66	32,932,400		1.554 x 10 ⁶		5.91		862
East Cation	1	8-5-66	8-25-66	4,346,000**	0.556 x 10 ⁶		5.16		257,600	
East Anion	1	8-5-66	8-25-66	4,346,000**		1.291 x 10 ⁶		5.65		1230
West Cation	2	8-25-66		8,689,200	0.483 x 10 ⁶		5.10		419,000	
West Anion	2	8-25-66		8,689,200		1.923 x 10 ⁶		5.98		2260
Plant Demineralizer										
Monobed	101	6-21-66	7-3-66	22,230						
Monobed	102	7-3-66	7-9-66	24,790						
Monobed	103	7-9-66	7-14-66	21,520						
Monobed	104	7-14-66	7-19-66	20,660						
Monobed	105	7-19-66	7-27-66	12,640						
Monobed	106	7-27-66	8-3-66	27,370						
Monobed	107	8-3-66	8-8-66	25,470						
Monobed	108	8-8-66	8-9-66	24,000						
Monobed	109	8-9-66	8-20-66	24,050						
Monobed	110	8-20-66	9-2-66	19,960						
Monobed	111	9-2-66	9-9-66	27,230						
Monobed	112	9-9-66	9-24-66	22,270						
Monobed	113	9-24-66								

* The higher-than-normal radioactivity content is due to diversion of a primary coolant leak to the pool cleanup system.

** This demineralizer was partially depleted during preoperational tests when no record of throughput was maintained.

Table 11. Water Analysis Results

Date	Total Solids (ppm)	Non-Volatile Material (ppm)	Si (ppm)	Cl (ppm)	Cu (ppm)	Hg (ppm)	Na (ppm)	Ca (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 (d/min/ml)
Primary Water																		
7-5-66	1.3	<0.5	<1.0	<1.0	<2.0	<2.0	1.1		2.63 x 10 ⁻⁶									2.01 x 10 ⁴
7-13-66																		2.64 x 10 ⁴
7-25-66													4.5	5.5	<5.0	0.5	5.0	2.51 x 10 ⁴
8-12-66	2.0	<0.5	<1.0	<1.0	<1.0	<1.0	<1.0		2.69 x 10 ⁻⁶				5.0	6.5		0.55	0.2	3.22 x 10 ⁴
8-31-66													4.4	7.5	0.66	<0.1	<0.2	
9-2-66	11.8	3.2	2.0	<1.0	<1.0	<1.0	<0.1		3.10 x 10 ⁻⁶									
9-6-66																		1.50 x 10 ⁵
9-15-66													3.0	4.4	0.69	<0.1	<0.2	8.15 x 10 ⁴
Pool Water																		
7-5-66	2.7	0.7	<1.0	<1.0	<2.0		0.8	<0.04	6.5 x 10 ⁻⁷									
8-12-66	<0.5	<0.5	<1.0	<1.0	<1.0		<1.0	<1.0	6.5 x 10 ⁻⁷									
9-2-66	2.6	1.2	2.0	<1.0	<1.0		<0.1	<0.5	6.25 x 10 ⁻⁷									
Secondary Water																		
7-5-66				19.0						6.03	438	16.3						
8-12-66				20.0						5.7	409	22.0						
9-2-66				18.0						6.8	421	16.4						

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16.	C. D. Cagle	91.	G. R. Owens
17.	W. R. Casto	92.	K. H. Poteet
18.	R. D. Cheverton	93.	M. E. Ramsey
19.	R. L. Clark	94.	L. D. Roberts
20.	W. G. Cobb	95.	H. M. Roth, AEC
21-25.	T. E. Cole	96.	D. P. Roux
26.	J. A. Conlin	97.	E. F. Roy
27.	D. F. Cope, AEC	98.	A. F. Rupp
28-29.	B. L. Corbett	99.	H. W. Schmitt
30.	R. A. Costner, Jr.	100.	R. L. Scott, Jr.
31.	W. D. Cottrell	101.	H. E. Seagren
32-46.	J. A. Cox	102.	C. L. Segaser
47.	E. N. Cramer	103.	T. M. Sims
48.	J. H. Crawford, Jr.	104.	M. J. Skinner
49.	F. L. Culler	105.	W. L. Smalley, AEC
50.	J. E. Cunningham	106.	A. H. Snell
51.	H. P. Danforth	107.	L. E. Stanford
52.	S. J. Ditto	108.	J. H. Swanks
53.	G. J. Dixon	109.	C. A. Sweet
54.	E. P. Epler	110.	W. H. Tabor
55.	W. K. Ergen	111.	E. H. Taylor
56.	J. H. Gillette	112.	D. B. Trauger
57.	R. J. Griffin	113.	G. M. Watson
58.	H. Grima	114.	C. C. Webster
59.	L. A. Haack	115.	A. M. Weinberg
60.	T. P. Hamrick	116.	R. C. Weir
61.	J. A. Harvey	117.	K. W. West
62.	J. W. Hill, Jr.	118.	M. K. Wilkinson
63.	R. M. Hill, Jr.	119.	E. J. Witkowski
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