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High Flux Isotope Reactor Quarterly Report October Through December 1986

B. L. Corbett
M. B. Farrar

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ORNL/TM-10390

Operations Division

HIGH FLUX ISOTOPE REACTOR QUARTERLY REPORT OCTOBER THROUGH DECEMBER 1986

B. L. Corbett and M. B. Farrar

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Operations Division

NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and, therefore, does not represent a final report.

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CONTENTS

	Page
SUMMARY	1
OPERATIONS	1
Reactor Pressure Vessel Embrittlement	2
Control Cylinder 9 Blister	3
SHUTDOWNS	5
LOW-POWER OPERATIONS	6
PLANT MAINTENANCE	6
INSTRUMENTATION AND CONTROLS	6
SYSTEM SURVEILLANCE TESTS AND RESULTS	11
Vessel Head Studs	11
Stack Filters	11
Summary of Surveillance Tests	11
REVISIONS TO THE HFIR OPERATING MANUAL	11
UNUSUAL OCCURRENCES	11
REACTOR EXPERIMENTS	11
Experiment Facilities	11
HFIR Target Loading	11

LIST OF TABLES

Table		Page
1	HFIR basic operating data (October 1 - December 31, 1986)	1
2	Cycles of operation	4
3	HFIR material inventories	4
4	Description of HFIR shutdowns	5
5	Process systems - maintenance and changes	6
6	Instrumentation - maintenance and changes	9
7	Vessel head stud-tensioning cycles	11
8	Particulate and iodine removal efficiencies	12
9	Summary of Technical Specification surveillance tests	14
10	Experiment facility assignments	16

LIST OF FIGURES

Figure		Page
1	HFIR target loading (Cycle 286)	17
2	HFIR target loading (Cycle 287)	18

HIGH FLUX ISOTOPE REACTOR QUARTERLY REPORT
OCTOBER THROUGH DECEMBER 1986

SUMMARY

Two routine cycles of operation were completed during the quarter. The shutdowns to end these cycles were both scheduled. The end-of-cycle 287 shutdown was extended indefinitely to investigate the embrittlement of reactor vessel materials due to radiation damage. The reactor remains down at the end of the quarter. Following the scheduled end-of-cycle 287 shutdown period, subsequent shutdown time was designated as unscheduled. The two scheduled shutdowns, fourth quarter downtime resulting from a third quarter scheduled shutdown, and the extended unscheduled shutdown account for the low 44.2% on-stream time for the quarter.

The scheduled control plate replacement and vessel internals inspection was completed at the end-of-cycle 287. The inspection revealed a blister on control cylinder 9. This flaw was attributed to a manufacturing defect.

OPERATIONS

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

Table 1. HFIR basic operating data
(October 1 - December 31, 1986)

	This quarter	Last quarter	Year to date
Total energy, MWd	4060	8317	28,431
Time operated, h	975.368	1998.466	6832.453
Average operating power, MW	99.9	99.9	99.9
Time operating, %	44.2	90.5	78.0
Reactor availability, %	44.2	93.8	79.3
Reactor water radioactivity, cpm/ml (av)	259,436	300,266	
Pool water radioactivity cpm/ml (av)	46	63	

REACTOR PRESSURE VESSEL EMBRITTLEMENT

The original intent of the reactor vessel design was to provide at least 20 full-power years of service at 100 MW. There had been 17.2 full-power years accumulated as of the end-of-cycle 287 shutdown on November 14, 1986. The design of the vessel assumed that no radiation damage would occur to the shell of the vessel. The shell material is carbon steel (ASTM A-212, Grade B) clad with stainless steel on both sides. However, damage in the areas adjacent to the beam tube penetrations was assumed, since the beam tubes displace moderator which would otherwise provide shielding from high energy neutrons. Thus, greater nozzle radiation damage was anticipated; therefore, the nozzles were made from ASTM A-350, Grade LF3 and ASTM A-105, Grade II, which had greater initial fracture toughness.

Pressure vessel material surveillance specimens removed from the reactor during the Fall 1983 beryllium replacement shutdown, but not analyzed until November 1986, indicated an unexpected increase in the nil ductility transition temperature (NDT) - a measure of fracture toughness. This information was received just prior to the scheduled end-of-cycle 287 shutdown on November 14, 1986. The reactor operators were instructed to depressurize the vessel immediately following that shutdown while maintaining as high a vessel temperature as practicable so to minimize the possibility of a vessel fracture. The reactor was shut down and depressurized without incident.

Efforts persisted throughout the remainder of the quarter to evaluate the state of the reactor vessel materials. Additional surveillance samples were removed from the vessel for evaluation and vessel weld material was removed from the vessel itself for chemical analysis. Vessel drop-out pieces retained from the original vessel fabrication were analyzed for chemical content as well as fracture toughness. In addition to these efforts, a program of accelerated irradiation of HFIR vessel fracture toughness specimens fabricated from the retained drop-outs was begun at the ORR to provide more information on the characteristics of irradiated vessel materials.

The fracture toughness specimens removed in November 1986 showed further embrittlement of the reactor vessel materials (indicated by increased NDT). This can be noted in the following tablulation. Using the Pellini concept of fracture mechanics, a conservative figure of 60°F is added to the NDT to obtain the minimum allowable temperature for pressurized operation. This concept was used as the basis for the 70°F HFIR Technical Specification minimum pressurizing temperature. As can be noted in the table, several of the vessel materials had exceeded this criterion in 1983, and at least one more of the materials which had not exceeded the limit in 1983 exceeded it in 1986.

Vessel location	Material	Unirradiated NDT (°F)	1983 NDT + 60°F	1986 NDT + 60°F
HB-1, HB-4	ASTM A 105 II	-65	45	--
HB-2	ASTM A 350 LF3	-115	55	75
HB-3	ASTM A 350 LF3	-85	85	100
Shell (IC3)	ASTM A 212 B	0	80	--
HB-1A, HB-4A	ASTM A 212 B	0	115	135

Data obtained from the on-going efforts to further characterize the properties of the vessel materials will be evaluated using linear elastic fracture mechanics. The results of this analysis will determine whether or not the HFIR may be operated with the present reactor vessel. If the reactor can be operated, this analysis will also determine the permissible operating parameters and ultimate vessel lifetime.

CONTROL CYLINDER 9 BLISTER

Control cylinder 9 was removed from the reactor vessel following the end-of-cycle 287 shutdown for a routine control plate change and vessel inspection. A 1-in.-diam blister was noted in the europium section of the cylinder. This blister is similar to those noted on failed control cylinder 8 in January 1986. Further inspection revealed that the blister had occurred on a nonconforming plate which was used in the fabrication of the cylinder. This plate can be traced to a common fabrication problem from a fabrication campaign in 1976. During fabrication, each control plate is epoxy-bonded to a backup plate to prevent core cracking during the break press forming operation. Apparently some inconsistent epoxy bonding occurred on five control plates during this fabrication campaign. When this defect occurs, the core material can be upset and weakened in this area. One of these five plates was used in the cylinder which failed, and three of the plates were used in cylinder 8 which failed in January 1986. The last nonconforming plate has not been placed in service.

The defective control plates were not summarily rejected at the time of their fabrication, but were identified as nonconforming and evaluated by the project manager. Since the defects were less than 0.003 in. deep, the maximum permitted, the plates were accepted for use in the reactor. However, to alleviate this condition for the next fabrication campaign, a flat anneal step was specified before epoxy bonding the control plate to the backup plate.

This control cylinder was placed in the reactor with the knowledge that the plates with similar nonconformances failed after 42,377 MWd. Its

lifetime was assumed to be limited; however, the cylinder 8 failure occurred with only 12,378 MWd. A decision was made not to reuse this cylinder for power operation even though the cladding had not yet been breached. The future use of the remaining nonconforming control plate (13-1) is currently being reviewed. No other cylinders or control plates in inventory have this common fabrication problem.

The starting and ending dates for Cycles 286 and 287 are presented in Table 2.

Table 2. Cycles of operation

Cycle No.	Fuel assembly	Date started	Date ended	Accumulated power (MWd)
286	285	10/2/86	10/23/86	2034
287	286	10/25/86	11/14/86	2026

The status of the HFIR fuel and control-plate inventories on the last day of the quarter are indicated in Table 3. Only fuel assemblies which have undergone testing at the critical facility are included in this inventory.

Table 3. HFIR material inventories

Item	This quarter	Last quarter
New fuel assemblies placed in service	2	3
New fuel assemblies available for use at end of quarter (EOQ)	8	8
Spent fuel assemblies on hand at EOQ	11	12
Spent fuel assemblies shipped	3	1
New sets of control plates placed in service	0	0
New sets of control plates available for use at EOQ	3	3
New control cylinders placed in service	0	0
New control cylinders available for use at EOQ	0	0

SHUTDOWNS

The quarter began during the scheduled end-of-cycle 285 shutdown. This shutdown continued 47.533 hours into the quarter before the reactor was started up to begin cycle 286. The reactor was shut down twice more during the quarter. Both shutdowns were scheduled; however, the last shutdown was extended indefinitely to investigate the embrittlement of the reactor vessel materials. Total downtime for the quarter was 1,233.632 hours. Of this, 249.632 hours were scheduled and 984.000 hours were designated as unscheduled downtime. No downtime was attributed to experiment work. Table 4 gives further details.

Table 4. Description of HFIR shutdowns

Date	Downtime, h	Remarks
		Scheduled
9/29	86.533	End-of-cycle 285. The total energy accumulated on fuel assembly 284 during this cycle was 2,039 MWd. Of the total 86.533 hours down, 39.000 hours were accumulated in the third quarter and, 47.533 hours were accumulated during the fourth quarter.
10/23	51.766	End-of-cycle 286. The total energy accumulated on fuel assembly 285 during this cycle was 2,034 MWd.
11/14	150.333*	End-of-cycle 287. The total energy accumulated on fuel assembly 286 during this cycle was 2,026 MWd. This shutdown has been extended through the end of the quarter as unscheduled downtime (see unscheduled shutdowns).
		Unscheduled
--	984.000*	The scheduled end-of-cycle 287 shutdown was extended to investigate the embrittlement of the reactor vessel due to radiation damage. All downtime following the originally scheduled cycle 288 startup date was designated as unscheduled downtime. This shutdown continues through the end of the quarter.

*The first 150.333 hours of the shutdown were scheduled. All remaining downtime through the end of the quarter is designated as unscheduled downtime. The total downtime for the end-of-cycle 287 shutdown during this quarter was 1,134.333 hours.

LOW-POWER OPERATIONS

No Mode 2 or Mode 3 runs were performed during the fourth quarter.

PLANT MAINTENANCE

Maintenance and changes in the various process systems are listed in Table 5.

INSTRUMENTATION AND CONTROLS

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

Table 5. Process systems - maintenance and changes

Date	Component	Remarks
		Primary system
10/1	Component letdown valve, Cell 112	The valve was replaced with a rebuilt spare.
10/1	Control rod drive 3	The drive rod seal housing was replaced.
10/1	Safety channel 2 flux/flow test valve	The safety channel 2 flux/flow test valve was removed for repair. A manual autoclave valve was temporarily installed in its place.
10/1	Head tank overflow line	The new head tank overflow line to the primary underground storage tank was installed and opened.
10/24	Letdown valve, Cell 111	The valve was replaced with a rebuilt spare.
10/24	Letdown valve, Cell 113	The valve was replaced with a rebuilt spare.
11/3	Primary heat exchanger, 1D	Leaking tube 8 in row 5 was plugged.

Table 5. (continued)

Date	Component	Remarks
11/17	EF-3	The EF-3 vessel marmon flange was removed for the new pneumatic tube installation. Work was stopped awaiting a decision on whether or not a vessel inspection is to be performed.
11/19	Fission chamber thimble	The channel 1 fission chamber thimble-to-bottom head seal housing and seals were replaced.
11/19	Relief valve/rupture disk cavity monitoring system	A broken 1/4-in. line was repaired.
11/20	Primary relief valves	The primary system relief valves were replaced. New rupture disks were installed.
11/21	Pressure vessel	The interior of the vessel was inspected visually and videotaped using the underwater camera.
11/26	Pressure vessel	The bottom head studs and nuts were ultrasonically inspected per the ASME B&PV code.
12/12	Pressure vessel	A sample hole was drilled into the exterior of the vessel in the vertical seam weld to obtain samples of the vessel weld metal for chemical analysis.
12/13	Pressure vessel	A second metal sample hole was drilled into base metal on the exterior of the reactor vessel for chemical analysis.
		Secondary system
10/23	Cooling tower basin make-up valve	The valve was found to have a cracked body and was replaced with a spare valve.
11/19	Primary heat exchangers	The shell side relief valves were replaced with calibrated valves.

Table 5. (continued)

Date	Component	Remarks
		Miscellaneous
10/1	Control room annunciator panel	Annunciator panel D was replaced with a rebuilt panel.
10/1	Switchgear batteries	The battery bank and connections were cleaned.
10/1	SBHE stack/duct breeching	New breeching material was laid over the existing torn breeching.
10/1	Control room annunciator noise suppressors	The old capacitor-type noise suppressors were replaced with MOV-type suppressors.
10/2	Sulfuric acid mixer header	The acid mixer header spool piece was replaced.
10/3	Secondary pump flume screens	Two damaged screens were replaced.
10/10	Instrument batteries	Seismic tie-downs were installed.
10/13	Plant demineralizer	One of the fiberglass resin canisters in the new plant demineralizer train ruptured. Continental Water Systems replaced the cylinder with a new one.
10/15	Nitric addition pump	The north nitric acid addition pump was refurbished.
10/15	HOG filters	The center bank charcoal filters were replaced.
10/23	Sulfuric acid dilution flow valve	The failed supply valve for the sulfuric acid dilution flow was replaced.
11/3	Demineralized water storage tank, level control valve, LCV-605	The leaking valve was replaced with a manual valve until a new control valve can be procurred and installed. Storage tank level is controlled manually.

Table 5. (continued)

Date	Component	Remarks
11/5	Pool cleanup pump inlet valve, V-1226	A faulty diaphragm was replaced which prevented PU-7A from pumping properly.
11/17	Control room annunciator noise suppressors	Work continued on replacing old capacitor-type noise suppressors with MOV-type suppressors.
11/21	Control room annunciators	A faulty annunciator strip was replaced on annunciator panel E.
11/21	Caustic storage tank	The steam trap, strainer, and piping were replaced.
10/1-12/31	New EF-3 pneumatic tube facility	Work continued through the quarter on the installation of the sections of the P-tube external to the pool.

Table 6. Instrumentation - maintenance and changes

Date	Component	Remarks
10/1	Control room recorders	Old multi-point recorders and Rustrak recorders were replaced with new recorders.
10/1	SBHE flow measurement	The following SBHE flow transmitters and switches were calibrated: FT-903, FS-903B, FT-904, FS-904B, FT-913, FS-913B, FT-914, and FS-914B.
10/23	Cooling tower basin level controller	The basin level transmitter and controller were repaired and calibrated.
10/24	Pressure indicators	The following pressure indicators were calibrated: PT-127, PDI-103, and PDI-106.
10/24	Safety channel 2	A loose connection in drawer S-4 was repaired.

Table 6. (continued)

Date	Component	Remarks
11/17	Safety system	Control room recorders were calibrated.
11/18	Pool surge tank level indicator, LI-401	The level indicator was calibrated.
11/18	Vessel outlet temperature recorders	The following recorders were calibrated: TR-100-1B, TR-100-2B, and TR-100-3B.
11/19	SBHE and HOG filter differential pressure gauges	The old magnehelic gauges were replaced with new calibrated gauges.
11/20	Fission chamber 1	The assembly was reinstalled into its thimble following thimble seal repairs.
11/20	Calibration program	The following instruments were calibrated: TDR-100-4, TDR-100-5, TDR-100-6, PRC-127, FR-258, FR-216, TRC-100-4, TRC-100-5, and TRC-100-6.
11/21	Calibration program	The following instruments were calibrated: FI-215, FI-407, TR-310-1, and TR-310-2.
11/25	Calibration program	The following instruments were calibrated: FT-100-3, FT-100-2, FT-100-3B, and FT-100-2B.
11/26	Calibration progam	The following instruments were calibrated: FT-100-4, FT-100-5, FT-100-6, FT-100-1, and FT-100-1B.

SYSTEM SURVEILLANCE TESTS AND RESULTS

VESSEL HEAD STUDS

The accumulated number of tensioning cycles on the reactor vessel head studs is presented in Table 7. These studs were designed for a fatigue life of 40 cycles loading due to tensioning of the bolts and 730 full-pressure 6.9-MPa (1000-psig) cycles. Installation of new reactor vessel head studs was completed in June 1972. In November 1983, stud 72-1 was replaced by stud 73-9 because of a small anomaly discovered during previous ultrasonic inspections. The numbers in Table 7 represent the maximum cycles to which any stud has been exposed.

The annual ultrasonic inspection of all reactor vessel studs and nuts was completed on September 30, 1986. An indication was noted on stud 72-3 at a depth of 15 in. equal to 87% of the amplitude received from a 0.134-in. calibration. This depth corrsponds to the point at which the center drilled holes intersect. A reinspection of this stud was scheduled for the following shutdown and was performed on October 24, 1986. This inspection confirmed the results of the previous inspection in September. A more detailed investigation was deemed necessary, and the stud was scheduled to be removed and sent to Quality Department for radiographic inspection. The anomoly in stud 72-3 will be evaluated and a decision made to reinstall or replace it prior to reactor restart.

STACK FILTERS

Stack filtering systems in the special building hot exhaust (SBHE) and hot off-gas (HOG) systems were tested for particulate and iodine removal efficiencies. Results of the most recent tests are tabulated in Table 8.

Table 7. Vessel head stud-tensioning cycles

	This quarter	Last quarter	Total to date
Head bolts tensioned	0	0	8*
10.3 MPa (1500 psig)	0	0	0
6.5 MPa (950 psig)	0	0	11
5.2 MPa (750 psig)	2	6	215
4.5 MPa (650 psig)	0	0	117

*Stud 72-3 has been tensioned nine times to date.

Table 8. Particulate and iodine removal efficiencies

Filter bank	Elemental iodine				Filter position	Particulate retention			
	Last test		Previous test			Last test		Previous test	
	Date	Eff.,%	Date	Eff.,%		Date	Eff.,%	Date	Eff.,%
SBHE, west	10/7/86	99.967	4/22/86	99.981	South	9/22/86	99.99	3/31/86	99.99
					North	9/22/86	99.99	3/31/86	99.99
SBHE, center	10/24/86	99.992	4/18/86	99.975	South	9/22/86	99.99	3/31/86	99.99
					North	9/22/86	99.98	3/31/86	99.94[a]
								4/15/86	99.987[b]
SBHE, east	10/16/86	99.950	4/24/86	99.964	South	9/22/86	99.99	3/31/86	99.99
					North	9/22/86	99.99	3/31/86	99.99
CHOG, west	11/13/86	99.988	4/15/86	99.992					
HOG, center	11/4/86	99.992	4/30/86	99.799[a]					
OHOG, east	11/6/86	99.995	4/16/86	99.954					

[a]Below minimum acceptable efficiency.

[b]The HEPA filter was replaced, and the efficiency test was repeated satisfactorily.

SUMMARY OF SURVEILLANCE TESTS

Table 9 is a tabulation of the completion dates of the surveillance tests required by the Technical Specifications. This table contains all the surveillance tests scheduled for frequencies of one month or longer. Other surveillance requirements, which are not reported, are satisfied by the routine completion of daily and weekly check sheets, startup checklists, hourly data sheets, the operating logbooks, and miscellaneous quality assurance tests.

REVISIONS TO THE HFIR OPERATING MANUAL

There were no revisions to the HFIR Operating Manual during the quarter.

UNUSUAL OCCURRENCES

Two unusual occurrence reports were issued this quarter:

ORNL-86-18-HFIR-86-3	Unexpected increase in nil ductility transition temperature of reactor pressure vessel surveillance specimens
ORNL-86-19-HFIR-86-4	Cladding blister over europium section of control cylinder

REACTOR EXPERIMENTS

EXPERIMENT FACILITIES

Assignments of the various HFIR experiment facilities are tabulated in Table 10.

HFIR TARGET LOADING

A description of the HFIR target loading for each of the operating cycles this quarter is presented in Figs. 1 and 2.

Table 9. Summary of Technical Specification surveillance tests

Test	Most recent test	Previous test	Previous test
Decennial tests			
Pressure boundary components	11/83	7/75	NA
Annual tests			
Count rate channel A calibration	3/11/86	2/6/85	3/20/84
Count rate channel B calibration	3/12/86	2/8/85	3/22/84
Count rate channel C calibration	3/13/86	2/19/85	3/27/84
Normal emergency systems	7/22/86	11/20/85	5/29/85
Poison injection system	8/14/86	8/16/85	10/29/84
Pressurizer pump high-pressure cutoff	2/6/86	2/22/85	3/6/84
Pressure relief valves	11/19/86	11/15/85	10/3/84
Reactor vessel head studs	9/30/86	11/18/85	10/4/84
Radiation block valve test	9/8/86	9/30/85	10/29/84
Reactor bay in-leakage test	9/8/86	9/30/85	10/28/84
Reactor components	11/16/86	9/28/85	10/4/84
Safety channel A calibration	9/17/86	2/10/86	2/28/85
Safety channel B calibration	9/18/86	2/10/86	3/1/85
Safety channel C calibration	9/22/86	2/10/86	3/4/85
Servo channel A calibration	7/29/86	2/19/86	2/5/85
Servo channel B calibration	7/29/86	2/19/86	2/5/85
Servo channel C calibration	7/29/86	2/19/86	2/5/85
Speed of shim and regulating drives	11/20/85	11/19/84	12/20/83
Switchgear battery load test	5/12/86	5/8/85	4/30/84
Vessel material sample hole inspection	NA	NA	NA
Semiannual tests			
Main pump low-pressure cutoff	11/14/86	10/25/86	9/29/86
Pony motor battery E	9/8/86	5/11/86	2/6/86
Pony motor battery F	10/2/86	6/28/86	3/25/86
Pony motor battery G	10/25/86	7/11/86	6/4/86
Pony motor battery H	8/13/86	4/18/86	1/13/86
Radiation monitoring equipment	10/12/86	9/11/86	7/16/86
Monthly tests			
Cadmium nitrate tests	12/27/86	11/30/86	10/25/86
Diesel run test, No. 1	12/30/86	11/26/86	10/28/86
Diesel run test, No. 2	12/30/86	11/26/86	10/28/86

Table 10. Experiment facility assignments

Facility	Description	Sponsor
PTP-A1	Materials studies	Fusion Energy
PTP-A4	Materials studies	Fusion Energy
PTP-D1	Materials studies	Fusion Energy
PTP-D7	Materials studies	Fusion Energy
PTP-G4	Materials studies	Fusion Energy
PTP-G7	Materials studies	Fusion Energy
RB-1	Isotope production	Operations
RB-2	Isotope production	Operations
RB-3	Isotope production	Operations
RB-4	Isotope production	Operations
RB-5	Fuel studies	Engineering Technology
RB-6	Fuel studies	Engineering Technology
RB-7	Isotope production	Operations
RB-8	Isotope production	Operations
CR-1	Isotope production	Operations
CR-2	Isotope production	Operations
CR-3	Isotope production	Operations
CR-4	Isotope production	Operations
CR-5	Isotope production	Operations
CR-6	Isotope production	Operations
CR-7	Isotope production	Operations
CR-8	Isotope production	Operations
VXF-1	Isotope production	Operations
VXF-2	Isotope production	Operations
VXF-3	Isotope production	Operations
VXF-4	Isotope production	Operations
VXF-5	Isotope production	Operations
VXF-7	Pneumatic tube	Analytical Chemistry
VXF-8	Isotope production	Operations
VXF-9	Isotope production	Operations
VXF-10	Isotope production	Operations
VXF-11	Isotope production	Operations
VXF-12	Isotope production	Operations
VXF-13	Isotope production	Operations
VXF-14	Isotope production	Operations
VXF-15	Isotope production	Operations
VXF-16	Isotope production	Operations
VXF-17	Isotope production	Operations
VXF-18	Isotope production	Operations
VXF-19	Isotope production	Operations
VXF-20	Isotope production	Operations
VXF-21	Isotope production	Operations
VXF-22	Isotope production	Operations
HB-1	Neutron diffractometer	Solid State
HB-2	Neutron diffractometer	Chemistry
HB-3	Neutron diffractometer	Solid State
HB-4	Neutron diffractometer, SANS Facility	Solid State

Fig. 1.

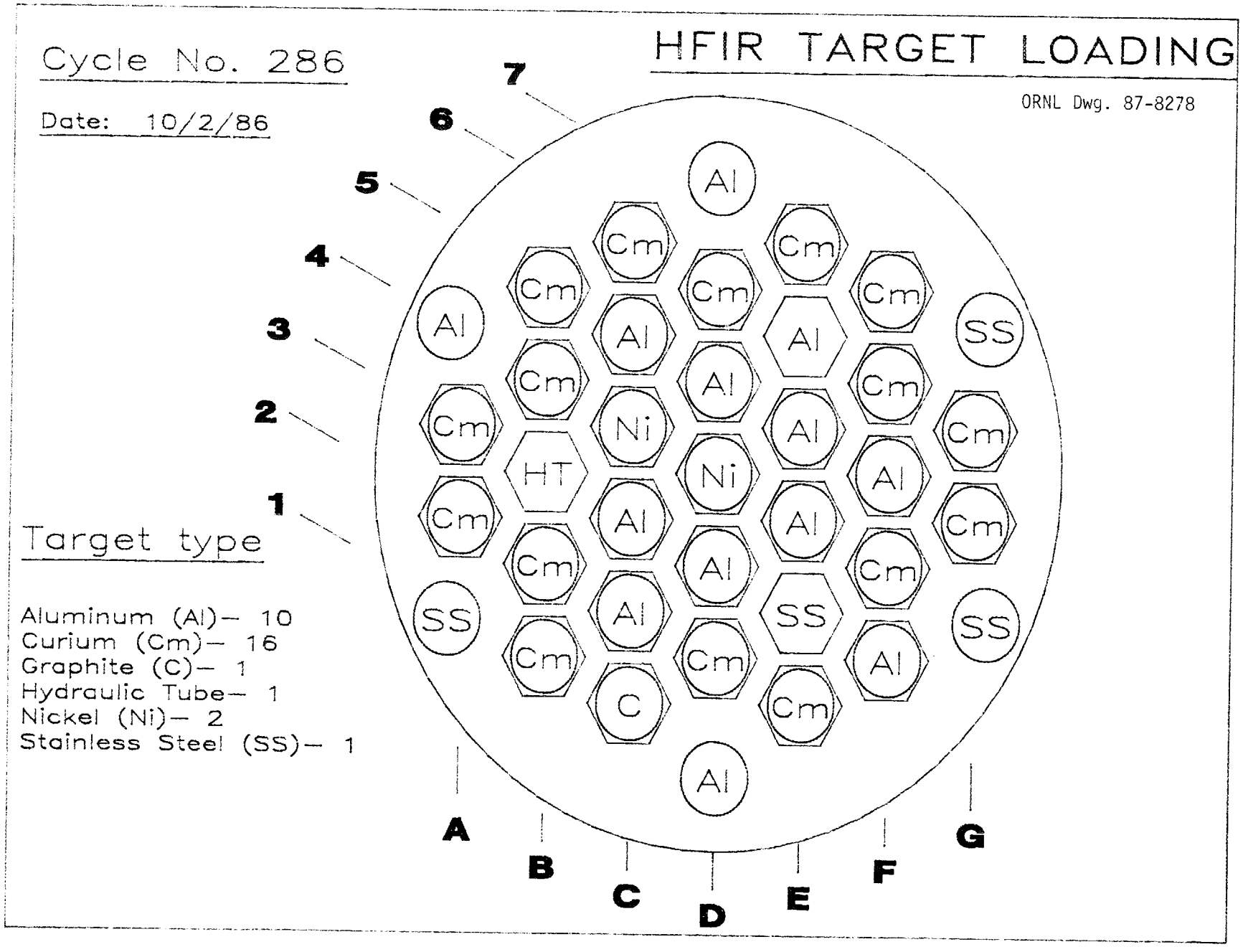
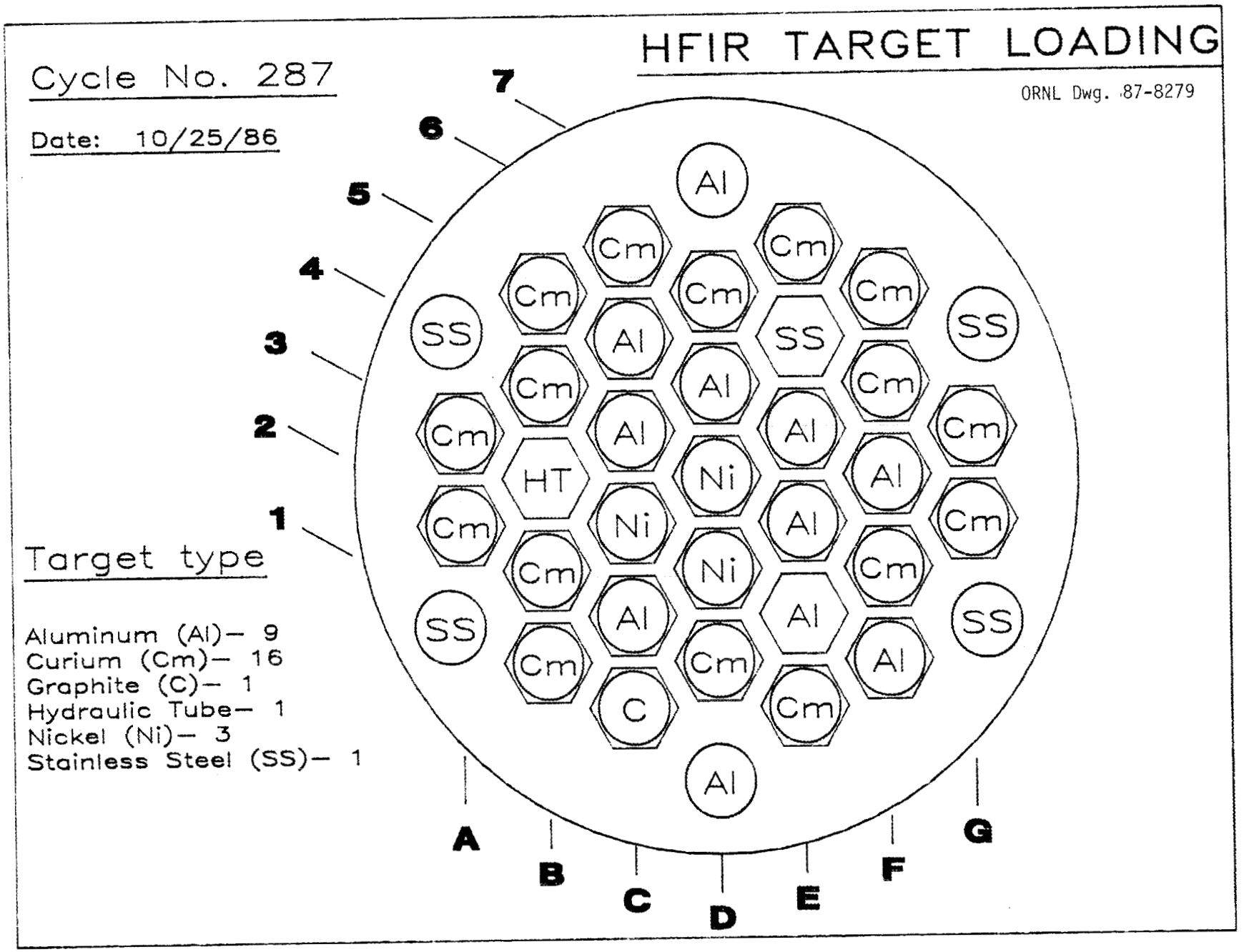

HFIR TARGET LOADING
ORNL Dwg. 87-8278
Cycle No. 286
Date: 10/2/86
Target type
Aluminum (Al)— 10
Curium (Cm)— 16
Graphite (C)— 1
Hydraulic Tube— 1
Nickel (Ni)— 2
Stainless Steel (SS)— 1
7
6
5
4
3
2
1
A
B
C
D
E
F
G
Al
Cm
Ni
HT
SS
C

Fig. 2.


HFIR TARGET LOADING
ORNL Dwg. 87-8279
Cycle No. 287
Date: 10/25/86
Target type
Aluminum (Al)— 9
Curium (Cm)— 16
Graphite (C)— 1
Hydraulic Tube— 1
Nickel (Ni)— 3
Stainless Steel (SS)— 1
7
6
5
4
3
2
1
A
B
C
D
E
F
G
Al
Cm
SS
HT
Ni
C

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