DISASSEMBLY OF THE FUSION-1 CAPSULE AFTER IRRADIATION IN THE BOR-60 REACTOR* H. Tsai (Argonne National Laboratory), V. A. Kazakov and V. P. Chakin (Research Institute of Atomic Reactors, Russia), and A. F. Rowcliffe (Oak Ridge National Laboratory)

SUMMARY

A U.S./Russia (RF) collaborative irradiation experiment, Fusion-1, was completed in June 1996 after reaching a peak exposure of ≈17 dpa in the BOR-60 fast reactor at the Research Institute of Atomic Reactors (RIAR) in Russia. The specimens were vanadium alloys, mainly of recent heats from both countries. In this reporting period, the capsule was disassembled at the RIAR hot cells and all test specimens were successfully retrieved. For the disassembly, an innovative method of using a heated diffusion oil to melt and separate the lithium bond from the test specimens was adopted. This method proved highly successful.

OBJECTIVE

The main objective of this task was to disassemble the Fusion-1 irradiation vehicle and retrieve the specimens contained inside.

BACKGROUND

The Fusion-1 experiment utilized a single lithium-bonded stainless steel capsule 508 mm long and 36 mm in diameter. The construction of the capsule consisted of (from bottom) a bottom end plug with a pedestal, an assembly of six tiers of U.S. specimens placed on top of the pedestal, four separate tiers of RF specimens place on top of the U.S. assembly, a hold-down spring, and a top end plug. Nichrome wires were used to tie the specimens into bundles in each tier, and additional nichrome wires were used to secure the bundles to the three spacer rods connecting the tiers. A fill tube at the top of the capsule was used to charge lithium into the capsule as the last step of the assembly.

As part of the collaborative agreement, the capsule was disassembled in the RIAR hot cell facilities. The central issue of the disassembly was how to remove the bulk of the lithium bond. The conventional method used in the U.S. on capsules (usually of much smaller sizes) is to dissolve the lithium bond with liquid ammonia. But that approach was judged to be impractical due to the large size of the Fusion-1 capsule. An alternative method of using heated diffusion-pump oil to melt the bulk lithium, proposed by RIAR, was adopted for the present work. After the bulk lithium had been removed with the hot oil, acetone would be used to remove the oil film on the specimens and alcohol would be used to remove the residual lithium and clean the specimens. Because of the potential for fire from molten lithium and/or hot oil in the air atmosphere of the hot cell, provisions to preclude and extinguish fires were incorporated into the procedures.

Before disassembly, simulated oil exposure tests were conducted with unirradiated vanadium specimens. The results showed that the heated oil would not affect the surface conditions of the materials under the anticipated heating conditions for the disassembly, i.e., ≤250°C for 4 h.

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RESULTS

The disassembly work was accomplished in two RIAR Materials Science hot cells, K2 for capsule opening and bulk lithium removal and K12 for final cleaning. Prior to the disassembly work, the K2 cell, which had been used for fuel element sectioning, was decontaminated by washing and wiping to a reported surface α level of 50 dpm/cm^2. The K12 cell, a structural materials testing cell, was clean and had no reported prior α contamination.

In the K2 cell, two circumferential cuts were made with an abrasive saw to remove the top and bottom end plugs of the capsule. Although part of the lower cut was through the lithium bond, the operation was completed with no incidents because the cutting speed was kept extremely low and the region of the cut was cooled periodically with poured liquid nitrogen. The opened capsule was placed immediately in a stainless steel pan filled with VM-1 oil, a mineral-based diffusion pump oil with only a moderate flash point. An electric heater was used to gradually heat the oil to the target temperature of 220°C (lithium melts at 181°C) in approximately 2 h. Noticeable smoking of the oil occurred above ≈200°C but otherwise the heating process was uneventful. A few nodules of lithium floated to the top of oil during the heating, lithium being lighter than the oil. When 220°C was reached, the capsule was lifted out of the oil with a hoist and all contents were poured out of the capsule into a clean tray. The liquid lithium at this point had a silvery shine but solidified immediately into grayish ingots in the tray. There was no fire with the exposed lithium. Most of the recovered specimens remained fixed in bundles in the tiers; however, some were loose, apparently due to breakage of the nichrome wires during irradiation.

All contents were returned to the oil pan to minimize oxidation of the residual lithium. The oil pan was kept at a reduced temperature of 200°C for 1 h to allow more complete separation of the lithium from the specimens. The bath was then allowed to cool to room temperature. The solidified lithium ingots on the oil surface were removed and the oil was drained to recover all specimens.

Following degreasing with acetone and several rinses with alcohol, the specimen assembly was taken apart tier-by-tier. The separated tiers were cleaned with additional alcohol. Visual inspection of the cleaned specimens (loose and in bundles) showed their condition to be satisfactory, i.e., none appeared to be bent or broken. Because of the care taken by the hot cell staff, no specimens appeared to have been lost in the operation. All bundles and loose specimens, in plastic pouches, were then transferred from the K2 cell to the K12 cell for wire removal, final cleaning, and sorting.

Preliminary smear testing of partially cleaned specimens in the K12 cell showed the surface α-contamination to be ≈ 1 dpm/cm^2, which is within the handling limitations of the U.S. hot cells.

CONCLUSIONS

The Fusion-1 capsule was successfully disassembled at RIAR. There was no loss or damage of the specimens during the disassembly operation. All tasks were accomplished without incident in the hot cells. For large-size capsules, such as the Fusion-1, using a heated oil appears to be a satisfactory method to separate the lithium bond from the specimens.

SCHEDULE AND STATUS OF IRRADIATION EXPERIMENTS – A. F. Rowcliffe and M. L. Grossbeck (Oak Ridge National Laboratory)

OBJECTIVE

To provide an updated summary of the status of irradiation experiments for the neutron-interactive materials program.

SUMMARY

The current status of reactor irradiation experiments is presented in tables summarizing the experimental objectives, conditions, and schedule.

PROGRESS AND STATUS

Currently, the program has two irradiation experiments in reactor; and 8 experiments in the planning or design stages. Postirradiation examination and testing is in progress on 18 experiments.

Summary of Reactor Irradiation Experiments

Experiment	Lead Lab	Collaborators	Responsible Person	Major Objectives	Materials	Temperature °C	Dose (dpa) or fluence	Irrad. Start	Irrad. Finish	Status
EBR-II, Reactor, ANL, Idaho Falls, ID										
COBRA 1A1	PNL	ORNL, ANL, MONBUSHO	M.L. Hamilton	Tensile and fatigue prop., Charpy impact, fracture toughness, TEM	Austenitic and ferritic steels, Fe-alloys, V, Be, low act. materials, Cu alloys, Ti-Al, SiC, C-C comp.	370, 500, 600	9	Nov-92	Apr-93	
COBRA 1A2	PNL	ORNL, ANL, MONBUSHO	M.L. Hamilton	Tensile and fatigue prop., Charpy impact, fracture toughness, TEM	Austenitic and ferritic steels, Fe-alloys, V, Be, low act. materials, Cu alloys, Ti-Al, SiC, C-C comp.	370, 400, 800	33	Nov-92	Sep-94	
X530	ANL		H. Tsai, H.M. Chung	He-effects, swelling, Charpy impact, fracture toughness, tensile prop.	V alloys	370	5	Aug-94	Sep-94	
High Flux Isotope Reactor, ORNL, Oak Ridge, TN										
HFIR-CTR-60	ORNL		S.J. Zinkle	Flexure bars, TEM, indentation disks	Isotopically tailored ceramics	100-600	2.4E+26 n/m2	Dec-94	Aug-95	
HFIR-CTR-61	ORNL		S.J. Zinkle	Similar to HFIR-CTR-60			7.20E+26	Dec-94	Aug-97	
HFIR-JP-9	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	He effects by isotopic tailoring, tensile prop., TEM	Austenitic and ferritic steels	300-600	57	Jul-90	Apr-94	
HFIR-JP-10	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	He effects by isotopic tailoring, tensile prop., TEM	Austenitic and ferritic steels	300-600	17	Jul-90	Sep-91	
HFIR-JP-11	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	Similar to HFIR-JP-10			17	Jul-90	Sep-91	
HFIR-JP-12	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	Similar to HFIR-JP-9			57	Jul-90	Apr-94	
HFIR-JP-13	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	Similar to HFIR-JP-10			17	Jul-90	Sep-91	
HFIR-JP-14	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	He effects by isotopic tailoring, tensile prop., TEM	Austenitic and ferritic steels	300-600	34	Jul-90	Sep-92	

Summary of Reactor Irradiation Experiments

Experiment	Lead Lab	Collaborators	Responsible Person	Major Objectives	Materials	Temperature °C	Dose (dpa) or fluence	Irrad. Start	Irrad. Finish	Status
HFIR-JP-15	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	Similar to HFIR-JP-9			57	Jul-90	Apr-94	
HFIR-JP-16	ORNL	JAERI	P.J. Maziasz/ J.E. Pawel	Similar to HFIR-JP-10			17	Jul-90	Sep-91	
HFIR-JP-17	ORNL	JAERI	M.L. Grossbeck/ J.E. Pawel	Fracture toughness, tensile prop. TEM	Austenitic and ferritic steels	250-300	3	Dec-91	Feb-92	
HFIR-JP-18	ORNL	JAERI	M.L. Grossbeck/ J.E. Pawel	Fracture toughness, tensile prop. TEM	Austenitic and ferritic steels	60-125	3	Aug-91	Oct-91	
HFIR-JP-19	ORNL	JAERI	M.L. Grossbeck/ J.E. Pawel	Similar to HFIR-JP-18		60-125	3	Aug-91	Oct-91	
HFIR-JP-20	ORNL	JAERI	J.E. Pawel	Tensile Prop., TEM, He effects by isotopic tailoring	Austenitic and ferritic steels	300-600	8	Dec-93	Jun-94	
HFIR-JP-21	ORNL	JAERI	J.E. Pawel	Similar to HFIR-JP-20			18	Dec-93	Apr-95	
HFIR-JP-22	ORNL	JAERI	J.E. Pawel	Similar to HFIR -JP-20			34	Dec-93	Jan-96	
HFIR-JP-23	PNL	MONBUSHO	D.S. Gelles	TEM	Austenitic and ferritic steels, Cu, Mo, V alloys, TiAl	300-600	8	Dec-93	Jun-94	
HFIR-MFE-60J	ORNL	JAERI	J.L. Scott/ M.L. Grossbeck	Spectrally tailored for fusion He prod. Began in ORR as ORR-MFE-6J (6.9 dpa). TEM, Charpy, irrad. creep, tensile and crack growth prop.	Austenitic and ferritic steels, and Ni alloys	60	19 (total)	Jul-90	Nov-92	
HFIR-MFE-330J	ORNL	JAERI	J.L. Scott/ M.L. Grossbeck	Similar to HFIR-MFE-60J. Began in ORR as ORR-MFE-7J (7.4 dpa)		330	19 (total)	Jul-90	Nov-92	
HFIR-MFE-200J	ORNL	JAERI	M.L. Grossbeck/ J.E. Pawel	Similar to HFIR-MFE-60J. Began in ORR as ORR-MFE-6J (6.9 dpa)		200	17 (total)	Nov-92	Jan-95	
HFIR-MFE-400J	ORNL	JAERI	M.L. Grossbeck/ J.E. Pawel	Similar to HFIR-MFE-60J. Began as ORR-MFE-7J (7.4 dpa)		400	17 (total)	Nov-92	Jan-95	
HFIR-HT-S1, -S7	ORNL		L.L. Snead	Thermal conductivity	Various insulators	80-350	0.01-1.0	Jun-95	Aug-95	
HFIR-HT-F Series	ORNL		L. L. Snead	Fiber tensile	SiC	80-800	0.001-1.0	Jan-95	Mar-96	

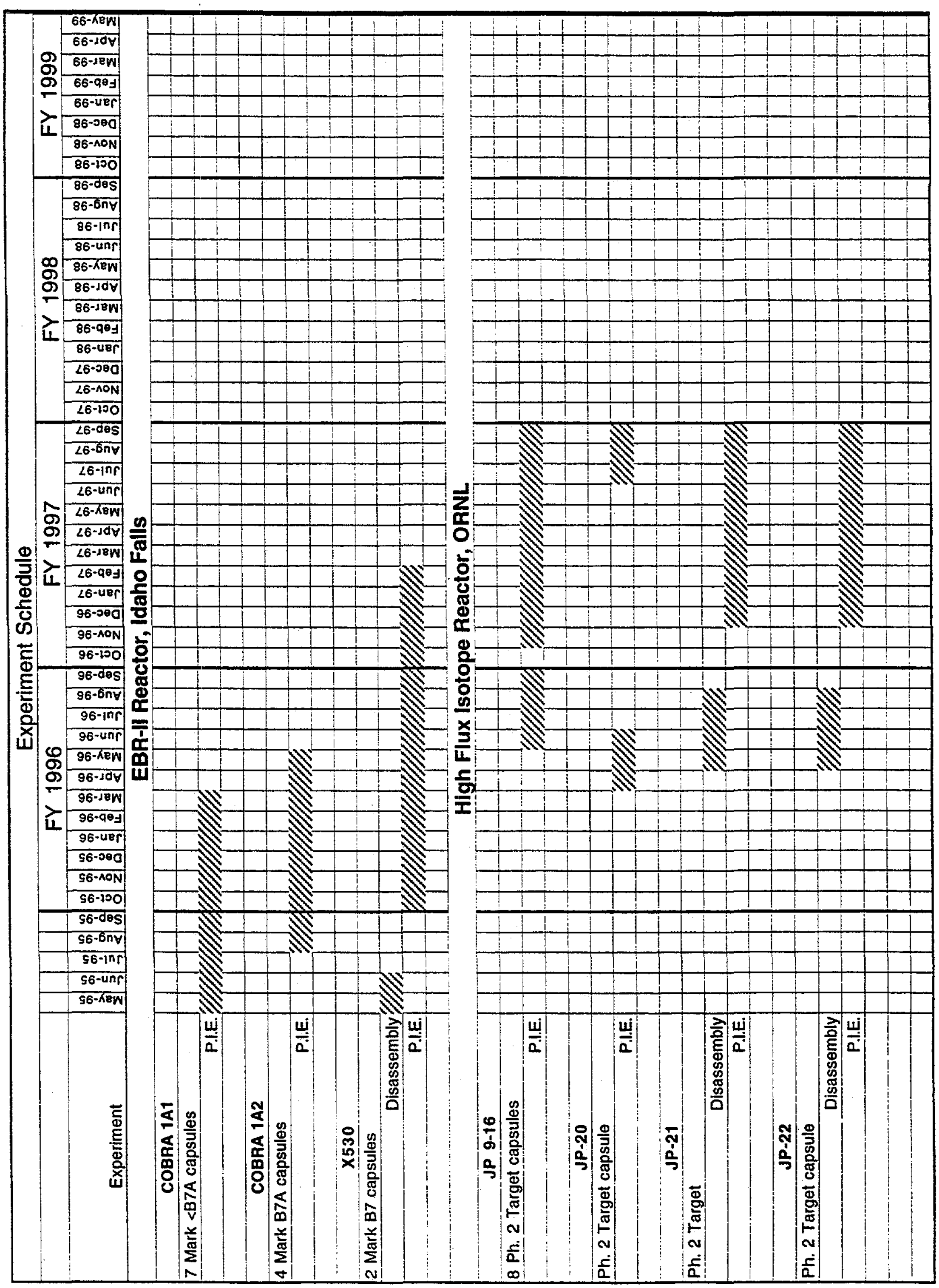
Summary of Reactor Irradiation Experiments

Experiment	Lead Lab	Collaborators	Responsible Person	Major Objectives	Materials	Temperature °C	Dose (dpa) or fluence	Irrad. Start	Irrad. Finish	Status
HFIR-TRIST-ER1	ORNL	MONBUSHO/ JAERI	S.J. Zinkle	In-situ electrical conductivity	Al2O3	450	3E+25 n/m2	Apr-96	Jun-96	
HFIR-MFE-RB-10J	ORNL	JAERI	J.E. Pawel	Tensile, fracture	Vanadium, 316LN-1G, J316	200, 500	5	Feb-98	Feb-99	
HFIR-MFE-RB-11J	ORNL	MONBUSHO/ JAERI	M. L. Grossbeck	Tensile, fracture, TEM	Low activation ferritics, V alloys, SiC	300	5	Feb-97	Feb-98	
HFIR-MFE-RB-12J	ORNL	MONBUSHO/ JAERI	M. L. Grossbeck	Tensile, fracture, TEM	Low activation ferritics, V alloys, SiC	500	5	Feb-97	Feb-98	
HFIR-CTR-62	ORNL	JAERI	R.L. Klueh	Charpy impact and He effects	Reduced act. and conventional ferritic steels	300, 400	13	Apr-95	Dec-95	
HFIR-CTR-63	ORNL	JAERI	R.L. Klueh	Charpy impact and tensile, TEM, He effects	Reduced act. and conventional ferritic steels	300, 400	13	Apr-95	Dec-95	
HFIR-JP25	ORNL	JAERI	R.L. Klueh	Tensile, fracture, TEM	Low activation ferritics	300, 500	20	Oct-97	Dec-98	
HFIR-JP27	ORNL	JAERI	L.L. Snead	Fracture, TEM	Intermetallics, SiC	500-800	10	Oct-97	Jan-98	
HFIR-JP28	ORNL	JAERI	L.L. Snead	Fracture, TEM	SiC	500-800	10	Sep-97	Mar-98	
HFIR-P3-6	ORNL	MONBUSHO	K. R. Thoms	Varying Temperature	TBD	400-600	5	May-97	Apr-98	
High Flux Beam Reactor, Brookhaven National Laboratory										
HFBR-ISEC-3	ORNL		L.L. Snead	In-situ electrical	WESGO Al2O3	450	1.5	Jul-95	Sep-95	
HFBR-V1	ORNL		L.L. Snead	Tensile, fracture	V-4Cr-4Ti	75, 150, 225	0.4	May-95	Jun-95	
HFBR-V2	ORNL		L.L. Snead	Tensile, fracture	V-4Cr-4Ti	75, 225, 300, 375	0.4	Jul-95	Aug-95	
HFBR-V3	ORNL		L.L. Snead	Tensile, fracture	V-4Cr-4Ti	160, 265, 315, 420	0.4	Aug-96	Sep-96	
HFBR-V4	ORNL		L.L. Snead	Tensile, fracture	V-4Cr-4Ti	105-505	0.1	Aug-96	Sep-96	
Advanced Test Reactor, Idaho Falls										
ATR-A1	ANL	MONBUSHO	D.L. Smith	Tensile, fracture toughness, TEM, creep	Vanadium alloys	200, 300	5	Dec-95	May-96	

Summary of Reactor Irradiation Experiments

Experiment	Lead Lab	Collaborators	Responsible Person	Major Objectives	Materials	Temperature °C	Dose (dpa) or fluence	Irrad. Start	Irrad. Finish	Status
BOR-60 Reactor, RIAR, Dimitrovgrad, Russia										
BOR-60-Fusion-1	ORNL, ANL	RDIPE, RIAR	A.F. Rowcliffe, D.L. Smith	Mechanical and microstructural properties	V alloys	350-380	10	Jul-95	Mar-96	
SM-2 Reactor, RIAR, Dimitrovgrad, Russia										
SM-2.1	ORNL, PNL	RIAR	S.J. Zinkle	Tensile, electrical, microstructural, and creep properties	Cu alloys	100, 200, 330	1, 5	Dec-93	Feb-94	
SM-2.2	PNL	SRIAR	D.J. Edwards	Mechanical behavior of bonded materials	Cu alloys/SS, Cu/Be	120, 300	0.2	Jan-96	Mar-96	
SM-2.3	PNL	SRIAR	D.J. Edwards	Mechanical behavior of bonded materials	Cu alloys/SS, Cu/Be	100, 250	0.2	Apr-97	Jun-97	

Legend	
	Irradiation complete
	Irradiation in progress
	Irradiation planned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EBR-II Reactor, Idaho Falls
COBRA 1A1
7 Mark <B7A capsules
P.I.E.
COBRA 1A2
4 Mark B7A capsules
P.I.E.
X530
2 Mark B7 capsules
Disassembly
P.I.E.
High Flux Isotope Reactor, ORNL
JP 9-16
8 Ph. 2 Target capsules
P.I.E.
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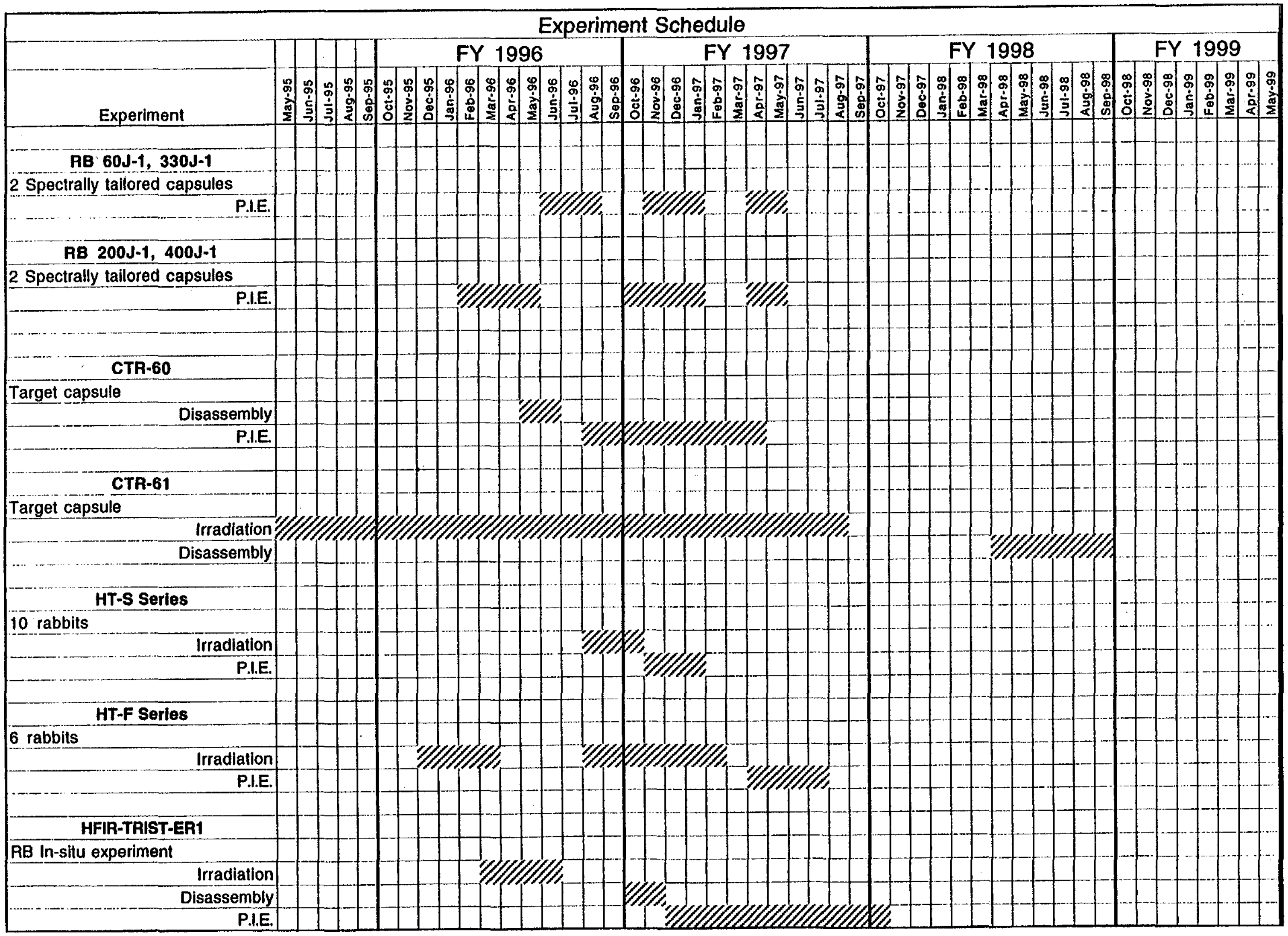
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RB 60J-1, 330J-1
2 Spectrally tailored capsules
P.I.E.
RB 200J-1, 400J-1
2 Spectrally tailored capsules
P.I.E.
CTR-60
Target capsule
Disassembly
P.I.E.
CTR-61
Target capsule
Irradiation
Disassembly
HT-S Series
10 rabbits
Irradiation
P.I.E.
HT-F Series
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Irradiation
P.I.E.
HFIR-TRIST-ER1
RB In-situ experiment
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Disassembly
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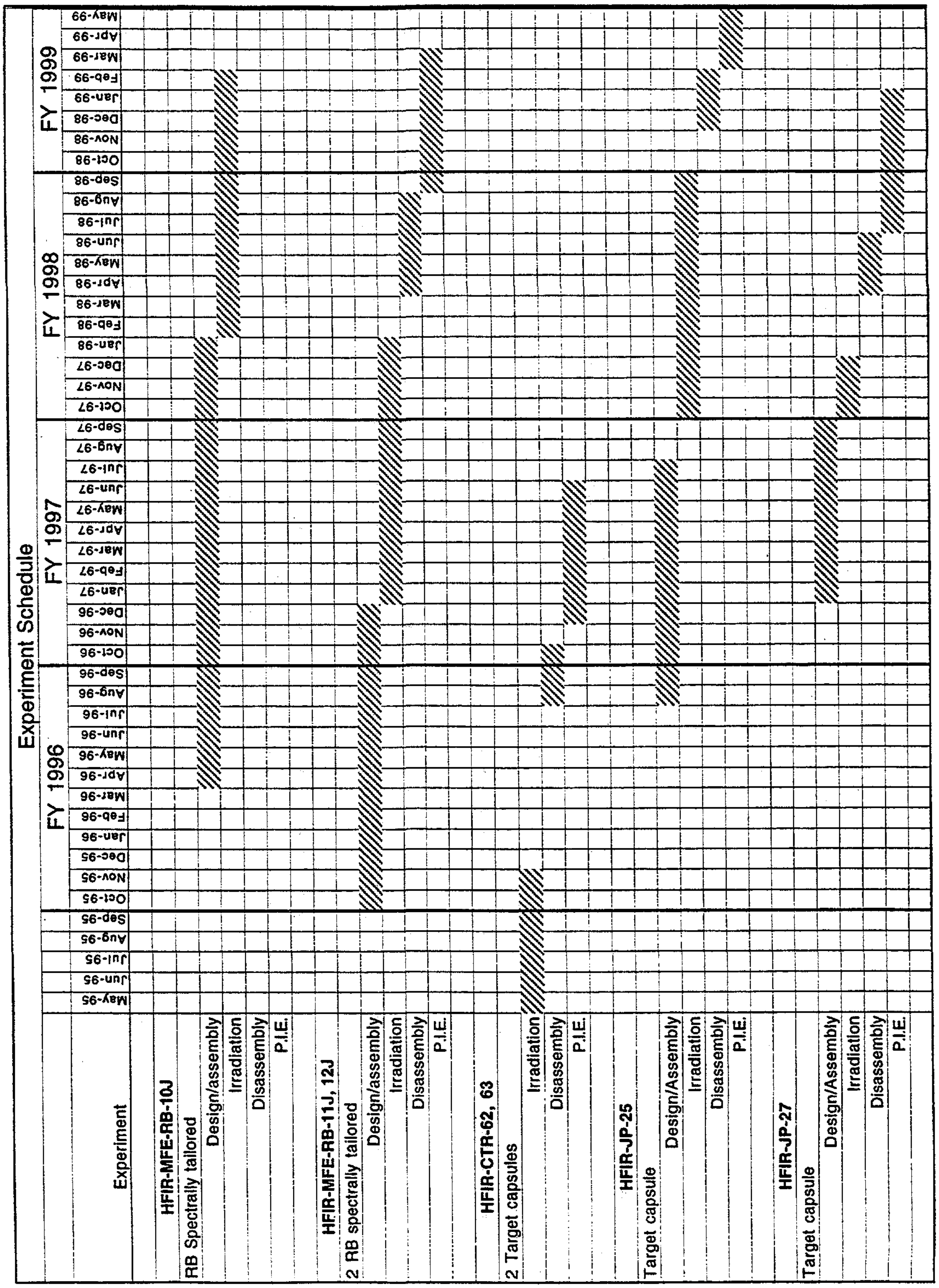
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Experiment
HFIR-MFE-RB-10J
RB Spectrally tailored
Design/assembly
Irradiation
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P.I.E.
HFIR-MFE-RB-11J, 12J
2 RB spectrally tailored
Design/assembly
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Disassembly
P.I.E.
HFIR-CTR-62, 63
2 Target capsules
Irradiation
Disassembly
P.I.E.
HFIR-JP-25
Target capsule
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HFIR-JP-27
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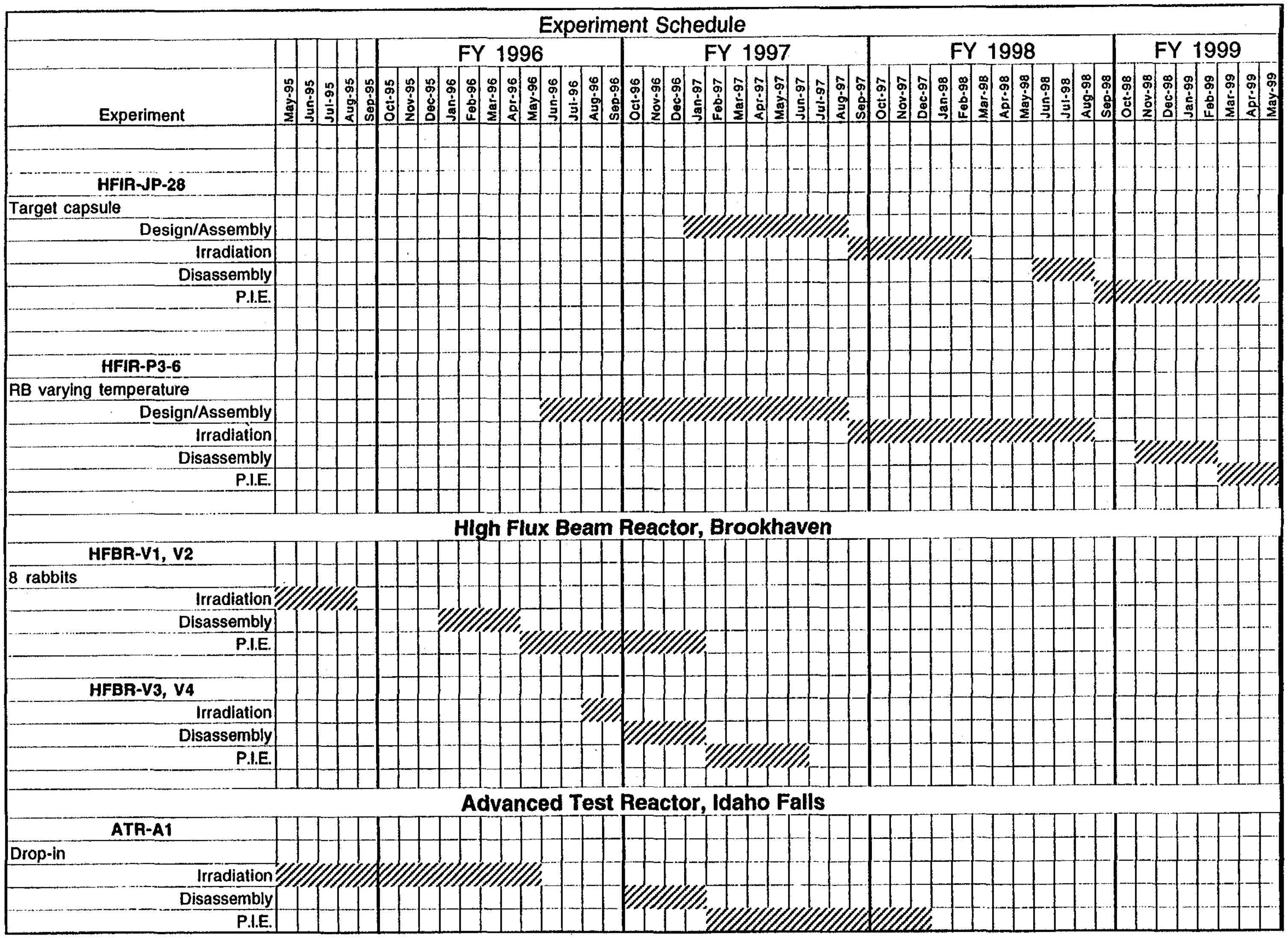

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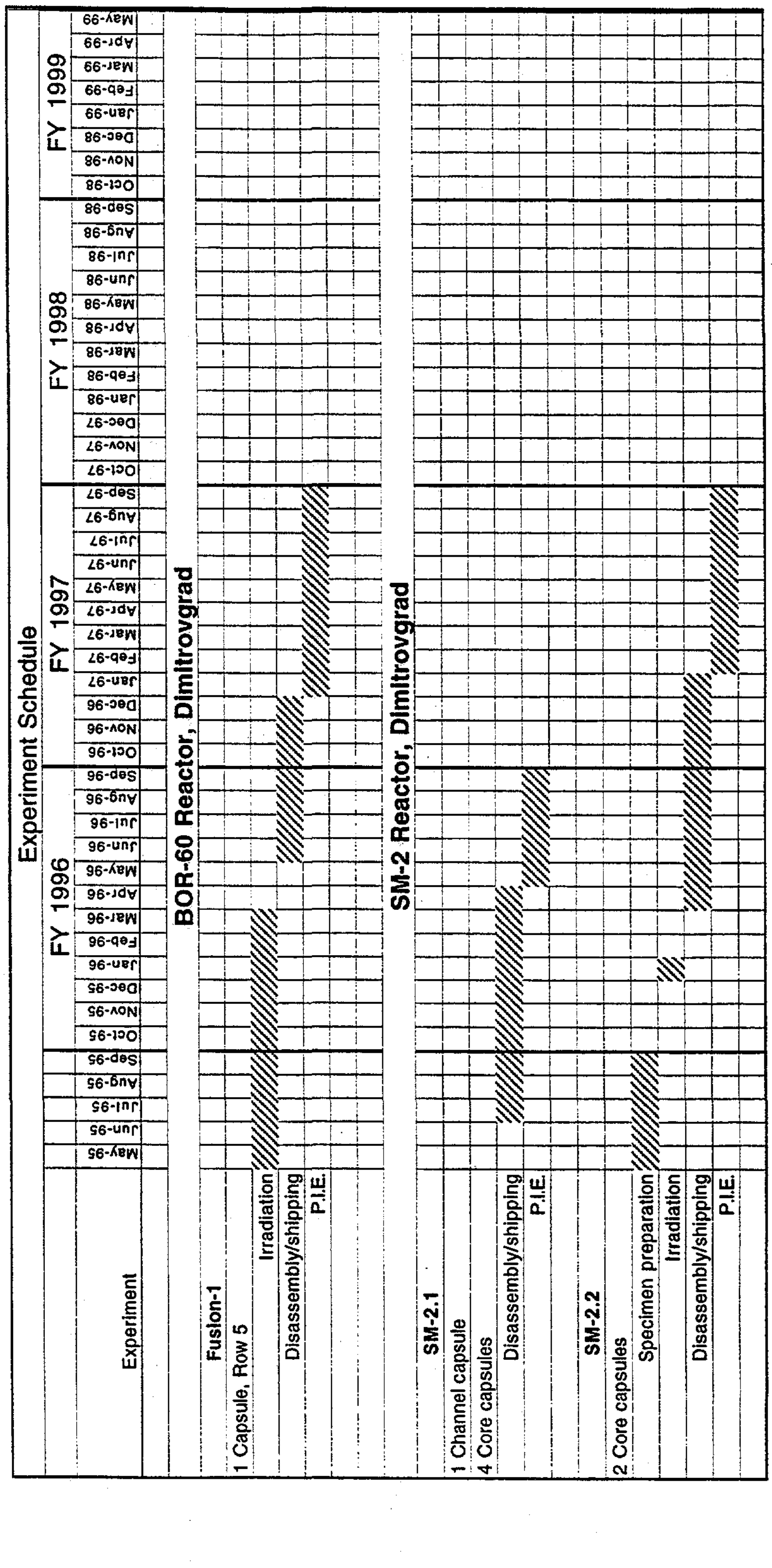
HFIR-JP-28
Target capsule
Design/Assembly
Irradiation
Disassembly
P.I.E.
HFIR-P3-6
RB varying temperature
Design/Assembly
Irradiation
Disassembly
P.I.E.
High Flux Beam Reactor, Brookhaven
HFBR-V1, V2
8 rabbits
Irradiation
Disassembly
P.I.E.
HFBR-V3, V4
Irradiation
Disassembly
P.I.E.
Advanced Test Reactor, Idaho Falls
ATR-A1
Drop-in
Irradiation
Disassembly
P.I.E.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BOR-60 Reactor, Dimitrovgrad
Fusion-1
1 Capsule, Row 5
Irradiation
Disassembly/shipping
P.I.E.
SM-2 Reactor, Dimitrovgrad
SM-2.1
1 Channel capsule
4 Core capsules
Disassembly/shipping
P.I.E.
SM-2.2
2 Core capsules
Specimen preparation
Irradiation
Disassembly/shipping
P.I.E.