OPERATING HISTORY OF THE HFIR MFE-RB-11J AND -12J (P3-2 AND P3-3) EXPERIMENTS

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OBJECTIVE

The objective of this report is to provide information on the irradiation history of the HFIR MFE-RB-11J and -12J experiments.

SUMMARY

The HFIR MFE-RB-11J and -12J experiments are being conducted under the auspices of the Japanese Monbusho, the Japan Atomic Energy Research Institute (JAERI), and the U.S. Fusion Energy Sciences Program. The irradiation of the experiments was completed in July of 1998, and the disassembly of the experiments is scheduled to be complete in early 1999. The operating history of both experiments, including the operating temperatures of the specimens, is discussed.

PROGRESS AND STATUS

Irradiation History

Both capsules and their associated europium liners were installed into HFIR at the beginning of fuel cycle 352 which began on February 7, 1997. RB-11J occupied position RB-1A in HFIR and RB-12J occupied position RB-5B, 180° apart. The desired ten cycles of irradiation were completed for both capsules at the end of fuel cycle 361, which ended on July 17, 1998. At the end of ten cycles, both capsules had accumulated 19,034 MWD (megawatt-days) of operation for a peak dose of 4.9 dpa (in stainless steel).

After HFIR cycle 361, the capsules and liners were removed from the reactor and placed in the HFIR pool for storage. In December of 1998, the RB-11J capsule was shipped to the hot cells at Oak Ridge.National Laboratory for disassembly. The RB-12J capsule is scheduled for shipment to the hot cells in January of 1999.

Detailed descriptions of the capsules and the associated liners have been reported previously. [1]

Temperature and Irradiation Data

Tables 1 and 2 contain information on the specimens loaded into the RB-11J and -12J capsules. Each table is sorted by specimen type: Charpy (CVN) specimens in two sizes, bend bars in eight sizes (BB), tensile specimens (SS-3), TEM holders, SiC fibers, J-type tensile specimens (SS-J), thermal diffusivity specimens (TD, includes temperature monitors), disk compact tension (DCT) specimens, and pressurized creep tube specimens (PT). Under each specimen type, except for the TEM holders, a listing of individual specimens is given, grouped by their location and accumulated dpa values. The operating temperatures are also shown. The same data is given for the TEM holders, but not for individual TEM disks. The data shown for each of the TEM holders relates to the centerline of the holder itself. The location of the TEM disks in each holder and the material composition of each specimen in both capsules was reported previously. [1]

A range is given for each of the temperatures shown in Tables 1 and 2. The range does not reflect the variation in temperature of an individual specimen. Instead, the specimen temperature lies within this range, and the variation of temperature for an individual specimen is less than that for

the group of specimens. With additional analyses, the temperature range for each individual specimen could be found. The ranges shown for the groups of specimens reflect several different factors. The factors include changes in HFIR power levels during operation, the change in temperatures as the capsules are rotated 180° at the end of each cycle, the variation in temperature over the length of each cycle due to the movement of the HFIR control plates, uncertainties in the relationship between specimen temperatures and thermocouple temperatures, and any variation in individual thermocouples over the course of the 10 cycles.

The reactor operated at 85 MW for the majority of the irradiation. However, during cycles 359, 360, and 361, the reactor operated at a reduced power level for short intervals. During cycle 359, the reactor operated at 10% power for 45 minutes. During cycle 360, the reactor power dipped to approximately 83 MW and returned to 85 MW over the course of 30 minutes. During cycle 361, the reactor operated at 50% power for 47 minutes. The reduced power operation affects less than 3.5 MWD of operation, which is 0.02% of the total MWD. Temperature data was collected during these periods of low power operation and the data is included in the results shown in Tables 1 and 2, but the low power data does not have a large impact on the results due to the low displacement damage accumulated during these periods of low power.

Also included in the temperature data shown in the tables is the observable difference in the thermocouple readings from cycle to cycle as the capsule is rotated 180° at the end of each cycle. The thermocouples are oriented such that one half of them are always on the side of the capsule nearest the reactor core, and the other half are on the other side of the capsule, facing away from the core. The thermocouple readings are noticeably lower when the thermocouples are not facing the core. For example, for cycle 354 the average reading on a particular thermocouple in RB-12J was 478°C, and for cycle 355, the average reading was 491°C. The variation is apparent in all of the thermocouples in both capsules, but the variation is less for the RB-11J capsule. For RB-11J, the temperature change is 2-10°C, and for RB-12J the temperature change is 5-15°C.

Temperature data was lost for both experiments on two occasions due to the failure of the computer systems that control the experiments and collect the data. Data is missing for 18 hours or 64 MWD of operation for the RB-11J experiment, which is 0.34% of the total MWD. The data is missing from cycle 355 (16 hours) and cycle 361 (2 hours). Data is missing for 13 hours or 46 MWD of operation for the RB-12J experiment, which is 0.24% of the total MWD. The data is missing from cycle 353 (4 hours) and cycle 358 (9 hours). The control equipment for both experiments is designed to automatically go to a failsafe mode if a control computer fails. This means that the specimen temperatures during these periods are expected to be lower than the temperatures shown in the tables by approximately 50°C in RB-11J and 100°C in RB-12J.

For RB-12J, the attempts to recover from the computer failure during cycle 353 also led to three separate high temperature excursions. The total time spent at temperatures above the desired values was 4 minutes (0.24 MWD). The peak temperatures for the specimens during this time are approximately 40°C above those shown in Table 2.

REFERENCES

1. M. L. Grossbeck, K. E. Lenox, M. A. Janney, T. Muroga, D. W. Heatherly, K. R. Thoms,"The Monbusho/U.S. Shielded HFIR Irradiation Experiment: HFIR-MFE-RB-11J and 12J (P3-2 And P3-3)," *Fusion Materials Semiannual Progress Report for the Period Ending June 30, 1997*, DOE/ER-0313/22, pp. 254-283.

2. R. L. Senn and W. R. Mixon, "Experimental Measurement of Gamma Heat in the High Flux Isotope Reactor," *Nuclear Technology*, Vol. 12, pp. 235-240, October 1971.

Table 1. Operating temperature, axial location, accumulated dpa of specimens in RB-11J.

Capsule:	11J		
Type:	1.5 CVN		
Temp. (°C)	DPA	z (cm)	ID Code
263±19	4.2	-12	LBV5
			LBV6
			LDV8
			LDV9
		12	L1V1
			L1V2
			LHV1
			LHV2
276±10	4.7	-6	LDV2
			LDV3
			LFV8
			LFV9
	4.8	-4	GF37
			LDV1
			LFV6
			LFV7
283±19	4.4	-10	LBV3
			LBV4
			LDV6
			LDV7
		10	L1V3
			L1V4
			LHV3
			LHV4
	4.6	-8	LBV1
			LBV2
			LDV4
			LDV5
		8	L1V5
			L1V6
			LHV5
			LHV6
	4.7	6	L2V1
			L2V2
			LHV7
			LHV8
	4.8	4	L2V3
			L2V4
			LFV5
			LHV9

Temp. (°C)	DPA	z (cm)	ID Code
283±19	4.8	-2	GF35
			GF36*
			LFV3
			LFV4
		2	GF31
			GF32
			L2V5
			L2V6
	4.9	0	GF33
			GF34
			LFV1
			LFV2
Grand Total of 52			

*Poorly marked

Capsule:	11J		
Type:	DCT		
Temp. (°C)	DPA	z (cm)	ID Code
240±19	3.6	16.8	FA13
			LFV5
			N202
			Z106
	3.8	15.5	FA12
			LFV4
			TJ02
			FA01
	4.0	14.15	FA11
			LFV3
			TWO2
261±19	3.6	-16.8	FA00
			FA08
			N201
			Z105
	3.8	-15.5	FA09
			LFV1
			LFW1
			TJ01
	4.0	-14.2	FA10
			LFV2
			LFW2
			TWO1
Grand Total of 23			

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 1. Operating temperature, axial location, accumulated dpa of specimens in RB-11J. (cont.)

Capsule:	11J		
Type:	1/3 CVN		
Temp. (°C)	DPA	z (cm)	ID Code
294±19	4.5	-9.29	138 Z1
			A026
		9.29	FK02
			N205
	4.5	-8.89	126 Z1
			FA40
			FA54
			TJ12
		8.89	A002
			FK33
			N202
			TW04
	4.7	-6.75	142 Z1
			A025
		6.75	FK01
			FK03
		-6.35	127 Z1
			FA39
		6.35	N203
			TW03
	4.8	-4.21	A024
		4.21	FK00
		-3.81	129 Z1
			FA38
		3.81	N204
			TW02
	4.9	-1.67	144 Z1
			A023
		-1.27	130 Z1
			A006
			FA49
			TJ15
		1.27	A005
			FA42
			FK30
			TW01
		1.67	145 Z1
			A021

*Surrounded by Zr foil

Temp. (°C)	DPA	z (cm)	ID Code
274±19	4.3	-11.43	125 Z1
			FA41
			FA55
			TJ11
		11.43	A001
			FK34
			N201
			TW05
	5.4	-11.83	QC62*
			QC63*
		11.83	QC61*
			QC64*
287±10	4.7	-6.35	FA51
			TJ13
		6.35	A003
			FK32
	4.8	-4.21	143 Z1
		4.21	FK04
		-3.81	FA50
			TJ14
		3.81	A004
			FK31
Grand Total of 60			

Capsule:	11J		
Type:	PT		
Temp. (°C)	DPA	z (cm)	ID Code
257±19	4.3	-11.2	L1VA
			LHVA
		11.2	LBVF
			LFVG
270±10	4.8	-4.48	L1VF
		4.48	LFVB
277±19	4.5	-8.96	L1VB
			LHVB
		8.96	LBVD
			LFVF
	4.7	-6.72	L1VD
			LHVD
		6.72	LBVB
			LFVD
	4.8	-4.48	LHVF
		4.48	LBVA
		-2.24	L2VB
			LHVG
		2.24	L2VF
			LFVA
	4.9	0	L2VA
			L2VD
Grand Total of 22			

Capsule:	11J		
Type:	TEM holder		
Temp. (°C)	DPA	z (cm)	ID Code
273±19	4.1	12.6	1-2
	4.3	11.5	1-1**
286±10	4.7	-5.4	1-5*
293±19	4.4	9.9	1-8
	4.6	-8	1-4*
		7.3	1-9
	4.8	4.8	1-10
		-2.9	1-6*
		2.2	1-11
	4.9	-0.3	1-12
Grand Total of 10			

*Holders made of Zr

** Contains previously irradiated TEMs

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 1. Operating temperature, axial location, accumulated dpa of specimens in RB-11J. (cont.)

Capsule:	11J		
Type:	B-1		
Temp. (°C)	DPA	z (cm)	ID Code
266±19	4.2	-12	Y603
			Y608*
		12	Y605*
			Y606
286±19	4.8	-3	Y602
			Y604*
		3	Y601
			Y607
	8.5	10.5	DY07
	8.7	-10.5	DY03
	8.8	-9	DY11
		9	DY08
	9.0	-7.5	DY12
		7.5	DY91
	9.2	-6	DY10
		6	DY09
		-7.5	DT05
		7.5	DT02
	9.5	-1.5	DY37
			DY40
		1.5	DY38
		-1	DY39
	9.6	-4.5	DT03
			DT06
		4.5	DT01
			DT04
	9.7	0	DY01
			DY05
Grand Total of 28			

*Poorly marked

Capsule:	11J		
Type:	B-2		
Temp. (°C)	DPA	z (cm)	ID Code
281±19	8.5	-10.5	DY18
			DY19
		10.5	DY13
	8.8	-9	DY17
		9	DY14
	9.2	-6	DY16
		6	DY15
Grand Total of 7			

Capsule:	11J		
Type:	B-3		
Temp. (°C)	DPA	z (cm)	ID Code
281±19	8.5	10.5	DY26
	8.8	-9	DY27
		9	DY25
	9.2	-6	DY23
			DY24
		6	DY21
			DY22
Grand Total of 7			

Capsule:	11J		
Type:	B-4		
Temp. (°C)	DPA	z (cm)	ID Code
281±19	8.5	10.5	DY31
			DY32
	8.8	-9	DY33
			DY34
		9	DY29
			DY30
Grand Total of 6			

Capsule:	11J		
Type:	B-5		
Temp. (°C)	DPA	z (cm)	ID Code
312±19	6.2	-2.25	FV1
		2.25	FY3
		-1.35	FV2
		1.35	FY2
		-0.45	FV3
		0.45	FY1
Grand Total of 6			

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 1. Operating temperature, axial location, accumulated dpa of specimens in RB-11J. (cont.)

Capsule:	11J		
Type:	B-7		
Temp. (°C)	DPA	z (cm)	ID Code
280±9	4.2	-12.5	I--1
		12.5	H--5
		-12.2	A--4
		12.2	D--5
	4.3	-11.5	I--2
		11.5	H--4
		-11.2	A--1
		11.2	D--4
312±19	4.4	-10.5	I--3
		10.5	H--3
		-10.2	A--2
		10.2	D--3
	4.5	-9.5	I--4
		9.5	H--2
		-9.2	A--3
		9.2	D--2
		-8.5	I--5
		8.5	H--1
	4.6	-8.2	A--5
		8.2	D--1
		-7.5	F--5
		7.5	F--3*
		-7.2	B--1
		7.2	C--5
	4.7	-6.5	E--3
		6.5	F--3*
		-6.2	B--2
		6.2	C--4
		-5.5	F--4
		5.5	F--2
		-5.2	B--3
		5.2	C--3

*These are labelled identically.

Temp. (°C)	DPA	z (cm)	ID Code
312±19	4.8	-4.5	J--1
		4.5	G--5
		-4.2	E--1
		4.2	C--2
		-3.5	J--2
		3.5	G--4
		-3.2	E--2
		3.2	C--1
		-2.5	J--3
		2.5	G--3
	4.9	-1.5	J--4
		-0.5	J--5
		0.5	G--1
		1.5	G--2
Grand Total of 46			

Capsule:	11J		
Type:	TD		
Temp. (°C)	DPA	z (cm)	ID Code
252±19	7.9	14.1	M1
Grand Total of 1			

Capsule:	11J		
Type:	B-8		
Temp. (°C)	DPA	z (cm)	ID Code
258±19	8.6	-11.25	843 M1
			919 T2
		11.25	917 T4
			919 M2
271±10	9.4	6.25	942 T4
			T13
	9.6	3.75	6 sticks*
			917 M4
278±19	9.0	-8.75	6 sticks*
			6 sticks*
		8.75	6 sticks*
			6 sticks*
	9.4	-6.25	942 M3
			T7
	9.6	-3.75	843 T1
			919 M1
	9.7	-1.25	917 T3
			T11
		1.25	843 M2
			942 M4
Grand Total of 20			

*These specimens are small unmarked bend bars that take up the space of one B-8.

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 1. Operating temperature, axial location, accumulated dpa of specimens in RB-11J. (cont.)

Capsule:	11J		
Type:	SS-3		
Temp. (°C)	DPA	z (cm)	ID Code
274±9	4.3	-11.43	A002
			A003
			N201
			N202
		11.43	FA11
			FA12
			FK08
			FK09
			TJ03
			TJ04
	5.4	-11.43	72*
			72*
			ST01*
			ST02*
		11.43	70*
			70*
307±19	4.5	-8.89	A006
			A008
			N203
			N204
		8.89	FA09
			FA10
			FK06
			FK07
			TW03
			TW04
	4.7	-6.35	A010
			A011
			TJ01
			TJ02
		6.35	FA07
			FA08
			FK04
			FK05
			TW01
			TW02
	4.8	-3.81	A012
			A022
			N205
			TH02
			TH03

Temp. (°C)	DPA	z (cm)	ID Code
307±19	4.8	3.81	FA05
			FA06
			FK02
			FK03
			ZH40
			ZH41
	4.9	-1.27	A023
			A024
			TH04
			TH05
			Z142
			Z143
		1.27	A025
			A026
			FK00
			FK01
			Z140
			Z141
	5.7	-8.89	71*
			72*
			ST03*
			ST04*
		8.89	70*
			UC15*
	6.0	-6.35	71*
			71*
			71
			72
		6.35	ST05*
			ST06*
	6.1	-3.81	ST07
			XC13*
			XC14*
		3.81	ZC13*
			ZC14*
	6.2	-1.27	XC15*
			ZC15*
		1.27	UC13*
			UC14*
Grand Total of 80			

*Surrounded by Zr foil

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 1. Operating temperature, axial location, accumulated dpa of specimens in RB-11J. (cont.)

Capsule:	11J
Type:	SS-J

Temp. (°C)	DPA	z (cm)	ID Code
274±9	4.2	-12	AL13**
			AL14**
			GD37
			GD39
			L2V1
			L2V2
		12	AL19
			AA47
			GB38
			GB39
			LFV6
			LFV7
	5.4	-12	F7A1*
			TD26*
			TD31*
			TD34*
			TD60*
			TD72*
			TD95*
			TD96*
		12	AV46*
			AV52*
			F4AR*
			F5AH*
			TA03*
			TD16*
			TD40*
			TD55*
307±19	4.4	-10.4	AF78
			AL15
			GA37
			GA38
			L2V3
			L2V4
		10.4	AF87
			AL17
			GA30
			GA39
			LFV4
			LFV5
	4.5	-8.8	AF88
			AF89
			L1V1

Temp. (°C)	DPA	z (cm)	ID Code
307±19	4.5	-8.8	L2V5
			LHV2
			LHV3
		8.8	AF82
			AF85
			LFV2
			LFV3
			LHV1
			LHV4
	4.6	-7.2	AA46
			AL18
			GB37
			L1V2
			L1V3
			YDO2
		7.2	AF84
			AF86
			LBV5
			LFV1
			LHV5
			YDO8
	4.7	-5.6	AA42
			AF83
			GD38
			L1V4
			L1V5
			YDO1
		5.6	AF91
			AF92
			GD30
			LBV3
			LBV4
			YDO9
	4.8	-4	AA38
			AA43
			AA48
			GF30
			GF37
			YDO7
		4	AA41
			AA44
			AF90^

Temp. (°C)	DPA	z (cm)	ID Code
307±19	4.8	4	LBV1
			LBV2
			YDO4
		-2.4	AA40
			AF77
			AF80
			GF38
			GF39
			YDO3
		2.4	AA39
			AA45
			AF79
			LDV4
			LDV5
			YD10
	4.9	-0.8	AA36
			AA49
			AL20
			LDV1
			LFV8
			YDO5
		0.8	AA37
			AF81
			AL16
			LDV2
			LDV3
			YDO6
	5.6	-10.4	F2AF*
			F347*
			F6A2*
			F6A4*
			TD14*
			TD22*
			TD42*
			TD66*
		10.4	F2A7*
			F2AG*
			F5AK*
			F6A1*
			TD25*
			TD36*
			TD84*
			TD85*

**Bent during installation *Surrounded by Zr foil ^ Poorly marked

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off to 2 decimal places.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 1. Operating temperature, axial location, accumulated dpa of specimens in RB-11J. (cont.)

Capsule:	11J										
Type:	SS-J	(cont.)									
Temp. (°C)	DPA	z (cm)	ID Code*	Temp. (°C)	DPA	z (cm)	ID Code*	Temp. (°C)	DPA	z (cm)	ID Code*
307±19	5.7	-8.8	F2A1	307±19	6.0	5.6	AV38	307±19	6.2	-0.8	AV43
			F2A8				AV41				AV45
			F5A7				F5A6				F4A9
			F7A6				F8A7				F8A0
			TD12				TD13				TA05
			TD24				TD54				TD32
			TD44				TD63				TD53
			TD46				TD90				TD80
		8.8	AV44		6.1	-4	AV40			0.8	F2A2
			AV53				AV47				F4A1
			F8A1				F6AM				F8AK
			F8AG				TA06				TD33
			TA00				TD21				TD70
			TD52				TD51				TD81
			TD65				TD62				TD91
			TD74				TD75				TD92
	5.9	-7.2	AV42			4	AV48	Grand Total of 224			
			AV54				AV50				
			F7B0				F4AB				
			F8AH				TA04				
			TD20				TD30				
			TD50				TD41				
			TD64				TD43				
			TD76				TD73				
		7.2	F340			-2.4	F34R				
			F34M				F4A3				
			F5A0				F6AH				
			F7A9				F7D0				
			TD10				TA01				
			TD45				TD11				
			TD83				TD35				
			TD93				TD61				
	6.0	-5.6	AV37			2.4	AV49				
			AV39				AV51				
			F6A6				F4AH				
			F7AD				F5AL				
			TA02				TD23				
			TD15				TD56				
			TD71				TD82				
			TD86				TD94				

*All of these specimens are surrounded by Zr foil.

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J.

Capsule:	12J		
Type:	1.5 CVN		
Temp. (°C)	DPA	z (cm)	ID Code
388±24	3.9	14.46	LDW4
			LDW5
			LDW6
			LHW2
414±23	3.9	-14.46	LDW1
			LDW2
			LDW3
			LHW1
481±22	4.4	-10.11	LHW3
490±17	4.2	-12	L1W1
			L2W1
		12	LBW6
			LFW6
501±22	4.6	-8.11	LHW4
509±22	4.4	-10	L1W2
			L2W2
		10	LBW5
			LFW5
	4.6	-8	L1W3
			L2W3
		8	LBW4
			LFW4
	4.7	-6	L1W4
			L2W4
		6	LBW3
			LFW3
	4.8	-4	L1W5
			L2W5
		-2	L1W6
			L2W6
		2	LBW1
			LFW1
		4	LBW2
			LFW2
	4.9	0	LHW5
			LHW6
Grand Total of 36			

Capsule:	12J		
Type:	PT		
Temp. (°C)	DPA	z (cm)	ID Code
399±21	4.8	3.79	LFWA
	5.96	6.18	12*
445±16	4.7	-5.18	LHWA
	4.8	-4.48	1010
476±22	4.2	-11.89	LFWG
			LHWG
	4.3	-11.2	1515
		11.2	L2WA
	5.45	11.26	3*
			5*
496±22	4.4	-9.65	LBWB
			LHWF
	4.5	-8.96	1414
		8.96	L2WB
	4.6	-7.41	L1WD
			LHWD
	4.7	-6.72	1111
		-5.18	LHWB
		6.72	L2WD
	4.8	-2.93	LBWD
			LFWF
		-2.24	X9X9
		1.55	L1WB
			LFWB
		2.24	X7X7
		3.79	L1WA
		4.48	X6X6
	4.9	-0.69	LBWA
			LFWD
		0	X8X8
	5.75	8.72	11*
			9*
	5.96	6.18	1*
Grand Total of 33			

*Sealed in a Zr tube

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J. (cont.)

Capsule:	12J		
Type:	1/3 CVN		
Temp. (°C)	DPA	z (cm)	ID Code
412±21	4.7	6.35	150 Z1
			FA46
	4.8	3.81	A027
			FA45
		4.32	135 Z1
458±16	4.7	-6.35	FA61
			FK11
			TW08
	4.8	-3.81	FA62
			FK13
			TW09
489±22	4.2	11.94	149 Z1
	4.3	-11.43	A008
			A028**
			FA58
			N206
			TW06
	5.4	11.43	QC65*
			QC66*
			QC67*
			QC68*
			QC69*
509±22	4.5	-8.89	A009
			A029
			FA59
			N207
			TW07
		8.89	151 Z1
			FA47
			FK09
			FK39
			N211
		9.4	148 Z1
	4.7	-6.35	A010
			A030
		-5.84	131 Z1
		6.35	FK06
			FK38
			N210
		6.86	147 Z1

*Surrounded by Zr foil

**Appeared bent prior to loading

Temp. (°C)	DPA	z (cm)	ID Code
509±22	4.8	-3.81	A011
			A031
		-3.3	132 Z1
		1.78	134 Z1
		3.81	FK05
			FK37
			N209
	4.9	-1.27	A012
			FA44
			FA64
			FK35
			TW10
		-0.76	133 Z1
		1.27	A007
			FA43
			FA48
			FK36
			N208
Grand Total of 58			

Capsule:	12J		
Type:	TEM holder		
Temp. (°C)	DPA	z (cm)	ID Code
412±21	4.8	4.6	2-9
489±22	4.2	12.2	2-12
	4.6	-7.8	2-6*
509±22	4.4	9.7	2-11
	4.6	7.1	2-10
	4.7	-5.3	2-5*
	4.8	-2	2-8
		-2.8	2-4*
	4.9	0.3	2-1**
		-0.9	2-2
Grand Total of 10			

*Holders made of Zr

** Contains previously irradiated TEMs

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J. (cont.)

Capsule:	12J		
Type:	B-1		
Temp. (°C)	DPA	z (cm)	ID Code
390±24	7.7	14.21	DY50
	7.9	14.21	DY41
406±21	9.5	4.5	DY02
			DY04
416±24	7.7	-14.21	DY51
	7.9	-14.21	DY42
483±22	4.21	-12	Y616
			Y616*
	8.4	12	DY06
			DY49
503±22	4.37	-10.5	Y609
		10.5	Y624
	4.5	-9	Y610*
		9	Y623
	4.61	-7.5	Y611
		7.5	Y622
	4.7	-6	Y612
		6	Y621*
	4.77	-4.5	Y613
		4.5	Y620
	4.82	-3	Y614
		3	Y619
	4.85	-1.5	Y615
		0	Y617*
		1.5	Y618
	8.7	-10.5	DY43
			DY48
		10.5	DY44
			DY45
	8.8	-9	DT13
			DT15
		9	DY80
			DY83
	9	-7.5	DY53
			DY55
		7.5	DY52
			DY54
	9.4	-6	DT08
			DT09
		-3	DY81
			DY82

*Poorly marked

Temp. (°C)	DPA	z (cm)	ID Code
503±22	9.4	3	DT14
			DT16
		6	DT07
			DT11
	9.5	-4.5	DY46
			DY47
		-1.5	DY94
			DY95
		1.5	DY93
			DY96
	9.7	0	DT10
			DT12
Grand Total of 53			

Capsule:	12J		
Type:	B-2		
Temp. (°C)	DPA	z (cm)	ID Code
390±24	7.7	14.21	DY56
			DY57
			DY58
			DY59
416±24	7.7	-14.21	DY60
			DY61
			DY62
			DY63
Grand Total of 8			

Capsule:	12J		
Type	B-3		
Temp. (°C)	DPA	z (cm)	ID Code
390±24	7.7	14.21	DY68
			DY69
			DY70
			DY71
			DY92
416±24	7.7	-14.21	DY28
			DY64
			DY65
			DY66
			DY67
Grand Total of 10			

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J. (cont.)

Capsule:	12J		
Type:	B-4		
Temp. (°C)	DPA	z (cm)	ID Code
390±24	7.7	14.21	DY35
			DY36
			DY72
			DY73
			DY78
416±24	7.7	-14.21	DY74
			DY75
			DY76
			DY77
			DY79
Grand Total of 10			

Capsule:	12J		
Type:	B-5		
Temp. (°C)	DPA	z (cm)	ID Code
484±17	5.3	12.05	FY6
	8.2	-12.05	None
503±22	5.5	-11.15	FVD
		11.15	FY5
	5.6	-10.25	FVA
		10.25	FY4
	5.7	-9.35	FZ1
		9.35	FX7
	5.8	-8.45	FZ2
		8.45	FX6
	5.9	-7.55	FZ3
		-6.65	FZ4
		6.65	FX4
		7.55	FX5
	6	-5.75	FZ5
		-4.85	FZ6
		4.85	FX2
		5.75	FX3
	6.1	-3.95	FZ7
		3.95	FX1
Grand Total of 20			

Capsule:	12J		
Type:	B-6		
Temp. (°C)	DPA	z (cm)	ID Code
355±33	7.8	14.71	D1
			D2
389±28	7.8	-14.71	D3
			D4
401±21	9.4	6.25	D7
	9.6	3.75	S7
447±16	9.4	-6.25	G1
	9.6	-3.75	H2
478±22	8.6	-11.25	P2
			S1
		11.25	P6
			S8
498±22	9	-8.75	H1
			N1
		8.75	D5
			N3
	9.4	-6.25	D6
		6.25	H3
	9.6	-3.75	H5
		3.75	G4
	9.7	-1.25	G3
			N2
		1.25	P5
			S3
Grand Total of 24			

Capsule:	12J		
Type:	B-8		
Temp. (°C)	DPA	z (cm)	ID Code
447±16	9.4	-6.25	917 T2
	9.6	-3.75	917 M2
478±22	8.6	11.25	942 M1
			T5
498±22	9	-8.75	917 T1
		8.75	T3
	9.4	6.25	942 T2
	9.6	3.75	942 M2
	9.7	-1.25	917 M1
		1.25	942 T1
Grand Total of 10			

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J. (cont.)

Capsule:	12J		
Type:	B-7		
Temp. (°C)	DPA	z (cm)	ID Code
486±17	4.2	-12.5	B-+5
			F-+4
		12.5	G-+5
			H-+3
505±22	4.3	-11.5	B-+2
			I-+1
		11.5	A-+5
			C-+3
	4.4	-10.5	A-+4
			E-+2
		10.5	E-+4
			I-+3
	4.5	-9.5	E-+3
			I-+5
		-8.5	J-+3
			K-+3
		8.5	H-+5
			M-+2
		9.5	D-+2
			I-+4
	4.6	-7.5	G-+4
			K-+2
		7.5	B--4
			D-+4
	4.7	-6.5	J-+4
			M-+1
		-5.5	G-+3
			J-+5
		5.5	A-+2
			G-+2
		6.5	C-+2
			H-+4
	4.8	-4.5	E-+5
			I-+2
		-3.5	B--5
			D-+3
		-3	A-+1
		-2.5	E--5
			H-+1
		-2	B-+1
		-1.5	C-+5
			K-+1

*Markings are poor.

Temp. (°C)	DPA	z (cm)	ID Code
505±22	4.8	1.5	H-+2
			J-+2
		2	F-+1
		2.5	A-+3
			B-+4
		3	G-+1
		3.5	D-+5
			F-+5
		4.5	F-+ 1*
			J-+1
	4.9	-1	C-+1
		-0.5	B-+3
			F-+2
		0	D-+1
		0.5	C-+4
			E--4
		1	E-+1
Grand Total of 59			

Capsule:	12J		
Type:	DCT		
Temp. (°C)	DPA	z (cm)	ID Code
343±33	3.8	15.46	FA03
			N204
			TWO4
			Z108
	4	14.15	FA02*
			N203*
			TWO3*
			Z107*
377±28	3.6	-16.78	LFTA
			LFTB
			FA14
			FA17
	3.8	-15.46	LFTD
			LFTG
			FA15
			FA18
	4	-14.15	LFTF
			LFTH
			FA16
			FA19
Grand Total of 20			

*2 out of 4 are actually at z=16.8 cm & 3.6 dpa

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J. (cont.)

Capsule:	12J		
Type:	SS-3		
Temp. (°C)	DPA	z (cm)	ID Code
478±17	4.3	-11.43	N208
			N209
			TH08
			TH09
			Z146
			Z147
		11.43	N206
			N207
			TH06
			TH07
	5.4	11.43	71*
			71*
497±22	4.5	-8.89	FA16
			FA17
			TW05
			TW06
			Z144
			Z145
		8.89	FA14
			FA15
			TW07
			TW08
	4.7	-6.35	A029
			A030
			FK10
			FK11
			TJ07
			TJ08
		6.35	A055
			A056
			TJ05
			TJ06
	4.8	-3.81	A031
			A033
			FK12
			FK13
		3.81	A038
			A039
			FK18
			FK19
497±22	4.9	-1.27	A034
			A035
			FK14
			FK15

*Surrounded by Zr foil

Temp. (°C)	DPA	z (cm)	ID Code
497±22	4.9	1.27	A036
			FA13
			FK16
			FK17
	5.7	8.89	70*
			70*
	6	6.35	UC16*
			UC17*
	6.1	-3.81	XC16*
			XC17*
		3.81	ZC16*
			ZC17*
	6.2	-1.27	ST08*
			ST09*
		1.27	ST10*
			ST11*
Grand Total of 60			

Capsule:	12J		
Type:	SiC Tube		
Temp. (°C)	DPA	z (cm)	ID Code
499±22	8.9	-9.6	J10
			J18
		9.6	J2
			J20
	9.5	-4.8	J16
			J8
		4.8	J12
			J4
	9.7	0	J14
			J6
Grand Total of 10			

Capsule:	12J		
Type:	TD		
Temp. (°C)	DPA	z (cm)	ID Code*
355±33	7.1	16.83	B1
			D1
			D2
			P1
			P2
			M2
Grand Total of 6			

*3 out of 6 are actually at z=14.1 cm & 8 dpa

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J. (cont.)

Capsule:	12J										
Type:	SS-J										
Temp. (°C)	DPA	z (cm)	ID Code	Temp. (°C)	DPA	z (cm)	ID Code	Temp. (°C)	DPA	z (cm)	ID Code
478±17	4.2	-12	AFK0	497±22	4.5	8.8	AFL3	497±22	4.9	-0.8	AA89
			AFK2				AFL8				AFJ0
			AFL0		4.6	-7.2	AF74				LFW3
		12	AA87^				AFJ9				LHW1
			AFJ7				AFM1				YD12
			AFL2				AFM2				YD13
			AFL7				YD15			0.8	AA96**
	5.4	-12	AV56				YD20				AF75
			AV93*			7.2	AA95				L1W2
			AV97*				AFK3				L2W1
			AV98*				AFK9		5.6	-10.4	AV55
			AV99*^				AFL9				AV94*
			AVB0		4.7	-5.6	AA88				AVB2*
			TH16*				AA91				AVC1
			TH37*				AFK7				F6AK*
			TH38				AFK8				F8A9*
			TH45*				YD11				TH15*
			TH78*				YD19				TH22*
		12	AV92*			5.6	AA92				TH52*
			AV95*^				AA99				TH67*
			F6A8*				AFL6			10.4	AVB5*
			F7F0*				LDW2				AVB6*
			TH23*		4.8	-4	AF73				F7A5*
			TH31*				AF76				F8AL*
			TH56*				LDW1				TH17*
			TH61*				LFW2				TH35*
			TH88*				YD14				TH46*
			TH92*				YD18				TH74*
497±22	4.4	-10.4	AA86			-2.4	AF67				TH84*
			AF68				AF71				TH93*
			AFK4				L1W1		5.7	-8.8	AV96*
			AFL5				LBW1				AVB8*^
		10.4	AA90				YD16				F343
			AF72				YD17				F344
			AFK5			2.4	AA94				TB01*
			AFL1				AA98				TB02*
	4.5	-8.8	AA93				LBW2				TH12*
			AF69				LHW2				TH40*
			AFK6			4	AF70				TH65*
			AFL4				AFK1^				TH81*
		8.8	AA97				L2W2				
			AFJ8				LFW1				

* Surrounded by Zr foil ** Bent during installation ^ Markings are poor

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.

Table 2. Operating temperature, axial location, accumulated dpa of specimens in RB-12J. (cont.)

Capsule:	12J										
Type:	SS-J	(cont.)									
Temp. (°C)	DPA	z (cm)	ID Code*	Temp. (°C)	DPA	z (cm)	ID Code*	Temp. (°C)	DPA	z (cm)	ID Code*
497±22	5.7	8.8	AV00	497±22	6	5.6	F2A6	497±22	6.1	4	F2A5
			AVB1				F5A4				F2AM
			F5AR				TB05				F4AM
			F6AL				TB06				F6A9
			TH33				TH26				TH24
			TH41				TH27				TH44
			TH71				TH51				TH75
			TH73				TH55				TH77
			TH87				TH91				TH86
			TH98				TH97				TH95
	5.9	-7.2	AVB4		6.1	-4	F2A3		6.2	-0.8	F349
			AVB7				F346				F4A2
			TH10				F6AD				F7AF
			TH34				F7G0				F8AM
			TH50				TB08				TH18
			TH70				TH42				TH21
		7.2	AVB3				TH48				TH53
			AVB9				TH76				TH62
			F4AF			-2.4	F2AK			0.8	F4A5
			F5AG				F4A7				F4A6
			F7A2				F6A5				TB04
			F8A4				F7AA				TB07
			TH14				TH11				TH32
			TH30				TH28				TH36
			TH58				TH47				TH64
			TH63				TH54				TH80
			TH82			2.4	F2AR				TH83
			TH96				F5AD				TH85
	6	-5.6	F5A2				TB00	Grand Total of 224			
			F5A8				TB03				
			F8AB				TH20				
			F8AD				TH25				
			TH13				TH66				
			TH43				TH72				
			TH57				TH90				
			TH60				TH94				

*All of the specimens on this page are surrounded by Zr foil.

All dpa values are calculated. Measured values will be reported upon completion of dosimetry analysis.

DPA calculation basis: 19034 MWD of operation; The peak DPA/MWD value is 0.000255 for SS, 0.000324 for V, 0.000498 for Al and 2*0.000255 for the ceramics. All DPA values have been rounded off.

DPA varies with axial location with the equation: cos(0.00858(z-12.7)) + 0.0000171(z-12.7)^2, z in mm (see Ref. 2).

z (cm) is the axial distance of the midpoint of the specimen from the HFIR centerline. All distances have been rounded off.

Operating temperatures are based on the thermocouple data, corrected for the specimen type and location. The given ranges represent the variation in thermocouple data.