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**Irradiation Performance
of HTGR Fuel Rods in HFIR
Experiments HRB-11 and -12**

F. J. Homan
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IRRADIATION PERFORMANCE OF HTGR FUEL RODS IN HFIR
EXPERIMENTS HRS-11 AND -12

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CONTENTS

ABSTRACT	1
INTRODUCTION	2
DESCRIPTION OF CAPSULES AND FUEL SPECIMENS	4
Capsules	4
Fuel	6
DESCRIPTION OF IRRADIATION	22
Irradiation Conditions	22
Capsule Operation	22
POSTIRRADIATION EXAMINATION	35
Disassembly and Visual Examination	35
Gamma Scans	40
Dimensional Inspection	52
Metallographic Examination	59
Fuel Rod HRB-11-1	59
Fuel Rod HRB-11-2	59
Fuel Rod HRB-11-3	63
Fuel Rods HRB-11-4 Through -6	63
Fuel Rod HRB-11-7	63
Fuel Rods HRB-11-8 Through -11	67
Fuel Rod HRB-11-16	67
Fuel Rods HRB-11-17 and -18	74
Fuel Rod HRB-11-19	74
Fuel Rod HRB-11-20	74
Fuel Rod HRB-11-21	74
Fuel Rod HRB-12-1	78
Fuel Rod HRB-12-2	78
Fuel Rod HRB-12-3	78
Fuel Rod HRB-12-4	85
Fuel Rod HRB-12-5	86
Fuel Rods HRB-12-6 Through -11	86
Fuel Rod HRB-12-18	86
Fuel Rod HRB-12-19	89

Fuel Rod HRE-12-20	89
Fuel Rod HRE-12-21	89
Summary	89
Electron Microprobe Examination	97
DISCUSSION	102
CONCLUSIONS	111
ACKNOWLEDGMENTS	112
REFERENCES	113
APPENDIX A. Thermal Analysis	117
APPENDIX B. Capsule Centerline Thermometry	123
APPENDIX C. Gamma Scan Data from Sleeves and Fuel Rods from Capsules HRE-11 and -12	129

IRRADIATION PERFORMANCE OF HTGR FUEL RODS IN HFIR
EXPERIMENTS HRC-11 AND -12

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ABSTRACT

Capsules HRC-11 and -12 were irradiated in support of development of weak-acid-resin-derived recycle fuel for the high-enriched uranium (HEU) fuel cycle for the HTGR.

Fissile fuel particles with initial oxygen-to-metal ratios between 1.0 and 1.7 performed acceptably to full burnup for HEU fuel. Particles with ratios below 1.0 showed excessive chemical interaction between rare earth fission products and the SiC layer.

Irradiated fissile particles fabricated from Duolite resin looked different from particles fabricated from Amberlite resin (the only resin for which there is previous irradiation experience). Kernels fabricated with Duolite resin were somewhat less dense initially and shrank more during irradiation. But the greater shrinkage did not appear to harm performance.

Fissile particles containing buffer layers of 40, 25, and 0 μ m (no buffer layer) performed the same. Thus the porous WAR-derived kernel has adequate void volume to accommodate fission gas, and fission recoil does not damage the inner pyrocarbon (PyC) layer of this type of fuel. The inner PyC layer thinned slightly in some of the particles with no buffer layer, apparently without degradation of performance.

Fission-product attack of the SiC layer appears to increase with increasing deposition rate for the SiC, although significant attack has been observed in other experiments where deposition rates were lower.

The ZrC-coated fuel fabricated by LASL did not perform well. This conclusion is based both on metallographic examinations and on gamma scanning studies of the graphite sleeve, which revealed high concentrations of fission products in the region adjacent to the fuel rods containing ZrC-coated fissile particles during irradiation.

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INTRODUCTION

This report describes the 11th and 12th capsules in a series of irradiation experiments in the High Flux Isotope Reactor (HFIR) Removable Beryllium (HRB) facility. This series of experiments has covered a ten-year period, with HRB-1 beginning irradiation in August 1969. These capsules and other irradiation experiments conducted at ORNL have been sponsored by the HTGR Program for the development and qualification of both fresh and recycle fuel for commercial reactors. The fuel designs have changed over the years, and the objectives of capsules HRB-11 and -12 were developed to support the effort to qualify and specify a recycle fuel for use with the high-enriched uranium (HEU) fuel cycle. At the time HRB-11 and -12 were being planned the reference recycle fuel system involved separable Triso-coated fissile particles and Biso-coated fertile particles. The specifics of the Triso and Biso particle designs are adequately covered in the references to this report and will not be repeated here. The fissile particle design included a porous weak-acid-resin (WAR)-derived kernel composed of UO_2 and UC_2 . The fertile particle design included a dense ThO_2 kernel.

In recent years the HRB capsules have been run in pairs of capsules with identical fuel loadings but operated at different temperatures. The objective was to gain information relative to the influence of temperature on fuel particle performance. Capsules HRB-4 and -5, HRB-7 and -8, and HRB-9 and -10 were operated that way.¹⁻³ The postirradiation examination techniques used for those capsules (metallography, electron microprobe, gamma scanning) were not sophisticated enough to detect significant effects of temperature on the ability of particle coatings to retain fission products. Therefore, for HRB-11 and -12 the test matrix was broadened (more batches of particles included) and the capsules were designed to operate at the same temperature.

The objectives of the HRB-11 and -12 experiments are listed below:

1. To supplement data from HRB-9 and -10 experiments on the effects of initial kernel oxygen-to-uranium ratio (O/U) on performance for the reference recycle particle. As indicated earlier, the reference recycle

particle included (at that time) a WAR-derived kernel composed of UO_2 and UC_2 . This objective, then, was to determine the proportions of UO_2 and UC_2 that gave best performance. This information was to be used to set the O/U specification for recycle fissile fuel.

2. To obtain performance data on a second resin material. All previous irradiation testing of WAR fuel had been on particles containing kernels made with Rohm and Haas Amberlite IRC-72 resin. The performance of the Amberlite-loaded fuel was good, but it was felt that at least one other resin source should be considered. In HRB-11 and -12 we tested particles that contained kernels fabricated from Diamond Shamrock Duolite C-464 resin. The Duolite resin had a lower density than the IRC-72 material, but it was not known if this would significantly influence irradiation performance.

3. To determine whether the minimum buffer layer thickness in the then current version of the Fuel Product Specification was optimal. Since the WAR-derived kernel has considerable porosity to accommodate fission gas, the function of the buffer layer in these particles is primarily to protect the inner LTI (low-temperature isotropic) layer from fission recoil damage. A reduction in buffer layer thickness would increase the heavy metal loading capability of the recycle fuel rods.

4. To test the influence of SiC coating deposition rate on fission product retention.

5. To test fuel produced in the 0.13-m coating furnace with a fritted gas distributor, and compare its performance with fuel coated with a conical gas distributor. This comparison would supplement information obtained from the OF-2 experiment.⁴

6. To test fuel fabricated by General Atomic Company (GA) with thermosetting matrices.

7. To further test fuel fabricated by Los Alamos Scientific Laboratory (LASL) with ZrC coatings in place of SiC in the Triso particle design. Such coated particles produced by LASL have been irradiated in other capsules and have looked promising, although no definitive examinations for fission product retentive capabilities have been made. Such examinations were included in the HRB-12 test plan.

Most of these objectives were achieved, as will be discussed later. Examination of the HRB-11 and -12 fuel with the IMGA system⁵ still remains and will provide additional information relatives to objectives 1 through 4. The General Atomic Company fuel was shipped to San Diego for examination and will be reported on separately (objective 6). The LASL fuel was examined in Oak Ridge, is discussed in this report, and will also be examined by IMGA (objective 7).

As indicated earlier, when these experiments were planned the reference fuel cycle for the HTGR was HEU, and the reference recycle kernel was WAR-derived uranium oxycarbide. In 1977 the HEU fuel cycle was replaced with a medium-enriched uranium (MEU) fuel cycle because of proliferation concerns associated with handling of the highly enriched feed material (93% ^{235}U) associated with the HEU cycle. The WAR-derived fissile particle was not considered for the MEU fuel cycle because so much more total uranium is required for this fuel cycle to load the same amount of ^{235}U . The low density associated with the WAR fuel limits the heavy metal loadings below those of a dense-kernel fuel. In addition, the combination of high fission gas release from failed WAR particles measured⁶ by GA and the availability of a new process for the fabrication of dense kernels containing the same uranium oxycarbide fuel has probably rendered the WAR-derived fuel obsolete, even if the HEU fuel cycle should again gain political acceptability.

DESCRIPTION OF CAPSULES AND FUEL SPECIMENS

Capsules

Capsules HRB-11 and -12 are similar in design^{2,3} to Capsules HRB-7 through -10. Features unique to HRB-11 and -12 have been discussed in detail elsewhere⁷ and will be briefly reviewed here. Each capsule contained 25 fuel specimens and one graphite crucible that contained loose particles for gamma spectrometry standards. The specimens were placed in a graphite sleeve, which in turn was encapsulated in a double-wall stainless steel containment vessel (as shown in Fig. 1). The capsules

Fig. 1. Configuration for HRB-11 and -12, Including Temperature Monitors.

were continuously swept with inert gas (mixtures of helium and neon) to facilitate temperature control and monitor capsule activity. The sweep gas occupied the gaps between the fuel and the graphite sleeve and between the graphite sleeve and the inner containment. Each capsule was instrumented with eight Chromel vs Alumel thermocouples placed in the graphite sleeve (Fig. 1) and a centerline thermometer. Fuel rods 1 through 9 were hollow to accommodate the centerline thermometer, and the capsules were designed for 1350°C maximum fuel temperature.

Preirradiation x radiographs of the capsules in Fig. 2 show the 25 fuel rod specimens in each. The loose particle crucibles can be seen at the bottom of the fuel column (at the opposite end from the centerline thermocouple assembly).

Fuel

In HRB-11 and -12, 19 types of fully enriched fissile particles and 22 types of fertile particles were tested in bonded-bed specimens. In addition, 24 Triso-coated fissile particles from batch OR-2211-H and 24 Triso-coated fertile particles from batch OR-2233-H were placed in a graphite crucible in each capsule for use as gamma spectrometry standards. Each rod specimen contained one fissile particle type, one Biso-coated fertile particle type, and Triso-coated inert particles. In HRB-11 the inert particles were from OR-2233-DH, and in HRB-12 inert particles were from batches OR-2323-BH and OR-2323-DH. Particle batch numbers, their respective positions in the capsule, and their specific objectives are shown in Table 1 for HRB-11 and Table 2 for HRB-12. Each of the GA bonded-bed specimens contained Triso-coated UC_2 fissile particles, Biso-coated ThO_2 fertile particles, and Triso-coated inert particles. All the particles coated at ORNL were heat-treated at 1800°C to stabilize the coatings. The characteristics of the ORNL fissile particle test set are described in Table 3, and the characteristics of the fertile particle test set is described in Table 4. Coating rates for each particle type are described for HRB-11 in Table 5 and for HRB-12 in Table 6.

Fig. 2. Preirradiation X Radiographs of Capsules (a) HRB-11 and (b) HRB-12.

Table 1. Coated Particles and Positions in HRE-11

Position in Capsule	Fissile Batch	Fertile Batch	Objective
1	OR-2466-H	J-488	WAR kernel oxygen content Second source resin
2	OR-2466-H	J-489	Buffer reduction
3	OR-2459-H	J-490	Buffer reduction
4	A-615	J-491	Frit vs cone gas distributor
5	A-601	J-488	WAR kernel oxygen content Frit vs cone gas distributor
6	A-611	J-489	WAR kernel oxygen content Frit vs cone gas distributor
7	OR-2463-H	J-490	WAR kernel oxygen content Second source resin
8	OR-2460-H	J-491	Buffer reduction
9	OR-2459-H	OR-2275-AHT	Buffer reduction
10	OR-2463-H	OR-2265-HT	WAR kernel oxygen content Second source resin
11	OR-2456-H	OR-2291-HT	WAR kernel oxygen content Second source resin
12	6151-17-020	6542-27-015	GA Thermosetting Matrix 4
13	6151-17-020	6542-27-015	GA Thermosetting Matrix 3
14	6151-17-020	6542-27-015	GA Thermosetting Matrix 2
15	6151-17-020	6542-27-015	GA Thermosetting Matrix 1
16	OR-2458-H	OR-2297-A.T	WAR kernel oxygen content Second source resin
17	OR-2471-H	OR-2271-HT	WAR kernel oxygen content Second source resin
18	OR-2466-H	OR-2262-HT	WAR kernel oxygen content Second source resin
19	OR-2456-H	OR-2294-HT	WAR kernel oxygen content Second source resin
20	OR-2458-H	OR-2299-HT	WAR kernel oxygen content Second source resin
21	OR-2471-H	OR-2273-HT	WAR kernel oxygen content Second source resin
22	6151-17-020	6542-27-015	GA Thermosetting Matrix 4
23	6151-17-020	6542-27-015	GA Thermosetting Matrix 3
24	6151-17-020	6542-27-015	GA Thermosetting Matrix 2
25	6151-17-020	6542-27-015	GA Thermosetting Matrix 1

Table 2. Coated Particles and Positions in HRB-12

Position in Capsule	Fissile Batch	Fertile Batch	Objective
1	3-HT	OR-2266-HT	ZrC vs SiC performance
2	9-HT	OR-2265-HT	ZrC vs SiC performance
3	10-HT	OR-2262-HT	ZrC vs SiC performance
4	OR-2486-H	OR-2261-HT	SiC deposition rate
5	OR-2494-H	OR-2266-HT	SiC deposition rate
6	OR-2480-H	OR-2265-HT	ZrC vs SiC performance SiC deposition rate
7	8-HT	OR-2262-HT	ZrC vs SiC performance
8	9-HT	OR-2261-HT	ZrC vs SiC performance
9	10-HT	OR-2274-HT	ZrC vs SiC performance
10	OR-2493-H	OR-2265-HT	SiC deposition rate
11	OR-2497-H	OR-2290-HT	SiC deposition rate
12	6151-17-020	6542-27-015	GA Reference Matrix 1
13	6151-17-020	6542-27-015	GA Thermosetting Matrix 5
14	6151-17-020	6542-27-015	GA Thermosetting Matrix 6
15	6151-17-020	6542-27-015	GA Thermosetting Matrix 7
16	OR-2458-H	OR-2296-AHT	SiC deposition rate
17	OR-2486-H	OR-2269-HT	SiC deposition rate
18	OR-2497-H	OR-2261-HT	SiC deposition rate
19	OR-2320-H	OR-2293-HT	WAR kernel oxygen content
20	OR-2493-H	OR-2298-HT	SiC deposition rate
21	OR-2320-H	OR-2272-HT	SiC deposition rate
22	6151-17-020	6542-27-015	GA Reference Matrix 1
23	6151-17-020	6542-27-015	GA Thermosetting Matrix 5
24	6151-17-020	6542-27-015	GA Thermosetting Matrix 6
25	6151-17-020	6542-27-015	GA Thermosetting Matrix 7

Table 3. Fissile Particle Test Set for HRB-11 and -12

Batch	Kernel ^a Composition	Kernel ^b Diameter (μ m)	Thickness, ^b μ m				Density ^{b, c} (Mg/m ³)					Capsule HRB-
			Buffer	ILTI	SiC	OLTI	Kernel	Buffer	ILTI	SiC	OLTI	
A-601	MAR-A	354.2(15.0)	58.8(10.1)	35.4(3.1)	30.0(1.4)	31.8(3.4)	3.034	1.217 ^d	1.713 ^e (0.012)	3.206(0.009)	1.724 ^e (0.008)	11
A-611	MAR-A	366.5(15.0)	47.6(10.2)	36.8(3.0)	30.5(1.4)	35.1(3.9)	3.102	1.159 ^d	1.753 ^e (0.020)	3.204(0.003)	1.696 ^e (0.006)	11
A-615	MAR-A	354.1(15.7)	51.0(12.3)	30.7(3.3)	29.5(1.5)	32.4(4.2)	3.076	1.040	1.857 ^e (0.009)	3.200(0.008)	1.910 ^e (0.004)	11
								1.330 ^d				
OR-2320-H	MAR-A, UC ₃ .12 ^g 01.34	374.0(20.6)	43.8(5.0)	36.8(3.4)	34.3(2.0)	38.6(3.1)	3.17	1.30 ^f	1.953(0.007)	3.205(0.002)	1.995(1.008)	12
OR-2436-H	MAR-D, UC ₃ .16 ^g 01.36	414.4(26.0)	42.8(4.0)	38.4(2.7)	34.1(1.8)	39.0(3.1)	2.43	1.23	1.964(0.006)	3.204(0.008)	2.011(0.004)	11
OR-2438-H	MAR-D, UC ₃ .83 ^g 01.09	413.4(21.7)	45.9(4.9)	34.3(2.4)	36.0(2.0)	38.4(2.0)	2.47	1.25	1.962(0.008)	3.203(0.007)	2.005(0.005)	11, 12
OR-2459-H	MAR-D, UC ₃ .83 ^g 01.09	407.9(23.9)	20.5(2.8)	35.2(3.4)	33.9(2.0)	26.5(2.6)	2.47	1.25	1.950(0.009)	3.199(0.009)	2.026(0.007)	11
OR-2460-H	MAR-D, UC ₃ .80 ^g 01.06	396.1(20.7)		36.3(3.4)	35.3(2.4)	33.8(2.5)	2.45		1.950	3.159(0.004)	2.008(0.010)	11
OR-2463-H	MAR-D, UC ₃ .32 ^g 01.65	415.7(23.1)	47.0(6.6)	39.8(3.6)	33.9(1.9)	36.2(2.1)	2.41	1.16	1.941(0.013)	3.200(0.006)	2.019(0.005)	11
OR-2466-H	MAR-D, UC ₃ .45 ^g 01.73	406.1(26.7)	50.6(4.9)	34.3(2.4)	34.9(1.8)	34.3(3.1)	2.38	1.24	1.952(0.007)	3.197(0.007)	2.024(0.006)	11
OR-2471-H	MAR-D, UC ₃ .48 ^g 01.62	391.4(20.0)	47.6(5.6)	34.7(2.6)	34.4(1.3)	33.9(3.8)	2.53	1.25	1.956(0.009)	3.194(0.008)	1.992(0.007)	11
OR-2480-H ^h	MAR-A, UC ₃ .58 ^g 01.13	362.8(20.2)	49.9(7.1)			72.1(3.8)	3.186	1.27			2.01(0.005)	12
OR-2486-H	MAR-A, UC ₃ .58 ^g 01.13	361.4(22.2)	48.2(6.5)	40.2(3.37)	30.7(1.5)	40.4(2.9)	3.186	1.27	2.004(0.008)	3.190(0.004)	2.020(0.006)	12
OR-2493-H	MAR-A, UC ₃ .60 ^g 01.10	363.3(23.1)	43.3(6.6)	36.6(3.9)	32.2(1.6)	36.1(3.0)	3.203	1.304	2.010(0.007)	3.190(0.007)	2.038(0.007)	12
OR-2494-H	MAR-A, UC ₃ .60 ^g 01.10	363.3(23.1)	43.3(6.6)	36.6(3.9)	32.2(1.3)	36.4(3.0)	3.203	1.304	2.010(0.007)	3.197(0.004)	2.027(0.006)	12
OR-2497-H	MAR-A, UC ₃ .58 ^g 01.13	361.4(22.2)	48.2(6.5)	40.2(3.37)	36.4(1.4)	38.5(3.7)	3.186	1.27	2.004(0.008)	3.15	2.011(0.010)	12
8-HT	MAR-A, UC ₃ .60 ^g 01.10	363.3(23.1)	43.3(6.6)	36.6(3.9)	30.0(1.88) ^h	37.6(4.15)	3.203	1.304	2.010(0.007)	†	†	12
9-HT	MAR-A, UC ₃ .60 ^g 01.10	363.3(23.1)	43.3(6.6)	36.6(3.9)	30.0(1.88) ^h	33.7(3.11) ^j	3.203	1.304	2.010(0.007)	†	†	12
10-HT	MAR-A, UC ₃ .60 ^g 01.10	363.3(23.1)	43.3(6.6)	36.6(3.9)	14.51(1.0) ^k	23.7(2.3) ^j	3.203	1.304	2.010(0.007)	†	†	12

^aMAR-A is Amberlite weak-acid resin; MAR-D is Duolite weak-acid resin.

^bNumbers in parentheses are standard deviations.

^cGradient column densities unless otherwise noted.

^dDensity after depositing ILTI.

^eCorrected gradient density.

^fTap density.

^gSize-coated fissile particle.

^hZrC coating.

ⁱNot measured.

^jZrC-doped OLTI.

^kZrC coating followed by ZrC-C coating 25.9 μ m thick (standard deviation 2.6 μ m).

Table 4. Fertile Particle Test Set for HKB-11 and -12

Batch	Kernel ^a Diameter (μm)	Thickness ^a (μm)		Gradient Column Density, ^a Mg/m ³				Capsule HKB-
		Buffer	LTI	Kernel	Buffer	LTI ^b		
						Observed	Corrected ^c	
J-488	497.2(2.7)	87.4(18.2)	78.7(6.6)	9.95	1.285	1.976(0.008)	1.873(0.007)	11
J-489	496.8(2.2)	74.7(13.8)	76.9(5.3)	9.95	1.168	1.904(0.009)	1.793(0.009)	11
J-490	495.6(2.8)	81.7(15.0)	74.8(5.4)	9.95	1.238	1.992(0.010)	1.858(0.009)	11
J-491	495.6(3.1)	83.8(13.8)	75.6(5.9)	9.95	1.232	2.004(0.006)	1.858(0.006)	11
OR-2261-HT	506(2.5)	95.8(10.8)	88.9(6.5)	10.0	1.15	1.886(0.005)		12
OR-2262-HT	507(2.5)	98.0(13.5)	85.1(5.6)	10.0	1.15	2.009(0.007)		11, 12
OR-2265-HT	508(2.5)	96.1(13.1)	94.2(8.1)	10.0	1.15	1.949(0.008)		12
OR-2266-HT	506(2.6)	94.8(15.8)	91.3(6.8)	10.0	1.15	2.019(0.013)		11, 12
OR-2269-HT	507(2.4)	88.8(10.8)	81.4(6.8)	10.0	1.17	1.908(0.007)		12
OR-2271-HT	507(3.1)	88.6(14.6)	80.3(5.8)	10.0	1.17	2.015(0.010)		11
OR-2272-HT	506(2.2)	86.8(13.2)	83.0(4.8)	10.0	1.17	1.860(0.006)		12
OR-2273-HT	507(2.3)	89.7(7.6)	83.5(4.8)	10.0	1.17	2.009(0.006)		11
OR-2274-HT	507(2.5)	99.7(12.3)	90.8(8.1)	10.0	1.15	1.957(0.012)		12
OR-2275-AHT	507(2.3)	93.0(11.1)	87.4(8.4)	10.0	1.15	2.053(0.009)		11
OR-2290-HT	507(2.2)	95.3(12.4)	94.4(5.4)	10.0	1.12	1.882(0.008)		12
OR-2291-HT	507(2.3)	95.1(14.9)	87.6(5.7)	10.0	1.12	1.982(0.007)		11
OR-2293-HT	506(2.7)	97.6(13.9)	89.0(5.1)	10.0	1.12	1.832(0.004)		12
OR-2294-HT	506(2.3)	90.0(15.6)	92.7(7.0)	10.0	1.12	1.961(0.007)		11
OR-2296-AHT	506(2.5)	97.1(14.6)	89.3(7.5)	10.0	1.12	1.898(0.007)		12
OR-2297-AHT	505(2.6)	96.5(12.3)	90.2(7.3)	10.0	1.12	1.975(0.011)		11
OR-2298-HT	506(2.5)	94.5(14.3)	84.4(5.8)	10.0	1.12	1.823(0.012)		12
OR-2299-HT	508(2.4)	94.5(13.1)	91.6(5.6)	10.0	1.12	1.910(0.005)		11

^aNumbers in parenthesis are standard deviations.

^bAfter heat treatment of 1800°C for 30 min.

^cCorrected for open porosity as described by W. A. Pechin et al., ORNL-5165 (June 1977), pp. 12-15.

Table 5. Deposition Rates for Fissile and Fertile Particles in HRB-11

Batch	Rate, $\mu\text{m}/\text{min}$			
	Buffer ^a	ILTI ^b	SiC ^c	OLTI ^b
<u>Fissiles</u>				
A-601	29.40	4.72	not given	4.84
A-611	26.74	4.72	0.15	5.14
A-615	17.70	3.99	not given	4.00
OR-2456-H	10.07	6.59	0.38	6.84
OR-2458-H	3.96	6.53	0.40	7.46
OR-2459-H	11.38	7.04	0.39	7.77
OR-2460-H	None	7.44	0.41	8.45
OR-2463-H	10.06	6.05	0.38	6.73
OR-2466-H	12.65	7.54	0.40	8.11
OR-2471-H	10.19	6.72	0.40	7.37
<u>Fertiles</u>				
J-488	25.56			7.22
J-489	22.98			5.83
J-490	25.14			6.18
J-491	24.29			9.10
OR-2262-HT	24.50			6.55
OR-2266-HT	23.70			14.04
OR-2271-HT	22.15			10.71
OR-2273-HT	22.30			5.22
OR-2275-AHT	23.25			23.00
OR-2291-HT	23.78			7.30
OR-2294-HT	22.50			3.57
OR-2297-AHT	24.13			4.88
OR-2299-HT	23.53			2.35

^aC₂H₂ used as coating gas; all A- and J- particle batches at 1350°C; all OR batches at 1125°C.

^bC₃H₆ used as coating for all A- and J- particle batches at 1350°C; MAPP gas used for OR- particle batches at 1275°C.

^cCH₃SiCl₃ used as coating gas; all A- particle batches at 1575°C; all OR- particle batches at 1550°C.

Table 6. Deposition Rates for Fissile and Fertile Particles in HRB-12

Batch	Rate, $\mu\text{m}/\text{min}$			
	Buffer ^a	ILTI ^b	SiC ^c	OLTI ^b
<u>Fissiles</u>				
8-HT	4.77	4.18	d	e
9-HT	4.77	4.18	d	e
10-HT	4.77	4.18	d	e
OR-2486-H	5.67	4.68	0.90	11.22
OR-2494-H	Mixture of OR-2465-H-OR-2478-H		0.52	9.71
OR-2480-H	5.87	8.48	None	None
OR-2493-H	Mixture of OR-2465-H-OR-2478-H		0.21	9.23
OR-2497-H	5.67	4.68	0.24	8.56
OR-2320-H	7.30	6.90	0.22	7.02
OR-2465-H	4.76	4.18		
OR-2478-H	5.67	4.68		
OR-2458-H	3.96	6.53	0.40	7.46
<u>Fertiles</u>				
OR-2265-HT	23.70			14.04
OR-2265-HT	24.03			15.70
OR-2262-HT	24.50			6.55
OR-2261-HT	23.91			7.41
OR-2274-HT	24.93			27.94
OR-2290-HT	23.83			8.58
OR-2296-AHT	24.28			5.58
OR-2269-HT	22.20			12.52
OR-2293-HT	24.40			3.87
OR-2298-HT	23.63			2.48
OR-2272-HT	21.70			6.15

^aC₂H₂ used as coating gas at 1125°C.

^bMAPP gas used as coating gas for all coatings. Coatings on fissile particles and fertile batches OR-2262-HT and OR-2266-HT were deposited at 1275°C. Outer LTI on other fertile batches was deposited at 1325°C.

^cCH₃SiCl₃ used as coating gas on all OR- particle batches at 1550°C.

^dZrC in place of SiC was applied by LASL.

^eOuter LTI applied by LASL.

All fuel rod specimens in both capsules were fabricated by the slug-injection method. The matrix materials for the GRNL specimens were the same: 29 wt % Asbury Natural Flake 635¹ graphite filler in Ashland 240 petroleum pitch. The particles were blended in an air blender. The matrix was injected through the particle bed at 180°C and 5.5 MPa (800 psi) in a metal mold. For specimens 1 through 9 a small metal rod, 3.48 mm (0.137 in.) in diameter, was placed in the center of the mold to form the hole for placement of the centerline thermometer. After rod removal specimens were carbonized at 900°C vertically in a packed bed of alumina at a heating rate of 60°C/h. They were then heat-treated at 1800°C for 30 min for dimensional stability.

The fuel rod specimens were characterized by dimensional measurements, weight, radiography, metallography, and photography. The specimens were all nominally 12.5 mm (0.49 in.) OD and 17.0 mm (0.67 in.) long, with specimens 1 through 9 having a 3.48-mm (0.137-in.) hole for placement of centerline thermometry. An identification mark was formed on one end of each specimen for orientation, so that the specimen dimensions could be measured at the same location both before and after irradiation. The heavy metal loadings and dimensions for each specimen are shown in Table 7.

Capsules HRB-11 and -12 each contained 24 well-characterized fissile particles and 24 well-characterized fertile particles for gamma spectrometry standards. These particles were located in holes in a special particle holder at the bottom of each capsule, with one fissile and one fertile particle located in each hole (see Fig. 2). The dimensions and heavy metal loadings for these particles are given in Tables 8 and 9, respectively, for HRB-11 and -12. The loading diagram for the particle holder is shown in Fig. 3. This loading scheme was used for both capsules. Pertinent data on coatings and coating conditions for the standard particles are given in Tables 10 and 11. X radiographs of the fissile and fertile batches from which the gamma spectrometry standards were taken are shown in Figs. 4 and 5.

Table 7. Dimensions and Heavy Metal Loadings for
ORNL Specimens in HRB-11 and -12

Rod ^a	Average Diameter		Average Length		Loading, Mg/m ³		
	(mm)	(in.)	(mm)	(in.)	²³⁵ U	²³⁸ U	²³² Th
<u>HRB-11</u>							
1	12.443	0.4899	16.774	0.6604	0.0275	0.0016	0.4594
2	12.426	0.4892	16.612	0.6540	0.0261	0.0015	0.4073
3	12.441	0.4898	16.977	0.6684	0.0254	0.0014	0.3552
4	12.441	0.4898	17.059	0.6716	0.0224	0.0013	0.3252
5	12.438	0.4897	16.731	0.6587	0.0221	0.0013	0.3207
6	12.436	0.4896	16.985	0.6687	0.0217	0.0012	0.3037
7	12.433	0.4895	16.998	0.6692	0.0201	0.0011	0.2915
8	12.446	0.4900	16.876	0.6644	0.0181	0.0011	0.2854
9	12.441	0.4898	17.107	0.6735	0.0187	0.0010	0.2770
10	12.443	0.4899	16.565	0.6561	0.0141	0.0008	0.2323
11	12.449	0.4901	16.883	0.6647	0.0111	0.0007	0.2264
16	12.456	0.4904	16.810	0.6619	0.0140	0.0008	0.2314
17	12.471	0.4910	16.640	0.6551	0.0145	0.0009	0.2429
18	12.443	0.4899	17.003	0.6694	0.0142	0.0008	0.2422
19	12.423	0.4891	17.015	0.6699	0.0155	0.0009	0.2489
20	12.423	0.4891	16.871	0.6642	0.0177	0.0010	0.2660
21	12.408	0.4885	16.919	0.6561	0.0170	0.0010	0.2743
<u>HRB-12</u>							
1	12.454	0.4903	16.673	0.6564	0.0277	0.0016	0.4614
2	12.451	0.4902	16.825	0.6624	0.0256	0.0015	0.4002
3	12.479	0.4913	17.059	0.6716	0.0234	0.0014	0.3511
4	12.449	0.4901	16.744	0.6592	0.0227	0.0013	0.3308
5	12.441	0.4898	16.876	0.6644	0.0219	0.0012	0.3178
6	12.461	0.4906	17.320	0.6819	0.0198	0.0012	0.2970
7	12.471	0.4910	16.634	0.6549	0.0190	0.0011	0.2960
8	12.469	0.4909	16.678	0.6566	0.0183	0.0011	0.2876
9	12.426	0.4892	16.690	0.6571	0.0179	0.0011	0.2846
10	12.456	0.4904	16.840	0.6630	0.0140	0.0008	0.2295
11	12.453	0.4905	16.911	0.6658	0.0137	0.0008	0.2256
16	12.466	0.4908	16.881	0.6646	0.0139	0.0008	0.2301
17	12.464	0.4907	16.868	0.6641	0.0143	0.0008	0.2399
18	12.451	0.4902	16.800	0.6614	0.0144	0.0008	0.2440
19	12.451	0.4902	16.904	0.6655	0.0155	0.0009	0.2493
20	12.449	0.4901	16.848	0.6633	0.0164	0.0010	0.2652
21	12.449	0.4901	16.640	0.6551	0.0172	0.0010	0.2770

^aSpecimens 1 through 9 have inside diameters of 3.48 mm (0.137 in.).

Table 8. Dimensions and Heavy Metal Loadings for Gamma Spectrometry Standards Irradiated in Capsule HRB-11

Fissile Particles (OR-2211-H)				Fertile Particles (OR-2233-H)		
Number	Kernel Diameter (μm)	Uranium, μg		Number	Kernel Diameter (μm)	Th (mg)
		Total	^{235}U			
2-1	369	62.3	57.9	2-1	491	0.548
2	360	51.3	54.2	2	490	0.541
3	384	70.7	65.8	3	493	0.555
4	374	65.4	60.8	4	492	0.548
5	378	67.5	62.7	5	492	0.548
6	391	75.3	70.0	6	490	0.541
7	343	50.9	47.3	7	493	0.555
8	399	74.4	69.2	8	491	0.548
9	345	51.7	48.1	9	490	0.541
10	371	64.3	59.8	25	490	0.541
11	373	65.3	60.8	26	490	0.541
12	381	69.6	64.8	12	488	0.535
13	383	70.7	65.8	13	496	0.562
14	357	57.3	53.3	14	491	0.548
15	374	65.4	60.8	15	492	0.548
16	367	62.3	57.9	16	491	0.548
17	357	53.3	49.6	17	490	0.541
18	408	84.8	78.9	18	490	0.541
19	391	75.3	70.0	19	490	0.541
20	393	71.1	66.1	20	493	0.555
21	348	52.7	49.0	21	495	0.562
22	370	63.3	58.9	22	490	0.541
23	358	57.3	53.3	23	491	0.548
24	372	64.3	59.8	24	490	0.541

Table 9. Dimensions and Heavy Metal Loadings for Gamma Spectrometry Standards Irradiated in Capsule HRP-12

Fissile Particles (OR-2211-H)				Fertile Particles (OR-2233-H)		
Number	Kernel Diameter (µm)	Uranium, µg		Number	Kernel Diameter (µm)	Th (mg)
		Total	235U			
4-1	391	75.3	70.0	4	495	0.562
4-2	368	62.3	57.9	4-2	492	0.548
4-3	383	70.7	65.8	4-3	489	0.541
4-4	369	62.3	57.9	4-4	490	0.541
4-5	371	64.3	59.8	4-5	487	0.535
4-6	368	62.3	57.9	4-6	490	0.541
4-7	367	62.3	57.9	4-7	490	0.541
4-8	382	69.6	64.8	4-8	492	0.548
4-9	375	66.4	61.8	4-9	492	0.548
4-10	399	74.4	69.2	4-10	490	0.541
4-11	366	61.2	57.0	4-11	490	0.541
4-12	368	62.3	57.9	4-12	493	0.555
4-13	375	66.4	61.8	4-13	489	0.541
4-14	331	45.7	42.5	4-14	490	0.541
4-15	385	71.8	66.8	4-15	491	0.548
4-16	385	71.8	66.8	4-16	487	0.535
4-17	376	66.4	61.8	4-17	493	0.555
4-18	343	50.9	47.3	4-18	493	0.555
4-19	358	57.3	53.3	4-19	492	0.548
4-20	360	58.3	54.2	4-20	490	0.541
4-21	373	65.3	60.8	4-21	488	0.535
4-22	370	63.3	58.9	4-22	491	0.548
4-23	345	51.7	48.1	4-23	492	0.548
4-24	366	61.2	57.0	4-24	490	0.541

ORNL-DWG 79-11851

Fig. 3. Loading Scheme for Gamma Spectroscopy Standards Irradiated in Capsules HRB-11 and -12. One fissile particle and one fertile particle were loaded into each hole.

Table 10. Particle Test Set for Gamma Spectrometry Standards Irradiated in Capsule HRB-11, and -12

	Batch OR-2211-H	Batch OR-2233-H
Particle Type	Fissile	Fertile
Kernel Composition	ThO ₂	UC _{4.63} O _{0.97}
Coating Thickness, ^a μ m		
Buffer	57.2(10.8)	59.3(8.6)
ILTI	35.6(3.7)	37.5(4.5)
SiC	43.9(2.1)	30.2(1.6)
OLTI	45.5(3.7)	42.0(4.1)
Densities, Mg/m ³		
Kernel	9.99 ^b	3.11
Buffer	1.25 ^b	1.09
ILTI	1.98	1.95
SiC	3.20	3.20
OLTI	2.04	2.00

^aNumbers in parentheses are standard deviations.

^bTap densities.

Table 11. Coating Conditions for Gamma Spectrometry Standards
Irradiated in Capsules NRE-11 and -12

Coating Layer	Coating Gas	Coating Temperature (°C)	Coating Time (min)
<u>Batch OR-2211-H</u>			
Buffer	4.1/1 Acetylene-Ar	1125	7.0
Buffer seal coat	0.42/1 MAPP-Ar	1325	2.6
ILTI	100% MAPP	1275	7.0
ILTI seal coat	0.57/1 MAPP-Ar	1125	1.0
SiC	Methyltrichlorosilane-H ₂	1550	185
OLTI	100% MAPP	1275	7.0
OLTI seal coat	0.62/1 MAPP-Ar	1125	1.5
<u>Batch OR-2233-H</u>			
Buffer	17.3/1 Acetylene-Ar	1125	2.0
Buffer seal coat	0.53/1 MAPP-Ar	1325	0.75
ILTI	100% MAPP	1300	2.75
ILTI seal coat	0.5/1 MAPP-Ar	1150	0.5
SiC	Methyltrichlorosilane-H ₂ -Ar	1550	180
OLTI	100% MAPP	1300	3.0
OLTI seal coat	1/1 MAPP-Ar	1125	0.5

Y-153756

(a)

(b)

Fig. 4. Preirradiation X Radiographs of Triso-Coated Fissile Particle Batch OR-2211-H. X-ray intensity adjusted to show (a) SiC coating and (b) pyrolytic carbon coating.

Fig. 5. Preirradiation X Radiographs of Triso-Coated Fertile (ThO_2) Particle Batch OR-2233-H. X-ray intensity adjusted to show (a) SiC coating and (b) pyrolytic carbon coating.

DESCRIPTION OF IRRADIATION

Irradiation Conditions

Capsules HRB-11 and -12 were operated similarly to HRB-7 through -10;^{2,3} that is, preirradiated in the VXF-13 position to burn out about half of the initial ^{235}U and then transferred to a removable beryllium (RB) facility for the remainder of the irradiation. The logic behind this method of operation and the locations of the various irradiation facilities in the HFIR Core have been described in detail previously.^{2,3}

Capsule Operation

The operating schedules for HRB-11 and -12 are shown in Table 12. Both capsules were irradiated for three cycles in the PB-13 (VXF-13) facility before going into the RB facility. The thermal flux in the PB facility is about 60% of the RB flux, and the fast flux is about 11%. Using the PB facility for preirradiations permits irradiation of fully enriched fissile particles, which could not be done otherwise because of very high power production rates at the beginning of the test. Capsule HRB-11 was moved to RB-7 for nine cycles at a design temperature of 1350°C (fuel centerline). Capsule HRB-12 was inserted into PB-13 at the beginning of HFIR cycle 129 (when HRB-11 was moved out) and later moved to RB-5 for the remainder of its irradiation. Capsule HRB-12 was irradiated in the RB-5 facility for eight cycles, removed from the reactor at the beginning of cycle 140, then reinserted at the beginning of cycle 141 for one additional cycle. This capsule was also irradiated at a design temperature of 1350°C (fuel centerline).

Calculated burnups for capsules HRB-11 and -12 are shown in Tables 13 and 14. Neutron fluxes and fluences are tabulated in Tables 15 and 16.

As with previous HRB capsules, the thermal analysis for Capsules HRB-11 and -12 was done for fuel rods adjacent to Chromel vs Alumel (C/A) thermocouples. For these capsules the C/A thermocouples were located in the graphite sleeve adjacent to fuel rods 2, 4, 5, 7, 8, 12, 13, 18, and

Table 12. Capsules HRB-11 and -12 Reactor Power and Irradiation History

HFIR Fuel Cycle	Operating Facility	Cycle Dates		Irradiation Time, h	
		Begin	End	In Cycle	Total Accumulated
<u>Capsule HRB-11</u>					
126	PR-13	12/7/75	12/30/75	559	559
127	PR-13	12/31/75	1/23/76	558	1117
128	PB-13	1/24/76	2/16/76	556	1673
129	RB-7	2/19/76	3/13/76	554	2227
130	RB-7	3/14/76	4/6/76	558	2785
131	RB-7	4/7/76	4/30/76	552	3337
132	RB-7	5/1/76	5/22/76	490	3827
133	RB-7	5/23/76	6/16/76	547	4374
134	RB-7	6/17/76	7/9/76	534	4908
135	RB-7	7/10/76	8/1/76	547	5455
136	RB-7	8/2/76	8/25/76	540	5995
137	RB-7	9/2/76	9/25/76	564	6559
<u>Capsule HRB-12</u>					
129	PB-13	2/19/76	3/13/76	554	554
130	PB-13	3/14/76	4/6/76	558	1112
131	PB-13	4/7/76	4/30/76	552	1664
132	RB-5	5/1/76	5/22/76	490	2154
133	RB-5	5/23/76	6/16/76	547	2701
134	RB-5	6/17/76	7/9/76	534	3235
135	RB-5	7/10/76	8/1/76	547	3782
136	RB-5	8/2/76	8/25/76	540	4322
137	RB-5	9/2/76	9/25/76	564	4886
138	RB-5	9/27/76	10/21/76	574	5460
139	RB-5	10/21/76	11/14/76	574	6034
140 ^a		11/15/76	12/14/76		
141	RB-5	12/15/76	1/10/77	568	6602

^aCapsule was removed from facility during cycle 140.

Table 13. Calculated Specimen Burnup in Capsule HRB-11

Specimen	Calculated Burnup, % FIMA								
	^{235}U			^{238}U			^{232}Th		
	PB-13	RB-7	Total	PB-13	RB-7	Total	PB-13	RB-7	Total
1	52.5	31.9	84.4	0.89	15.0	15.9	0.24	5.96	6.20
2	54.6	30.3	84.9	0.99	16.8	17.8	0.27	6.80	7.07
3	56.9	28.4	85.3	1.11	19.0	20.1	0.30	7.80	8.10
4	58.8	26.9	85.7	1.22	20.6	21.8	0.34	8.60	8.94
5	60.1	25.8	85.9	1.30	22.2	23.5	0.36	9.39	9.75
6	61.3	24.9	86.2	1.38	23.5	24.9	0.39	10.0	10.4
7	62.3	24.1	86.4	1.45	24.7	26.1	0.41	10.6	11.0
8	63.2	23.4	86.6	1.52	25.6	27.1	0.43	11.1	11.5
9	63.7	23.1	86.8	1.56	26.2	27.8	0.45	11.4	11.9
10	64.3	22.5	86.8	1.60	26.7	28.3	0.46	11.7	12.2
11	64.6	22.2	86.8	1.63	27.2	28.8	0.47	11.9	12.4
12 ^a	64.7	22.2	86.9	1.64	27.4	29.0	0.47	12.0	12.5
13 ^a	64.6	22.3	86.9	1.63	27.3	28.9	0.47	12.0	12.5
14 ^a	64.3	22.5	86.8	1.60	27.0	28.6	0.46	11.8	12.3
15 ^a	63.9	22.8	86.7	1.57	26.5	28.1	0.45	11.5	12.0
16	63.2	23.4	86.6	1.52	26.0	27.5	0.43	11.3	11.7
17	62.1	24.3	86.4	1.43	25.2	26.6	0.41	10.8	11.2
18	60.9	25.4	86.3	1.35	24.1	25.5	0.38	10.3	10.7
19	59.4	26.7	86.1	1.26	23.1	24.4	0.35	9.75	10.1
20	57.9	27.9	85.8	1.16	21.6	22.8	0.32	9.03	9.35
21	56.0	29.5	85.5	1.06	20.2	21.3	0.29	8.31	8.60
22 ^a	53.9	31.3	85.2	0.95	18.6	19.6	0.26	7.56	7.82
23 ^a	52.1	32.8	84.9	0.87	17.1	18.0	0.23	6.85	7.08
24 ^a	49.6	34.9	84.5	0.76	15.4	16.2	0.20	6.07	6.27
25 ^a	47.4	36.7	84.1	0.68	14.2	14.9	0.18	5.50	5.68

^aGA specimens.

Table 14. Calculated Specimen Burnup in Capsule HRB-12

Specimen	Calculated Burnup, % FIMA								
	^{235}U			^{238}U			^{232}Th		
	PB-13	RB-5	Total	PB-13	RB-5	Total	PB-13	RB-5	Total
1	52	32	84	0.9	15.2	16.1	0.2	6.3	6.5
2	54	31	85	1.0	17.1	18.1	0.3	7.1	7.4
3	57	28	85	1.1	19.2	20.3	0.3	8.1	8.4
4	59	27	86	1.2	20.9	22.1	0.3	9.0	9.3
5	60	26	86	1.3	22.5	23.8	0.4	9.8	10.2
6	61	25	86	1.4	23.8	25.2	0.4	10.5	10.9
7	62	24	86	1.4	24.9	26.3	0.4	11.1	11.5
8	63	24	87	1.5	25.8	27.3	0.4	11.6	12.0
9	64	23	87	1.5	26.5	28.0	0.4	12.0	12.4
10	64	23	87	1.6	26.9	28.5	0.5	12.1	12.6
11	64	23	87	1.6	27.4	29.0	0.5	12.4	12.9
12	65	22	87	1.6	27.6	29.2	0.5	12.5	13.0
13	64	23	87	1.6	27.5	29.1	0.5	12.5	13.0
14	64	23	87	1.6	27.2	28.8	0.5	12.3	12.8
15	64	23	87	1.6	26.7	28.3	0.4	12.1	12.5
16	63	24	87	1.5	26.2	27.7	0.4	11.8	12.2
17	62	24	86	1.4	25.4	26.8	0.4	11.3	11.7
18	61	25	86	1.3	24.4	25.7	0.4	10.7	11.1
19	59	27	86	1.2	23.4	24.6	0.3	10.3	10.6
20	58	28	86	1.1	21.9	23.0	0.3	9.4	9.7
21	56	30	86	1.0	20.5	21.5	0.3	8.7	9.0
22	54	31	85	0.9	18.9	19.8	0.3	7.9	8.2
23	52	33	85	0.9	17.3	18.2	0.2	7.2	7.4
24	49	36	85	0.8	15.6	16.4	0.2	6.4	6.6
25	47	37	84	0.7	14.4	15.1	0.2	5.7	5.9

Table 15. Calculated Thermal and Fast Fluences for HRB-11 Specimens

Specimen	Distance from HMP-2 (mm)	Fluence in PB-13, n/m ²		Fluence in RB-7, n/m ²		Total Fluence, n/m ²	
		Thermal, <1.86 eV	Fast, ^b >0.18 MeV	Thermal, <0.18 MeV	Fast, ^b >0.18 MeV	Thermal, <1.86 MeV	Fast, ^b >0.18 MeV
1	187.0	2.37 × 10 ²⁵	1.93 × 10 ²⁴	1.04 × 10 ²⁶	4.16 × 10 ²⁵	1.27 × 10 ²⁶	4.35 × 10 ²⁵
2	169.2	2.54	2.09	1.16	4.68	1.41	4.89
3	152.2	2.70	2.24	1.30	5.12	1.57	5.34
4	135.3	2.89	2.40	1.41	5.54	1.70	5.78
5	118.4	3.00	2.52	1.49	5.93	1.79	6.18
6	101.5	3.12	2.68	1.60	6.25	1.91	6.52
7	84.6	3.23	2.79	1.71	6.54	2.03	6.82
8	67.7	3.33	2.89	1.79	6.78	2.12	7.07
9	50.7	3.36	2.96	1.83	6.99	2.17	7.29
10	33.8	3.46	3.04	1.88	7.16	2.23	7.46
11	16.9	3.50	3.06	1.92	7.24	2.27	7.55
12 ^c	2.1	3.51	3.06	1.93	7.26	2.28	7.57
13 ^c	-10.6	3.51	3.04	1.92	7.24	2.27	7.54
14 ^c	-23.3	3.46	3.03	1.90	7.21	2.25	7.51
15 ^c	-36.0	3.42	2.99	1.86	7.12	2.20	7.42
16	-50.7	3.33	2.93	1.83	6.97	2.16	7.26
17	-67.7	3.21	2.87	1.74	6.78	2.06	7.07
18	-84.6	3.08	2.76	1.69	6.51	2.00	6.79
19	-101.5	2.93	2.63	1.60	6.21	1.89	6.47
20	-118.4	2.79	2.51	1.49	5.87	1.77	6.12
21	-135.3	2.62	2.36	1.41	5.44	1.67	5.68
22 ^c	-150.1	2.45	2.22	1.28	5.06	1.53	5.28
23 ^c	-162.8	2.33	2.10	1.20	4.66	1.43	4.87
24 ^c	-175.5	2.17	2.03	1.07	4.38	1.29	4.58
25 ^c	-188.2	2.00	1.93	0.985	4.05	1.18	4.24

^cHMP = horizontal midplane.

^bThese are actual fluences multiplied by 0.94 to provide a common basis of comparison for all HTGR fuel experiments, as outlined by H. T. Kerr, E. J. Allen, and D. L. Reed, *Lattice Displacement Calculations and Comparisons for Different Irradiation Facilities*, ORNL/TM-5269 (March 1976).

^cGA Specimens.

Table 16. Calculated Thermal and Fast Fluences for HRB-12 Specimens

Specimen	Distance from HMP ^a (mm)	Fluence in PB-13, n/m ²		Fluence in RB-5, n/m ²		Total Fluence, n/m ²	
		Thermal, <1.86 eV	Fast, ^b >0.18 MeV	Thermal, <0.18 MeV	Fast, ^b >0.18 MeV	Thermal, <1.86 MeV	Fast, ^b >0.18 MeV
1	187.0	2.36 × 10 ²⁵	1.92 × 10 ²⁴	1.03 × 10 ²⁶	4.21 × 10 ²⁵	1.29 × 10 ²⁶	4.40 × 10 ²⁵
2	169.2	2.53	2.08	1.17	4.73	1.42	4.94
3	152.2	2.68	2.23	1.31	5.18	1.58	5.40
4	135.3	2.87	2.38	1.43	5.60	1.72	5.84
5	118.4	2.98	2.51	1.51	6.00	1.81	6.25
6	101.5	3.10	2.66	1.62	6.32	1.93	6.59
7	84.6	3.21	2.78	1.73	6.62	2.05	6.90
8	67.7	3.31	2.87	1.81	6.85	2.14	7.14
9	50.7	3.34	2.94	1.85	7.07	2.18	7.36
10	33.8	3.44	3.02	1.90	7.24	2.24	7.54
11	16.9	3.48	3.05	1.94	7.32	2.29	7.63
12 ^c	2.1	3.49	3.05	1.95	7.34	2.30	7.65
13 ^c	-10.6	3.49	3.02	1.94	7.32	2.29	7.62
14 ^c	-23.3	3.44	3.01	1.92	7.29	2.26	7.59
15 ^c	-36.0	3.40	2.98	1.88	7.20	2.22	7.50
16	-50.7	3.31	2.91	1.85	7.05	2.18	7.34
17	-67.7	3.18	2.86	1.76	6.85	2.08	7.14
18	-84.6	3.06	2.74	1.71	6.58	2.02	6.83
19	-101.5	2.91	2.61	1.62	6.28	1.91	6.54
20	-118.4	2.77	2.49	1.51	6.93	1.79	6.18
21	-135.3	2.61	2.35	1.42	5.50	1.68	5.74
22 ^c	-150.1	2.44	2.21	1.29	5.11	1.53	5.33
23 ^c	-162.8	2.32	2.09	1.21	4.71	1.44	4.92
24 ^c	-175.5	2.16	2.02	1.08	4.43	1.30	4.63
25 ^c	-188.2	1.99	1.91	1.00	4.09	1.00	4.28

^aHMP = horizontal midplane.

^bThese are actual fluences multiplied by 0.94 to provide a common basis of comparison for all HTGR fuel experiments, as outlined by H. T. Kerr, E. J. Allen, and D. L. Reed, *Lattice Displacement Calculations and Comparisons for Different Irradiation Facilities*, ORNL/TM-5269 (March 1976).

^cGA Specimens.

and 21 (see Fig. 1, p. 5, for schematic diagram of thermocouple location). The details of the thermal analysis are presented in Appendix A. Plots of fission power density (kW/ft) vs time for these fuel rods are given in Figs. 6 and 7 respectively for Capsules HRB-11 and -12. The trends identified with other HRB Capsules are evident here:

1. Power density decreases steadily over the first 60 d of the irradiation as the initial ^{235}U inventory is rapidly burned out.
2. After the first 60 d the power density increases during each 23-d cycle at the ends of the cycle as a result of the operation of the HFIR control system.⁸ At the center of the rod the power density remains approximately constant during the 23-d cycle.
3. Power density vs time behavior remains approximately constant from cycle to cycle after the first 60 d, as the rate of ^{233}U buildup keeps the fissile concentration approximately constant.

The calculated operating temperatures for HRB-11 and -12 are shown in Figs. 8 and 9. Three curves are shown on each plot. The lowest curve on each plot is the temperature at the midwall position in the graphite sleeve, the center curve is the temperature at the fuel rod surface, and the highest curve is the temperature at the center of the fuel rod. This experiment was designed so that the fuel center temperature would be 1350°C . Temperature is controlled by changing the composition of the gas that sweeps through the capsule, which can be varied from 100% He to 100% Ne. Since the power density varies with axial location within the capsule, the temperature of all specimens cannot be kept the same. Therefore, a control thermocouple is chosen (in these experiments the thermocouple adjacent to fuel rod 8), and the temperature of this thermocouple is adjusted (by varying the sweep gas composition) to be consistent with 1350°C fuel center temperature. The temperatures of other fuel rods then vary somewhat around this design temperature, as shown in Figs. 8 and 9.

The fission gas Release to Birth (R/B) rate data are presented in Tables 17 and 18. The current HTGR fuel product specification calls for R/B values less than 3×10^{-5} for ^{85}mKr . The HRB-11 data are generally below this value during the first 5000 h of the experiment. However, during the last 1500 h the R/B values rise dramatically, exceeding the

Graphs (a) through (i) show Fission Power Density (KW/FT) vs Time from Beginning of Irradiation (DAYS) for various rods. (a) Rod 2. (b) Rod 4. (c) Rod 5. (d) Rod 7. (e) Rod 8. (f) Rod 12. (g) Rod 13. (h) Rod 1. (i) Rod 1.

(f) Rod 12. (g) Rod 13. (h) Rod 18. (i) Rod 21. Multiply by 3.28 to convert from

Fig. 7. Fission Power Density vs Time for HRB-12 Fuel Rods. (a) Rod 2. (b) Rod 4. (c) kW/ft to kW/m.

2. (b) Rod 4. (c) Rod 5. (d) Rod 7. (e) Rod 8. (f) Rod 12. (g) Rod 13. (h) Rod 18. (i) Rod 21. M

17. (e) Rod 8. (f) Rod 12. (g) Rod 13. (h) Rod 18. (i) Rod 21. Multiply by 3.28 to convert from

Fig. 8. Operating Temperatures vs Time for HRB-11 Fuel Rods. Lower curve is graphite
 (b) Rod 4. (c) Rod 5. (d) Rod 7. (e) Rod 8. (f) Rod 12. (g) Rod 13. (h) Rod 18. (i)

graphite midwall, middle curve is fuel surface, and upper curve is fuel centerline. (a) Rod 2.
8. (i) Rod 21.

Fig. 9. Operating Temperatures vs Time for HRB-12 Fuel Rods. Lower curve is graphite midwall, mid (b) Rod 4. (c) Rod 5. (d) Rod 7. (e) Rod 8. (f) Rod 12. (g) Rod 13. (h) Rod 18. (i) Rod 21.

is graphite midwall, middle curve is fuel surface, and upper curve is fuel centerline. (a) Rod 2.
 (b) Rod 18. (c) Rod 21.

Table 17. Capsule HRB-11 R/B Data

Sample ^a	Date	Accumulated Irradiation Time (h)	Fission Gas, R/B				
			⁸⁵ Kr	⁸⁷ Kr	⁸⁸ Kr	¹³⁵ Xe	¹³³ Xe
1	2/25/76	1821	7.20×10^{-6}	4.14×10^{-6}	4.58×10^{-6}	3.62×10^{-6}	1.46×10^{-5}
2	2/27/76	1871	4.56	3.73	3.34	2.72	0.468
3	3/2/76	1965	6.62	4.49	4.20	3.29	7.79
4	3/5/76	2038	6.98	3.56	4.31	3.35	10.7
5	3/9/76	2132	5.94	3.15	4.29	3.08	2.97
6	3/12/76	2204	17.80	7.06	9.65	5.43	40.80
7	3/16/76	2273	4.55	3.15	3.11	2.69	2.53
8	3/19/76	2341	62.7	22.7	26.6	18.9	210
9	3/23/76	2439	22.0	13.5	13.3	15.2	11.8
10	3/26/76	2509	28.0	15.7	15.8	24.0	30.8
11	3/30/76	2603	32.2	20.5	19.3	17.8	18.5
12	4/5/76	2748	27.5	20.2	16.4	19.7	23.3
13	4/13/76	2918	13.5	8.69	8.31	7.18	15.8
14	4/23/76	3158	6.46	3.39	3.41	2.37	2.80
15	4/27/76	3253	9.78	6.09	6.44	4.39	4.48
16	5/7/76	3470	7.55	5.33	5.98	4.84	6.38
17	5/14/76	3638	4.56	3.08	2.86	3.30	1.15
18	5/18/76	3737	6.31	6.65	4.10	4.95	3.91
19	6/2/76	4032	8.42	10.9	9.44	8.19	4.40
20	6/9/76	4204	6.05	7.68	7.56	5.44	3.42
21	6/11/76	4252	6.44	7.87	7.07	6.60	3.04
22	6/23/76	4529	10.5	17.4	5.86	6.22	3.54
23	6/30/76	4698	8.86	7.12	7.13	5.45	3.20
24	7/15/76	5034	145	103	101	90.5	60.3
25	7/20/76	5157	126	82.2	86.0	76.7	53.9
26	7/28/76	5345	147	95.9	104	104	128
27	8/11/76	5665	230	171	143	153	238
28	8/18/76	5836	242	151	174	168	242
29	9/9/76	6160	437	299	290	281	278
30	9/14/76	6281	300	329	356	277	267
31	9/21/76	6449	246	269	278	203	

^aSamples 1 through 7 were taken with the sweep gas at 100% He, while the remainder of the samples were taken with a helium-neon mixture and the specimens at design temperature.

Table 18. Capsule HRB-12 R/B Data

Sample ^a	Date	Accumulated Irradiation Time (h)	Fission Gas, R/B				
			⁸⁵ Kr	⁸⁷ Kr	⁸⁸ Kr	¹³⁵ Xe	¹³³ Xe
1	5/4/76	1723	9.35×10^{-5}	5.60×10^{-5}	5.49×10^{-5}	5.52×10^{-5}	3.15×10^{-4}
2	5/7/76	1795	6.19	7.18	5.56	5.77	3.12
3	5/14/76	1964	8.15	5.19	3.68	4.60	4.58
4	5/18/76	2063	9.01	6.70	6.86	5.17	3.52
5	5/21/76	2131	10.4	7.75	6.23	6.02	5.44
6	6/2/76	2359	12.9	8.46	8.78	12.0	7.47
7	6/9/76	2531	12.0	7.44	7.90	10.8	5.97
8	6/11/76	2577	15.6	8.26	9.90	11.7	89.7
9	6/23/76	2856	7.70	6.63	5.17	9.40	6.97
10	6/30/76	3024	7.33	4.44	5.25	8.11	6.44
11	7/15/76	3361	4.88	3.09	3.33	4.50	3.01
12	7/20/76	3483	4.81	3.39	4.00	4.09	4.02
13	7/28/76	3672	6.28	3.98	4.18	6.13	6.16
14	8/11/76	3992	3.49	2.92	3.49	2.80	1.95
15	8/18/76	4163	4.11	3.59	3.64	3.33	4.05
16	9/9/76	4487	10.6	7.58	8.42	5.85	6.14
17	9/14/76	4607	7.99	8.59	9.20	6.51	9.71
18	9/21/76	4775	7.12	6.51	8.92	5.70	1.17
19	9/30/76	4964	6.13	5.36	6.22	4.89	0.668
20	10/6/76	5104	8.13	6.33	5.74	3.71	0.709
21	10/12/76	5248	8.11	6.54	6.75	4.18	8.06
22	10/19/76	5415	7.31	5.79	6.22	4.78	5.22
23	10/26/76	5570	9.30	6.70	7.54	5.22	6.67
24	11/3/76	5764	10.9	6.90	8.26	4.81	8.68
25	11/10/76	5931	11.3	7.37	7.50	5.51	7.27

^aSamples 1 through 7 were taken with the sweep gas at 100% He, while the remainder of the samples were taken with a helium-neon mixture and the specimens at design temperature.

specification by a factor of almost 9. Because each capsule contains many varieties of fuel, nothing definitive can be said about the R/B value for any one fuel type. The high R/B values measured at the end of life could be associated with interactions between the fuel and the centerline thermocouple assembly. Completion of the IMGA work on these specimens should provide additional information.

The HRB-12 R/B data exceeded the fuel product specification from the very beginning of the irradiation. The ZrC-coated particles are suspected to be a major contributor to the high R/B , but again the IMGA results will provide more definitive information.

POSTIRRADIATION EXAMINATION

Disassembly and Visual Examination

HRB-11 was disassembled by cutting off the lead tube and making the first cut on the capsule about 0.1 m (4 in.) from the upper weld. The thermocouple assembly was removed, and the top fuel rod came out with the centerline thermocouple. This rod was replaced in the graphite sleeve, and the sleeve was gamma scanned with the fuel rods in place. The gamma scan indicated that fuel rods 1 and 2 had shifted position, leaving a gap between rods 2 and 3. Rods 1 through 11 were easily pushed out of the graphite sleeve. Rods 12 through 15 had large cracks in the matrix but were intact except for some debonding at the edges. Rods 16 through 21 were pushed out easily. Rods 22 through 25 were pushed out easily and were in the same conditions as rods 12 through 15. Rod 9 had about 38 mm (1.5 in.) of rhenium foil from the centerline thermocouple assembly (see Appendix B) attached after removal from the graphite sleeve. The gamma spectrometry standards that were located at the bottom of the capsule were spilled and lost in the hot cell during disassembly.

HRB-12 was disassembled in the same manner as HRB-11, with the first cut made about 0.1 m (4 in.) from the weld, followed by removal of the end cap and the thermocouples. All thermocouples came out intact. The Johnson noise thermometer (discussed in Appendix B) came out without its rhenium foil sheath. The porous plug came out with the thermocouples.

A second cut was made about 38 mm (1.5 in.) from the bottom of the capsule and the bottom portion of the capsule was removed. The bottom sleeve plug came off with the bottom section. The fuel rods were pushed out from the top of the capsule. The gamma spectrometry standards crucible was removed intact. Rods 25 through 13, 11 and 10, 8 through 5, and 3 through 1 were removed easily and in good condition. Rod 12 was severely debonded; rods 9 and 4 were removed with parts of the rhenium foil and beryllium oxide insulator stuck to the walls of the central holes.

Side views of fuel rods after removal from the capsules are shown in Figs. 10 and 11.

General Atomic Company specimens in HRB-11 included rods 12 through 15 and 22 through 25. These rods were examined visually and photographed at orientations of 0, 90, 180, and 270°. The ends were also photographed. The GA rods were dimensionally inspected and then shipped to GA.

Rods 1 through 3 from HRB-11 were in good condition with some debonding at the edges. No broken or cracked particles were observed on the surfaces of the rods. Numerous failures of the outer coatings were observed on rod 4. On rod 5 we noted one broken particle, which appeared to have resulted from a scratch; perhaps a piece of material became wedged between the fuel rod surface and the graphite sleeve during disassembly and was dragged across the surface of the rod. Rod 7 had one particle with part of the outer LTI missing and one particle with a straight line fracture. A straight line fracture means a broken coating in which all the coating fragments are still attached to the particle. Rod 8 also had one particle with a straight line fracture. Part of the rhenium thermocouple sheath was still attached to rod 9. One fabrication defect and one cracked particle were also noted on this rod. Rods 10 and 11 were in good condition with no cracked or broken particles. Rods 12 through 15 had large cracks in the matrix but were intact except for some debonding at the edges. Rod 16 had debonded on the bottom edge, showing particles with multiple straight line fractures in the debonded area. One more particle with multiple straight line fractures was found on the surface of rod 16. Rod 17 had one particle with broken outer LTI and SiC layers. Rods 18 and 19 were in good condition with no cracked or broken particles. Rod 19 had one particle with a fabrication defect. Rods 20

R-75463

Fig. 10. Fuel Rods from Capsule HRE-11 After Capsule Disassembly.

R-75464

Fig. 11. Fuel Rods from Capsule HRB-12 After Capsule Disassembly.

and 21 were in good condition with no broken or cracked particles observed. All rods except 12 through 15 were in very good condition and had little debonding except for the top and bottom edges.

Rod 1 from HRB-12 was in very good condition with no debonding. Seven failed particles were observed on the surface of this rod, all with outer LTI and ZrC coatings broken. Some particles still retained the kernel but most of the kernels were missing. Rod 2 had some debonding at the bottom edge, which appeared to be due to physical damage as four or five broken particles were seen along a scratch adjacent to the debonded area. In addition, six failed particles with broken outer LTI and ZrC coatings were observed, all with most of the fuel kernels missing. White deposits were noted on several particles (see Fig. 11). Rod 3 was in good condition except for slight debonding at the bottom edge. More particles had white deposits, and 13 particles had broken outer LTI and ZrC coatings. Several reddish particles appeared not to have outer LTI coatings. One particle had a broken outer LTI layer and a cracked ZrC coating. Rod 4 was in very good condition with slight debonding at the top edge. It had no broken or cracked particles. Rod 5 was in very good condition with slight debonding at the bottom edge. No broken or cracked particles were found, but one particle appeared sooty. Rod 6 was in good condition with no debonding. About 100 particles appeared sooty. No particles were broken or cracked. Some debonding was noted at the top edge of rod 7. Thirteen particles had both outer LTI and ZrC coatings broken. Two particles had exposed ZrC coatings. Slight debonding was noted at the bottom edge of rod 8. Five broken particles with kernels missing were found, and one particle had the outer LTI broken and the ZrC layer exposed. Rod 9 was severely debonded at the top end. About 50 particles had broken coatings, about half of them with broken outer LTI coatings and the rest with both outer LTI and ZrC coatings broken. Rod 10 was in excellent condition with no indications of particle failure or debonding. Rod 11 was also in excellent condition, except for some abrasion damage from handling. Rods 16 and 17 were in excellent condition, with no debonding or broken particles. One fabrication defect (coating fragment) was noted on rod 17. Rod 18 was in good condition except for some very slight debonding at the top and bottom edges. Three

or four particles were debonded in each case; no broken or cracked particles were visible. Rod 19 was accidentally broken in half and partially debonded by an object dropping on it in the hot cell. One particle was cracked by the impact. No other indications of particle failure were observed. Rods 20 and 21 were in very good condition with only slight debonding at the edges. No broken or cracked particles were noted.

The visual examination results are shown in Tables 19 and 20. It is clear from Table 20 that the performance problems are associated with the rods containing ZrC-coated fissile particles and Biso-coated fissile particles. The high number of failures associated with the ZrC-coated particles is evident. The sooty appearance associated with rod 6 of HRB-12 has been observed before.³ This appearance of the fuel rod surface has been associated with high fission product activity in the graphite sleeve (see Figs. 18 and 19 of ref. 3).

Gamma Scans

The gamma scan data for HRB-11 and -12 are presented in Fig. 12 through 16, in Tables 21 and 22, and in Appendix C. The data shown in Figs. 12 through 16 represent "gross scans" covering the energy range of 88 to 120 fJ (550 to 750 keV). Tables 21 and 22 are extracted from the tabulations included in Appendix C. As can be seen from Appendix C, the energy range covered by the "gross scans" includes major activity peaks for ^{134}Cs , ^{137}Cs , and ^{95}Zr . Since ^{95}Zr is expected to remain in the fuel particles, even after coating failure, most of the activity detected in the graphite sleeves (Figs. 13 and 16) would be due to cesium.

The gamma scan data presented in Appendix C represent individual activity peaks of fixed energy, corresponding to a single fission product in most cases. Pertinent counting statistics are also given. The precise information presented in Appendix C is in sharp contrast to the more qualitative information shown in Figs. 12 through 16. These figures are intended as a concise summary of the vast amount of data included in Appendix C.

Table 19. Visual Examination Summary for HRB-11 Fuel Rods

Rod	Fissile Fuel Type ^a	Observations at Fuel Rod Surfaces		
		Debonding	Number of Failures	
			Outer LTI	SiC or ZrC
1	WAR, 44, A, SiC, 48	Slight at edges	0	0
2	WAR, 47, D, SiC, 0	Slight at edges	0	0
3	WAR, 46, D, SiC, 21	Slight at edges	0	0
4	WAR, 77, A, SiC, 51, C		Numerous	0
5	WAR, 69, A, SiC, 59, F		0	0
6	WAR, 12, A, SiC, 48, F		0	0
7	WAR, 18, D, SiC, 47		2	0
8	WAR, 47, D, SiC, 0		1	0
9	WAR, 46, D, SiC, 21		1	0
10	WAR, 18, D, SiC, 47		0	0
11	WAR, 32, D, SiC, 46		0	0
12	GA thermosetting matrix 4	Only at edges		
13	GA thermosetting matrix 3	Only at edges		
14	GA thermosetting matrix 2	Only at edges		
15	GA thermosetting matrix 1	Only at edges		
16	WAR, 46, D, SiC, 46	Bottom edge	Several in Debonded Area	
17	WAR, 69, D, SiC, 48		1	1
18	WAR, 64, D, SiC, 51		0	0
19	WAR, 32, D, SiC, 43		0	0
20	WAR, 64, D, SiC, 46		0	0
21	WAR, 69, D, SiC, 48		0	0
22	GA thermosetting matrix 4			
23	GA thermosetting matrix 3			
24	GA thermosetting matrix 2			
25	GA thermosetting matrix 1			

^aWAR is followed by % conversion = $100[1 - (1/2)(O/U)]$, resin type (A = Amberlite, D = Duolite), SiC or ZrC coating in Triso design, and buffer thickness (μ m), and if large coater was used C = cone, F = frit.

Table 20. Visual Examination Summary for HRB-12 Fuel Rods

Observations at Fuel Rod Surfaces					
Rod	Fissile Fuel Type ^a	Debonding	Number of Failures		Other
			Outer LTI	SiC or ZrC	
1	WAR, 45, A, ZrC, 43	None	7	7	
2	WAR, 45, A, ZrC, 43	Bottom edge	6	6	
3	WAR, 45, A, ZrC, 43	Bottom edge	13	13	
4	WAR, 44, A, SiC, 48	Top edge	0	0	Re foil and BeO insulator attached
5	WAR, 45, A, SiC, 43	Bottom edge	0	1	1 Sooty particles
6	WAR, 44, A, Biso, 50	None	0		100 Sooty particles
7	WAR, 45, A, ZrC, 43	Top edge	13	13	
8	WAR, 45, A, ZrC, 43	Bottom edge	6	5	
9	WAR, 45, A, ZrC, 43	Severe at top	50	25	Re foil and BeO insulator attached
10	WAR, 45, A, SiC, 43	None	0	0	
11	WAR, 44, A, SiC, 40	None	0	0	
12	GA reference matrix	Severe			
13	GA thermosetting matrix 5				
14	GA thermosetting matrix 6				
15	GA thermosetting matrix 7				
16	WAR, 46, D, SiC, 46	None	0	0	
17	WAR, 44, A, SiC, 48	Slight at top and bottom	0	0	
18	WAR, 44, A, SiC, 48		0	0	
19	WAR, 23, A, SiC, 44		0	0	
20	WAR, 45, A, SiC, 43		0	0	
21	WAR, 23, A, SiC, 44		0	0	
22	GA reference matrix				
23	GA thermosetting matrix 5				
24	GA thermosetting matrix 6				
25	GA thermosetting matrix 7				

^aWAR is followed by % conversion = 100[1 - (1/2)(O/U)], resin type (A = Amberlite, D = Duolite), SiC or ZrC coating in Triso design, and buffer thickness (μm).

Fig. 12. Gross Gamma Scan of Capsule HRB-11 Before Disassembly. The top of the capsule is on the left. The General Atomic Company rods (12, 13, 14, 15, 22, 23, 24, 25) were about 13 mm long; the rest of the rods were about 17 mm long. Full scale for this scan was set at 50,000 counts/min in the energy range of 0.55 to 0.75 MeV. The lead collimator slit used was 0.51 mm wide. Note the activity above and below the fuel column, presumably due to volatile fission product condensation there.

ORNL-DWG 79-11855

Fig. 13. Gross Gamma Scan of Empty Graphite Sleeve from HRB-11. Full scale for this scan was 10^6 counts/min in the energy range 0.55 to 0.75 MeV. The lead collimator slit used was 3.2 mm wide. The highest activity release to the graphite sleeve appears to have come from the rods in the center of the capsule (probably 11 through 17). Activity data for specific fission products from Appendix B are superimposed on the gross gamma scan (the Y-axis scale applies to these data). It appears that most of the activity in the sleeve comes from ^{137}Cs . Note that the 722-keV peak includes ^{154}Eu and ^{156}Eu as well as ^{95}Zr .

ORNL-DWG 79-41854A

Fig. 14. Gross Gamma Scan of ORNL Fuel Rods from Capsule HRB-11. Full scale for this scan was set at 2×10^6 counts/min in the energy range 0.55 to 0.75 MeV. The lead collimator slit used was 1.51 mm wide. Note the apparent inhomogeneity in several of the fuel rods.

Fig. 15. Gross Gamma Scan of Capsule HRB-12 Before Disassembly. The top of the capsule is on the left. The General Atomic Company rods (rods numbered 12, 13, 14, 15, 22, 23, 24, 25) were about 13 mm long, the rest of the rods were about 17 mm long. Full scale for this scan was set at 25,000 counts/min in the energy range from 0.55 to 0.75 MeV. The lead collimator slit used was 0.25 mm wide. Activity above and below the fuel column is presumably due to volatile fission product condensation there.

Fig. 16. Gross Gamma Scan of Empty Graphite Sleeve from HRB-12. Full scale for this was 10^6 counts/min in the energy range 0.55 to 0.75 MeV. The lead collimator slit used was 3.2 mm wide. The highest activity release to the graphite sleeve appears to have come from the rods at the top of the capsule (left of figure) where the ZrC-coated fissile particles (fabricated by LASL) were located.

Table 21. Fission Products Activities for Four Specific Peaks for HRB-11 Graphite Sleeve and Fuel Rods (from Data in Appendix C)

Rod	Activity in Gammas per Second ^a						
	In Empty Graphite Sleeve Where Rod Had Been				In Rod		
	(1)	(2)	(3)	(4)	(2)	(3)	(4)
1	4.69	17.64	37.18	6.41	515.5	30.4	207.8
2	4.84	14.61	51.37	9.79	478.0	24.9	212.7
3	5.85	4.83	55.74	6.52	475.0	18.8	216.0
4	5.44	3.26	59.71	4.42	485.7	21.1	211.9
5	6.98	17.04	108.5	8.49	487.0	21.9	229.5
6 ^b	7.18	86.21	126.3	277.8	574.2	29.4	257.5
7 ^b	7.23	65.38	192.1	193.6	557.7	24.8	267.1
8 ^b		85.78	263.9	238.4	571.2	20.6	267.6
9	7.09	29.24	226.9	34.84	540.7	15.9	267.4
10	7.26	7.35	138.6	10.89	517.8	24.2	233.8
11	7.26	6.98	69.3	13.44	542.7	18.32	249.3
12	8.34	6.81	52.06	11.05			
13	4.89	4.82	37.90	13.61			
16					521.9	25.44	240.0
17					268.3	7.99	143.0
18					486.3	18.92	241.5
19					455.8	23.3	215.5
20					468.4	25.2	230.8
21					494.3	23.3	207.6

^aThe peaks noted are as follows: (1) ^{110m}Ag at about 657 keV; (2) peak at about 722 keV of ⁹⁵Zr, ¹⁵⁴Eu, and ¹⁵⁶Eu; (3) ¹³⁷Cs at about 661 keV; (4) ¹⁴¹Ce at about 145 keV.

^bUC₂ rods.

Table 22. Fission Products Activities for Four Specific Peaks for HRB-12 Graphite Sleeve and Fuel Rods (from Data in Appendix C)

Activity in Gammas per Second ^a							
Rod	In Empty Graphite Sleeve Where Rod Had Been			In Rod		Remarks	
	(1)	(2)	(3)	(2)	(3)		(4)
1			34.9	303.9	21.4	83.6	ZrC
2			80.5	318.9		73.8	ZrC
3			79.8	297.1	19.8	79.6	ZrC
4	3.6		102.6	292.6	19.2	66.3	SiC deposited at 0.9 $\mu\text{m}/\text{min}$
5		2.9	79.8	306.3		70.1	SiC deposited at 0.52 $\mu\text{m}/\text{min}$
6			55.8	313.3		91.1	ZrC vs SiC
7	5.7		82.1	334.8	20.1	75.4	ZrC vs SiC
8	5.3	5.2	109.0	350.9	13.7	91.3	ZrC vs SiC
9	4.4		105.0	335.2	7.8	83.3	ZrC vs SiC
10	4.8	1.44	113.8	353.2	29.7	101.1	SiC deposited at 0.21 $\mu\text{m}/\text{min}$
11	5.2		116.3	370.4		107.8	SiC deposited at 0.24 $\mu\text{m}/\text{min}$
12	4.2		60.0	326.8		108.3	UC ₂
13	2.4		40.3	301.2	12.8	91.3	UC ₂
14			64.0	295.6		94.6	UC ₂
15	3.6		69.0	266.3		70.8	UC ₂
16			30.5	336.2		110.6	
17	4.5		68.3	348.5	16.3	97.4	
18	3.6		46.8	344.0	14.9	87.5	
19	2.7		29.9	350.7	13.7	104.6	
20	1.5		13.9	351.3	23.6	102.0	
21	1.7		11.6	319.0	25.3	96.9	
22	2.9		18.0	291.3		93.6	UC ₂
23			1.6	292.3		82.5	UC ₂
24	1.4		6.7	321.9	22.5	59.7	UC ₂
25	1.1		2.4	282.7	19.7	85.3	UC ₂

^aThe peaks noted are as follows: (1) ^{110m}Ag at about 657 keV; (2) peak at about 722 keV of ^{95}Zr , ^{154}Eu , and ^{156}Eu ; (3) ^{137}Cs at about 661 keV; (4) ^{141}Ce at about 145 keV.

Comparison of the HRB-11 data from Appendix C with the HRB-12 data reveals some differences. The counting statistics are generally better with the HRB-11 data (smaller numbers in the column marked ERR), and more gamma peaks are tabulated. These differences are due to the differences in the delay times between the completion of irradiation and the gamma counting. The HRB-11 capsule was gamma counted 26 d after it came out of the reactor; the HRB-12 capsule was counted after 90 d. The additional time for fission product decay associated with the HRB-12 capsule is responsible for weaker peaks (poorer statistics) and some peaks not detected. The presence of ^{233}Pa in the empty HRB-11 sleeve should also be discussed. This isotope is probably there as a result of some particles on the surface of fuel rods being crushed as the rods were pushed out of the graphite sleeve during capsule disassembly. The GA rods in HRB-11 experienced debonding during irradiation and were the source of some loose particles and debris.

Examination of the gross gamma scans revealed several trends:

1. The gross scans of the capsule before disassembly (Figs. 12 and 15) show that the activity is greatest at the center of the capsule, where the fuel burnup was highest.
2. The gross scans also show that the fuel rods were relatively inhomogeneous relative to fissile fuel distribution. The fissile concentration appears to be highest at the bottom of the rods. This is also shown by the gross scan of the HRB-11 rods after they were removed from the capsule (Fig. 14). This observation was also made³ with the HRB-9 and -10 fuel rods.
3. The total activity shown in the scans of the capsules before disassembly appears to be somewhat higher at the bottom of the capsules than at the top. This is somewhat surprising, because the total calculated burnups (see Tables 13 and 14, pp. 24 and 25) are slightly higher at the tops of the capsules.
4. The highest activity in the graphite sleeve of HRB-11 (Fig. 13) appears to be adjacent to the specimens containing UC_2 fissile particles. These specimens (rods 12 through 15) contained dense UC_2 fissile particles and ThO_2 fertile particles bonded with thermosetting matrix materials.

5. High activity also appears adjacent to HRB-11 rod 16 (Fig. 13). This rod showed some debonding along the bottom edge in the visual examination, with several broken particles visible in the debonded area (outer LTI failures).

6. The highest activity in the HRB-12 graphite sleeve (Fig. 16) appears in the top half of the capsule, where numerous failures were visible in the specimens containing particles with ZrC coatings.

Tabulations were made from the Appendix C data of fission product activity for both the graphite sleeves and fuel rods stacks in HRB-11 and -12. Four fission product peaks are included in Tables 21 and 22, and these were arbitrarily selected and have no special significance. For HRB-11, 13 positions were used for the detailed scans of the graphite sleeve. These positions are shown in Fig. 13. For HRB-12 detailed scans were taken adjacent to each fuel rod. Detailed scans were taken of all ORNL fuel rods in HRB-12 (including the GA-fabricated rods). The numbers cannot be compared from table to table because of the differences in elapsed time between completion of irradiation and gamma counting and because of different geometries used with the collimator. The following general trends are observed from the data shown in Tables 21 and 22:

1. The highest activities associated with the graphite sleeve of HRB-11 are those adjacent to the rods containing UC_2 fissile particles. These rods were adjacent to positions 6, 7, and 8 for the gamma scan.

2. The cesium activity in the HRB-11 sleeve was also high for gamma scan positions 9 and 10. These were WAR particles, which showed good performance in the metallographic and visual examinations. Perhaps the cesium originated in rods 12 through 15 and deposited in the graphite somewhat above those fuel rods.

3. There was significant evidence of ^{95}Zr , ^{154}Eu , and ^{156}Eu activity in the HRB-11 empty sleeve at 722 keV. The scans shown in Appendix C do not include ^{156}Eu because it decays rapidly. But because these scans were taken so quickly after the capsule came out of the reactor, significant ^{156}Eu was still present. These high activities are most dramatic adjacent to the rods containing UC_2 -fueled fissile particles. Thus, most of the activity is believed attributable to the europium and its behavior in UC_2 -containing particles. The same trend is observed with ^{141}Ce and ^{140}La , which are listed at 1594 keV in the gamma scans in Appendix C.

4. The activity profiles for the fuel rods generally follow the burnup curve for the capsule.

5. Cesium activities in the top half of the HRB-12 sleeve are generally higher than in the bottom half, as observed in the gross gamma scan (Fig. 16). The top half of the capsule contained the specimens with ZrC-coated fissile particles.

Dimensional Inspection

The dimensional change data for the HRB-11 and -12 fuel rods are tabulated in Tables 23 and 24. Both diameter and length changes are given. These data are plotted in Figs. 17 through 20. The following comments can be made about the dimensional change data:

1. Visual curve fits of the HRB-11 data show the maximum diameter shrinkage to be about 1.5% at a fluence of about $6 \times 10^{25} \text{ n/m}^2$ ($>0.18 \text{ MeV}$). Maximum shrinkage in length appears to be about 2% at a fluence of about 5×10^{25} . The scatter in the data is about what was expected from the experience with other experiments. The HRB-12 data show the maximum shrinkage to be about 2% at a fluence of about $4 \times 10^{25} \text{ n/m}^2$.

2. The lack of agreement between the diameter change and length change data shown for HRB-11 is not unusual. The rods rarely shrink isotropically. The agreement between length and diameter change data for HRB-12 is unusual, but not significant. Comparing the dimensional data^{2,3} for capsules HRB-7, -8, -9, and -10 with the HRB-11 and -12 rods shows that the HRB-11 and -1 rods shrank less (which will be discussed later) and behaved more isotropically on the average. Considering the range of the ratio of percentage diameter change to percentage length change, the HRB-11 and -12 rods appear to have behaved more anisotropically. But the HRB-11 and -12 shrinkages were smaller by nearly a factor of 3 than those for the other four capsules; therefore the quotients would be expected to vary more. But the averages of the percent diameter change to percent length change ratios for HRB-11 and -12 are 1.00 and 0.94, respectively, compared with 0.86, 0.92, and 0.94 for capsules HRB-7 through -9, respectively.

Table 23. Dimensional Changes of ORNL Fuel Rods in HRB-11a

Specimen	Diameter, mm (in.)		Change (%)	Length, mm (in.)		Change (%)	Change Ratio ^b
	Preirradiation	Postirradiation		Preirradiation	Postirradiation		
HRB-11-1	12.443(0.4899)	12.248(0.4822)	-1.57	16.774(0.6604)	16.469(0.6484)	-1.82	0.86
-2	12.426(0.4892)	12.301(0.4843)	-1.00	16.612(0.6540)	16.215(0.6384)	-2.39	0.42
-3	12.441(0.4898)	12.289(0.4838)	-1.22	16.977(0.6684)	16.571(0.6524)	-2.39	0.51
-4	12.441(0.4898)	12.324(0.4852)	-0.94	17.059(0.6716)	16.812(0.6619)	-1.44	0.67
-5	12.438(0.4897)	12.286(0.4837)	-1.23	16.731(0.6587)	16.513(0.6501)	-1.31	0.94
-6	12.436(0.4896)	12.261(0.4827)	-1.41	16.985(0.6687)	16.805(0.6616)	-1.06	1.33
-7	12.433(0.4895)	12.281(0.4835)	-1.23	16.998(0.6692)	16.998(0.6692)	0.00	
-8	12.446(0.4900)	12.324(0.4852)	-0.98	16.876(0.6644)	16.647(0.6554)	-1.35	0.73
-9	12.441(0.4898)	12.291(0.4839)	-1.20	17.107(0.6735)	16.782(0.6607)	-1.90	0.63
-10	12.443(0.4899)	12.253(0.4836)	-1.29	16.665(0.6561)	16.464(0.6482)	-1.20	1.08
-11	12.449(0.4901)	12.205(0.4805)	-1.96	16.883(0.6647)	16.695(0.6573)	-1.11	1.78
-16	12.456(0.4904)	12.375(0.4872)	-0.65	16.810(0.6619)	16.761(0.6599)	-0.30	2.17
-17	12.471(0.4910)	12.375(0.4872)	-0.77	16.640(0.6551)	16.538(0.6511)	-0.61	1.26
-18	12.443(0.4899)	12.233(0.4816)	-1.69	17.003(0.6694)	16.718(0.6582)	-1.67	1.01
-19	12.423(0.4891)	12.240(0.4819)	-1.47	17.015(0.6699)	16.673(0.6564)	-2.02	0.73
-20	12.423(0.4891)	12.238(0.4818)	-1.49	16.891(0.6642)	16.673(0.6564)	-1.17	1.27
-21	12.408(0.4885)	12.212(0.4808)	-1.58	16.919(0.6661)	16.485(0.6490)	-2.57	0.61
						Ave. = 1.00	

^aRods 12-15 and 22-25 were GA rods and are not reported here.

^bPercentage diameter change divided by percentage length change.

Table 24. HRB-12 Fuel Rod Dimensional Changes

Rod ^a	Postirra- diation Diameter (mm)	Change (%)	Postirra- diation Length (mm)	Change (%)	Change Ratio ^b
1	12.217	-1.90	16.312	-2.16	0.88
2	12.220	-1.86	16.528	-1.77	1.05
3	12.291	-1.51	16.744	-1.85	0.82
4	12.283	-1.33	16.477	-1.59	0.84
5	12.286	-1.25	16.629	-1.46	0.86
6	12.258	-1.63	16.891	-2.48	0.66
7	12.291	-1.45	16.467	-1.01	1.44
8	12.206	-1.30	16.665	-0.08	
9	12.271	-1.25			
10	12.375	-0.65	16.695	-0.86	0.76
11	12.352	-0.86	16.744	-0.99	0.87
16	12.385	-0.65	16.754	-0.75	0.87
17	12.339	-1.00	16.716	-0.90	1.11
18	12.324	-1.04	16.645	-0.92	1.13
19	13.329	-0.98	16.650	-1.50	0.65
20	12.294	-1.24	16.690	-0.93	1.33
21	12.306	-1.12	16.401	-1.43	<u>0.78</u>
Ave. = 0.94					

^aRods 12-15 and 22-25 were GA rods and are not reported here.

^bPercentage diameter change divided by percentage length change.

Fig. 17. Diameter Change Versus Fast Fluence Data for HRB-11 Fuel Rods.

Fig. 18. Length Change Versus Fast Fluence Data for HRB-11 Fuel Rods.

ORNL-DWG 79-9254

Fig. 19. Diameter Change Versus Fast Fluence Data for HRB-12 Fuel Rods.

ORNL-DWG 79-9255

Fig. 20. Length Change Versus Fast Fluence Data for HRB-12 Fuel Rods.

3. That the HRB-11 and -12 diameter and length change data show considerably less shrinkage than observed in other HRB capsules is worthy of some discussion. Maximum shrinkage for the HRB-7 and -8 capsules was about 5.5%, for HRB-9 about 3.5%, and for HRB-10 about 4.5%. The lower shrinkage in HRB-11 and -12 can be attributed to the use of Triso-coated inert particles in those capsules. Biso-coated inert particles were used in HRB-7 through -10. The data from HRB-2 show decidedly less shrinkage for fuel rods containing Triso-coated particles than for rods containing Biso-coated particles.⁹ The reason is the dimensional stability of the SiC coating, which does not shrink* under irradiation. The number of fissile, fertile, and inert particles varies with position in the capsule, as a higher loading of fissile and fertile material is needed at the ends of the capsule to compensate for the lower neutron flux there. In HRB-11 there were about 750 fissile, 1375 fertile, and 2550 inert particles in fuel rod 1. Fuel rod 11 had about 440 fissile, 800 fertile, and 2750 inert particles. Therefore, the ratio of Triso- to Biso-coated particles was about 2.2 in rod 1 and about 4.0 in rod 11.

4. From the experience with previous capsules^{2,3} more shrinkage would be expected in fuel rods operated at higher temperature, and the rods would experience maximum shrinkage at a lower fluence. From this earlier observation and the shrinkage data for HRB-11 and -12 shown in Figs. 17 through 20, we would have expected HRB-12 fuel rods to have operated hotter than the rods from HRB-11. However, examination of the calculated operating temperatures (Appendix A) shows the HRB-11 temperatures to be slightly (but not significantly) higher. There is, of course, uncertainty in the calculated temperatures, but a more likely explanation for this apparent inconsistency is the lack of dimensional change data over the whole fluence range of interest, which precludes drawing an accurate curve. The HRB-12 data, for instance, which are shown in Figs. 19 and 20, show a minimum shrinkage at a fast fluence of about $4 \times 10^{25} \text{ n/m}^2$, but there are no data points to the left of the minimum.

*Actually SiC swells slightly, about 0.5% linear expansion at a fluence of $8 \times 10^{25} \text{ n/m}^2$ in pyrolytic SiC (R. J. Price, "Properties of Silicon Carbide for Nuclear Fuel Coatings," *Nucl. Technol.* 35(2): (September 1977)).

During the dimensional inspection of fuel rods from a later capsule, HRB-13, we discovered that for an undetermined period of time the flat anvil on the stem of the dial micrometer had been replaced with a knife-edged tip. A flat anvil had been used routinely in the dimensional inspection of HTGR fuel rods to produce more representative diameters. Dimensions obtained by using a knife-edged tip would be affected by the degree of surface roughness and the difference in elasticity of pyrocarbon coatings and matrix material. It was not possible to establish for a fact that a knife-edged tip was or was not used during the dimensional inspection of the fuel rods from HRB-12. Thus, the data represented in this section of the report would be conservative if a knife-edged tip were used; that is, a flat-anvil tip would have shown even smaller decreases in diameter. It is now a part of our quality assurance procedure to establish that flat anvil tips are used in the dimensional inspection of HTGR fuel rods.

Because of these uncertainties in how the dimensional data were taken we decided to use dimensional change data obtained¹⁰ from fuel rods irradiated in the OF-2 capsule (Fig. 21) for the detailed thermal analysis

Fig. 21. Dimensional Changes Versus Fast Fluence for OF-2 Fuel Rods.

of HRB-11 and -12. The data used in the thermal analysis came from rods carbonized in C magazine (broken curve in Fig. 21) that had a relatively constant ratio of Biso- to Triso-coated particles that ranged from 3.5 to 3.6 and showed a maximum diametral shrinkage less than 2.5%.

Metallographic Examination

Approximately half of the fuel rods were examined metallographically. Pertinent observations are given below. For the readers' convenience, the chemical composition of the fissile kernels contained in each fuel rod are cross indexed in Table 25, from information contained in Tables 1 through 3.

Fuel Rod HRB-11-1

One transverse metallographic mount contained 8 fissile particles and 28 fertile particles. None had failed. The fissile kernel appeared like a carbide fuel, with a highly reflective phase dispersed in a second phase, which had low reflectivity. Gas bubbles in the kernel and amoeba effect were not seen, and kernel shrinkage was typical of WAR-derived fuels. The inner LTI layer was not graphitized and four of the fissile particles had laminations in the SiC coating. We observed SiC corrosion on some fissile particles in the area where the kernel was immediately adjacent to the coating. Fission products migrated up to 50% of the way through the LTI layer. An example fissile particle is shown in Fig. 22 and a fertile particle in Fig. 23.

Fuel Rod HRB-11-2

One transverse metallographic mount contained 11 fissile particles and 19 fertile particles. None had failed. The fissile kernel had segregated, principally into two interdispersed phases. Fissile kernel shrinkage was typical of WAR-derived fuels, and the fissile kernels were optically active. Some gas bubbles were present in the kernels. These fissile particles had no buffer layer (by design), and some "thinning" of the inner LTI layer (which amounted to changes in the optical properties — best observed under polarized light) occurred where the kernel had

Table 25. Fissile Kernel Compositions
for HRB-11 and -12 Fuel Rods
Fabricated at ORNL

Fuel Rod Position	Kernel Composition in Each Capsule	
	HRB-11	HRB-12
1	UC _{4.45} O _{0.73}	UC _{4.60} O _{1.10} ^a
2	UC _{4.80} O _{1.06}	UC _{4.60} O _{1.10} ^b
3	UC _{4.83} O _{1.09}	UC _{4.60} O _{1.10} ^c
4	UC _{4.12} O _{0.47}	UC _{4.58} O _{1.13}
5	UC _{4.38} O _{0.61}	UC _{4.60} O _{1.10}
6	UC _{5.45} O _{1.75}	UC _{4.58} O _{1.13}
7	UC _{5.32} O _{1.65}	UC _{4.60} O _{1.10} ^a
8	UC _{4.80} O _{1.06}	UC _{4.60} O _{1.10} ^b
9	UC _{4.83} O _{1.09}	UC _{4.60} O _{1.10} ^c
10	UC _{5.32} O _{1.65}	UC _{4.60} O _{1.10}
11	UC _{5.16} O _{1.36}	UC _{4.59} O _{1.13}
16	UC _{4.83} O _{1.09}	UC _{4.83} O _{1.09}
17	UC _{4.48} O _{0.62}	UC _{4.58} O _{1.13}
18	UC _{4.45} O _{0.73}	UC _{4.58} O _{1.13}
19	UC _{5.16} O _{1.36}	UC _{5.12} O _{1.54}
20	UC _{4.83} O _{1.09}	UC _{4.60} O _{1.16}
21	UC _{4.48} O _{0.62}	UC _{5.12} O _{1.54}

^aZrC coating replace SiC in Triso design.

^bZrC coating replace SiC; outer coating was ZrC-doped PyC.

^cSiC coating replaced by ZrC, followed by ZrC-C coating; outer coating was ZrC-doped PyC.

Fig. 22. Fissile Particle from Rod HRB-11-1. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 1.0 mm from the outside of the rod and operated with an average temperature of 1070°C and average temperature gradient of 450°C/cm. The hot side of the particle was on the right. This particle, containing a 60%-converted kernel (made from Duolite resin) shows no separation between inner LTI and SiC layers. Fission product penetration of the SiC layer was noted in some cases, but always less than 50% of the SiC layer thickness. The attack always occurred at the SiC layer adjacent to the kernel. This implies a solid-state mechanism for movement of fission products to the SiC.

100 μ m

Fig. 23. Fertile Particle from Rod HRB-11-1. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 3.0 mm from the outside of the rod and operated at an average temperature of 1090°C and average temperature gradient of 190°C/cm. The hot side of the particle was on the right.

adhered to this layer. In one case the inner LTI layer separated from the SiC. There was some evidence of very localized fission product penetration of the SiC layer (less than 50% through). There was a laminar structure of the SiC in what appears to be a result of a change in coating conditions about halfway through the SiC layer. An example photomicrograph of the fissile particle is shown in Fig. 24, both in bright field and polarized light illumination. A higher magnification of the coating layer in Fig. 25 shows the fission product penetration of the SiC layer.

Fuel Rod HRB-11-3

We observed 14 fissile particles in the plane of polish. None had failed. Two kernel phases were dispersed in the densified buffer. Kernel densification was typical of WAP-derived fuels. Some gas bubbles were present in the kernels. No apparent thinning of the inner LTI layer resulted from the thin buffer layer (20 μ m in thickness compared with the nominal design thickness of 45 μ m). Some fission products accumulated at the SiC layer where the kernel and buffer were attached. Fission products penetrated the SiC to less than half thickness. A typical fissile particle is shown in Fig. 26.

Fuel Rods HRB-11-4 Through -6

These rods were not examined metallographically. They were electrolytically deconsolidated under conditions given in ref. 11 and the particles will be examined with the IMGA system (see ref. 5). The fissile particles in these rods were from batches that were also irradiated in the OF-2 capsule¹⁰ and will be irradiated in the Fort St. Vrain Test Element Program.¹² The IMGA results will be compared to those already reported¹³ for rods irradiated in OF-2.

Fuel Rod HRB-11-7

We observed 6 fissile and 13 fertile particles in the plane of polish. None had failed. Of the 88 Triso-coated inert particles observed in the plane of polish four had failed outer LTI layers. The fissile

Fig. 24. Fissile Particle from Rod HRB-11-2. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 1.2 mm from the outside of the rod and operated at an average temperature of 1070°C and average temperature gradient of 490°C/cm. The hot side of the particle was on the right. This particle contained a kernel with initial conversion ratio of 46%, made from Duolite resin. The particle had no buffer layer. Some thinning of the inner LTI layer is apparent but does not seem to degrade performance.

Fig. 25. Fission Product Corrosion of the SiC Layer in a Fissile Particle from Rod HRB-11-2. (a) Bright-field illumination. (b) Polarized light illumination. This particle was on the outside of the fuel rod and operated with an average temperature of 1000°C and an average temperature gradient of 670°C/cm. The hot side of the particle was toward the bottom.

Fig. 26. Fissile Particle from Rod HRB-11-3. (a) Bright-field illumination. (b) Polarized light illumination. This particle was on the outside of the rod and operated at an average temperature of 1050°C and average temperature gradient of 650°C/cm. The hot side of the particle was on the right.

kernels were dispersed in the densified buffer layers. No gas bubbles were visible in the kernel. In every fissile particle observed, the buffer layer and inner LTI coating had debonded from the SiC and densified around the kernel. No attack of the SiC layer was visible in the plane of polish. An example fissile particle from this fuel rod is shown in Fig. 27. A broken buffer layer in one fertile particle is shown in Fig. 28.

Fuel Rods HRB-11-8 Through -11

No metallographic analysis was performed on these rods. They contained fissile particles from batches that had been irradiated in other positions in the capsule (positions 2, 3, 7, and 19 respectively). The rods were electrolytically deconsolidated¹¹ and the particles will be examined with the DMGA system. The fissile batches were irradiated in two separate locations within the capsule to permit both metallographic and DMGA examinations.

Fuel Rod HRB-11-16

The plane of polish displayed 4 fissile and 21 fertile particles. None of these particles had failed. Of the 113 Triso-coated inert particles visible, 5 had broken outer LTI layers. The breakage was due to fast-neutron-induced damage. The fissile kernels appeared as two phases dispersed in the densified buffer. Kernel densification was typical of WAR-derived kernels. In two of the four fissile particles viewed, the inner LTI layer had separated from the SiC coating. Fission products penetrated the SiC layer but less than half of its thickness. An example fissile particle is shown in Fig. 29. A higher magnification of the coatings is shown in Fig. 30, showing the fission product penetration of the SiC. An example fertile particle and high magnification of the fertile particle coating layers on the cold side are shown in Figs. 31 and 32. Some thermal migration of the ThO_2 is apparent from slight thinning of the buffer on the hot side and optically active deposit on the cold side.

100 μ m

Fig. 27. Fissile Particle from Rod HRB-11-7. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 0.8 mm from the outside of the rod and operated at an average temperature of 1200°C and average temperature gradient of 550°C/cm. The hot side of the particle was on the top. This particle contained a 15%-converted kernel and a 50- μ m-thick buffer layer.

100 μm

Fig. 28. Fertile Particle with Broken Buffer Coating from Rod HRB-11-7. (a) Bright-field illumination. (b) Polarized light illumination. This particle was on the outside of the rod and operated at an average temperature of 1150°C and average temperature gradient of $670^{\circ}\text{C}/\text{cm}$. The hot side of the particle was on the right.

100 μ m

Fig. 22. Fissile Particle from Rod HRB-11-16. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 1.6 mm from the outside of the rod and operated with an average temperature of 1250°C and average temperature gradient of 540°C/cm . The hot side of the particle was on the right.

Fig. 30. Fission Product Corrosion of SiC in Fissile Particle from HRB-11-16. (a) Bright-field illumination. (b) Polarized light illumination. This is a higher magnification of the side of the particle shown in Fig. 29 that was adjacent to the densified kernel.

100 μ m

Fig. 31. Fertile Particle from Rod HRB-11-16. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 1.35 mm from the outside of the rod and operated with an average temperature of 1240°C and average temperature gradient of $565^{\circ}\text{C}/\text{cm}$. The hot side of the particle was on the right.

50 μm

Fig. 32. Cold Side of the Fertile Particle from HRB-11-16. (a) Bright-field illumination. (b) Polarized light illumination. This is a higher magnification of the same particle shown in Fig. 31.

Fuel Rods HRB-11-17 and -18

No metallographic analysis was performed on these rods. The fissile particle batches irradiated in these rods were also irradiated in rods 21 and 1, respectively, which were examined metallographically. Rods 17 and 18 will be electrolytically deconsolidated and analyzed with the IMGA system.

Fuel Rod HRB-11-19

The plane of polish showed 5 fissile and 26 fertile particles. None of these particles had failed. Of the 108 Triso-coated inert particles visible, 4 had outer LTI layer failure due to fast-neutron-induced damage. The fissile kernels appeared as a single phase, dispersed in the densified buffer. The buffers showed some optical anisotropy and were densified in the fashion typical for WAR-derived fuels. The inner LTI layer had shrunk away from the SiC layer in four of the five fissile particles observed. There was no evidence of fission product accumulation at the SiC layer. An example fissile particle is shown in Fig. 33 both in bright field illumination and polarized light.

Fuel Rod HRB-11-20

This rod was not examined metallographically. It was electrolytically deconsolidated for IMGA examination. The fissile particles batch irradiated in rod 20 was also irradiated in rod 16, which was examined metallographically.

Fuel Rod HRB-11-21

The plane of polish showed 5 fissile particles and 16 fertile particles. The fissile kernels appeared to be two phases, one dispersed in the other. This has become expected for WAR-derived fissile kernels with conversion levels over about 50%. The SiC layer was penetrated to less than half the thickness by fission products in all the fissile particles in the plane of polish. Two of the fissile particles showed a laminar structure in the SiC layer, as described earlier. An example fissile particle is shown in Fig. 34. A higher magnification of the coatings, showing the fission product penetration, is shown in Fig. 35.

100 μ

Fig. 33. Fissile Particle from Rod HRB-11-19. (a) Bright-field illumination. (b) Polarized light illumination. This particle was on the outside of the fuel rod and operated at an average temperature of 1150°C and average temperature gradient of $790^{\circ}\text{C}/\text{cm}$. The hot side of the particle was on the right. This particle, containing a 30%-converted kernel (made from Duolite resin), shows no SiC attack, but the inner LTI has separated from the SiC layer and densified. The kernel and buffer have densified, and the kernel has two major phases surrounded by the densified buffer.

100 μ m

Fig. 34. Fissile Particle from Rod HRB-11-21. (a) Bright-field illumination. (b) Polarized light illumination. This rod was 1.1 mm from the outside of the rod and operated at an average temperature of 1220°C and an average temperature gradient of 580°C/cm. The hot side of the particle was on the right.

Fig. 35. Fission Product Corrosion of SiC in Fissile Particle from Rod HRB-11-21. (a) Bright-field illumination. (b) Polarized light illumination. This is the same fissile particle shown in Fig. 34, but at a higher magnification.

Three of the fertile particles in the plane of polish show small anisotropic areas of graphitization in the buffer layer on the cold side as seen in Fig. 36. There were 115 Triso-coated inert particles visible in the plane of polish. One of these had a broken outer LTI layer as a result of fast-neutron-induced damage.

Fuel Rod HRB-12-1

Nine fissile particles were visible in the plane of polish; three had failed. One failure appeared to be caused by rod fabrication, while the others appeared to be pressure vessel failures (see Fig. 37). The inner LTI layers had shrunk away from the ZrC. No fission product accumulations in the inner LTI layers were noted; however, some fission product accumulation in the inner 50% of the ZrC layer was observed under polarized light. Cracks in the ZrC were observed, but they are believed to be artifacts from the metallographic preparation. A nonfailed particle is shown in Fig. 38.

Fuel Rod HRB-12-2

Of the 20 fissile particles visible in the plane of polish, nine had failed. Six of the failures were in the outer LTI layer; three were pressure vessel failures (see Fig. 39). About 10 μm penetration of fission products into the ZrC layer was observed. The outer LTI layers appeared to be very anisotropic, appearing optically active under polarized light. (see Fig. 39).

Fuel Rod HRB-12-3

All fissile particles in the plane of polish had cracked ZrC layers. Researchers at LASL believe that these cracks are artifacts from the metallographic preparation.¹⁴ The ZrC penetrated the inner LTI coating about 10 μm deep. This penetration occurred during application of the ZrC coating, indicating that the inner LTI layers were somewhat permeable to the coating gases. The inner LTI layer was separated from the ZrC layer on most of the particles in the plane of polish. No corrosion or fission product accumulation in the ZrC layers was noted, although the ZrC coating had a peppery appearance, indicating porosity. A typical particle is shown in Fig. 40.

Fig. 36. Cold Side of Fertile Particle from Rod HRB-11-21. (a) Bright-field illumination. (b) Polarized light illumination. This figure shows the areas of graphitization in a particle located 2.8 mm from the outside of the rod. The particle operated at an average temperature of 1305°C and average temperature gradient of 390°C/cm.

100 μm

Fig. 37. Pressure Vessel Failure of Fissile Particle from Rod HRB-12-1. (a) Bright-field illumination. (b) Polarized light illumination. This particle was located 1.1 mm from the outside of the fuel rod and operated at an average temperature of 990°C and an average temperature gradient of 450°C/cm. The hot side of the particle was on the right.

100 μ m

Fig. 38. Fissile Particle from Rod HRB-12-1. (a) Bright-field illumination. (b) Polarized light illumination. This particle was located on the outside of the rod and operated at an average temperature of 935°C and average temperature gradient of $580^{\circ}\text{C}/\text{cm}$. The hot side of the particle was on the right.

100 μ m

Fig. 39. Pressure Vessel Failure of Fissile Particle from Rod HRB-12-2. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 2.7 mm from the outside of the rod and operated at an average temperature of 1080°C and average temperature gradient of 230°C/cm. The hot side of the particle was on the right.

100 μ m

Fig. 40. Fissile Particle from Rod HRB-12-3. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 2.7 mm from the outside of the rod and operated with an average temperature of 1155°C and average temperature gradient of 220°C/cm. The hot side of the particle was on the right.

(a)

(b)

100 μ m

Fig. 41. Fissile Particle from Rod HRB-12-4. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 3.2 mm from the outside of the rod and operated at an average temperature of 1210°C and average temperature gradient of $165^{\circ}\text{C}/\text{cm}$. The hot side of the particle was on the right.

Fuel Rod HRB-12-4

No fissile particle failures were noted in the plane of polish. Kernel shrinkage was typical of WAR-derived fuel, and phase separation was typical of the behavior of intermediate and highly converted fuel (30% conversion and above). Some graphitization of the inner LTI layer occurred in the areas of fission product accumulation. Localized fission product accumulations were observed, but there was no apparent temperature dependence. Fission products penetrated the SiC to about 60% of the thickness. Failed outer LTI layers were observed on three of the Triso-coated inert particles in the plane of polish. An example fissile particle from this rod is shown in Fig. 41. A comparison of the fission product penetration rate into the SiC from this rod and rod HRB-12-5, with data¹⁵ from HT-33 and several other capsules is shown in Fig. 42. The penetrating species in rods HRB-12-4 and -5 was identified as palladium (by microprobe analysis).

Fig. 42. Comparison of Data for Palladium Penetration into SiC from Several Irradiation Capsules, Including HRB-11 and -12.

Fuel Rod HRB-12-5

No fissile particle failures were noted in the plane of polish. Kernel shrinkage and phase separation were as described above. Fission products penetrated the SiC layer, but less than the 60% of thickness described above. An example fissile particle is shown in Fig. 43.

Fuel Rods HRB-12-6 Through -11

These rods were not examined metallographically but were electrolytically deconsolidated for IMGA analysis. The fissile particles from these rods were from batches also irradiated in other rods, which were examined metallographically, except for the particles in rod 6. Rod 6 contained Biso-coated fissile particles, which will be used as a standard for comparison of the fission product retention capabilities of ZrC-coated fissile fuel and of SiC-coated fuel from different coating rates. This comparison will be based on IMGA results. The fissile particle batches contained in rods 7 through 10 were also irradiated in rods 1 through 3 and 20, respectively, which were examined metallographically. The fissile particle batch contained in rod 11 was also irradiated in rod 18, which was examined metallographically.

Fuel Rod HRB-12-18

Four fissile particles were visible in the plane of polish, and none had failed. One particle looked more like UO_2 than $UC_{4.58}O_{1.13}$. This particle had gas bubbles, whereas the others showed two phases dispersed in the densified buffer, typical of 44%-converted fuel. The SiC layer of the fissile particle (deposited at about $0.2 \mu\text{m}/\text{min}$) appeared to be in very good condition. There was some fission product accumulation at the ILTI-SiC interface, but very little (less than $3 \mu\text{m}$) attack. The fission product accumulation appeared to be palladium. Similar accumulations have been observed^{10,15} in previous tests and identified as palladium. An example fissile particle is shown in Fig. 44.

100 μ m

Fig. 43. Fissile Particle from Rod HRB-12-5. (a) Bright-field illumination. (b) Polarized light illumination. This particle was at the center of the fuel rod and operated at an average temperature of 1260°C and temperature gradient of 0°C/cm.

100 μ m

Fig. 44. Fissile Particle from Rod HRB-12-18. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 2.6 mm from the outside of the rod and operated at an average temperature of 1165°C and average temperature gradient of 355°C/cm. The hot side of the particle was on the right.

Fuel Rod HRB-12-19

This rod 19 was not examined metallographically but was electrolytically deconsolidated for IMGA analysis. The particle batch irradiated in this rod was also irradiated in rod 21, which was examined metallographically.

Fuel Rod HRB-12-20

Six fissile particles were visible in the plane of polish, and none had failed. The kernel was dispersed in the densified buffer layer. No gas bubbles were noted, and no metallic inclusions. The SiC layer was in very good condition in all fissile particles in the plane of polish. There was a very slight fission product accumulation (believed to be palladium — see refs. 10 and 15) at the ILTI-SiC interface, but very little penetration of the SiC layer (less than 3 μ m). The thermal gradient could not be correlated with the penetration or accumulation. An example fissile particle is shown in Fig. 45.

Fuel Rod HRB-12-21

Six fissile particles were observed in the plane of polish, and none had failed. The dispersed kernel phases appeared like neither UO_2 nor UC_2 . The inner LTI layer shrank on all fissile particles and separated from the SiC on some. The inner LTI was graphitized where fission products had accumulated. The SiC layer had corroded on two fissile particles. The accumulation of fission products was large, with penetrations to about 60% of the thickness of the SiC. The accumulation was made up of a metallic-appearing phase but was too large to be palladium. Considering the relatively high oxygen content of these particles, we doubt that the rare earth fission products were involved.¹⁶ The accumulation could have contained uranium, as chlorine-induced redistribution of uranium has been observed² in other experiments. An example fissile particle is shown in Fig. 46. Corrosion of the SiC is shown in Fig. 47.

Summary

The metallographic results for Capsule HRB-11 and -12 are summarized in Tables 26 through 29.

100 μ m

Fig. 45. Fissile Particle from Rod HRB-12-20. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 0.7 mm from the outside of the rod and operated at an average temperature of 1070°C and average temperature gradient of 555°C/cm. The hot side of the particle was on the right.

(a)

(b)

100 μ m

Fig. 46. Fissile Particle from Rod HRB-12-21. (a) Bright-field illumination. (b) Polarized light illumination. This particle was 1.6 mm from the outside of the fuel rod and operated at an average temperature of 1115°C and average temperature gradient of 455°C/cm . The hot side of the particle was on the right.

50 μ m

Fig. 47. Corrosion of the SiC Layer in Fissile Particle from Rod HRB-12-21. (a) Bright-field illumination. (b) Polarized light illumination. This particle was located at the center of the fuel rod and operated at an average temperature of 1220°C and temperature gradient of 0°C/cm.

Table 26. Features of HxB-11 Fuel Rods to Be Related to Metallographic Observations^a

Fuel Rod	Fissile Batch	Fissile Kernel Composition	Conversion (%)	Irradiation Temperature, °C				Special Features
				Average ^b		Peak		
				Rod Surface	Rod Center	Rod Surface	Rod Center	
1	OR-2466-H	UC _{4.45} O _{0.73}	64					Duolite resin
2	OR-2460-H	UC _{4.80} O _{1.06}	47	1150	1000	1330	1100	No buffer layer
3	OR-2459-H	UC _{4.83} O _{1.09}	46					Thin buffer (20 μm)
4	A-615	UC _{4.15} O _{0.47}	77	1250	1100	1380	1180	Cone gas distributor, 0.13-m coater
5	A-601	UC _{4.35} O _{0.62}	69	1250	1100	1390	1180	Frit gas distributor, 0.13-m coater
6	A-611	UC _{5.53} O _{1.77}	12					Frit gas distributor, 0.13-m coater
7	OR-2463-H	UC _{5.32} O _{1.65}	18	1300	1150	1340	1180	Duolite resin
8	OR-2460-H	UC _{4.80} O _{1.06}	47	1350	1170	1360	1200	No buffer layer
9	OR-2459-H	UC _{4.83} O _{1.09}	46					Thin buffer (20 μm)
10	OR-2463-H	UC _{5.32} O _{1.65}	18					Duolite resin
11	OR-2456-H	UC _{5.16} O _{1.36}	32					Duolite resin
12 ^a				1375	1180	1500	1260	
13 ^a				1350	1150	1500	1250	
16	OR-2458-H	UC _{4.83} O _{1.09}	46					Normal buffer (46 μm)
17	OR-2471-H	UC _{4.48} O _{0.62}	69					Duolite resin
18	OR-2466-H	UC _{4.45} O _{0.73}	64	1400	1150	1530	1230	Duolite resin
19	OR-2455-H	UC _{5.16} O _{1.36}	32					Duolite resin
20	OR-2458-H	UC _{4.53} O _{1.09}	46					Normal buffer (46 μm)
21	OR-2471-H	UC _{4.48} O _{0.62}	69	1370	1150	1500	1250	Duolite resin

^aRods 8-11 and 22-25 were prepared by GA from its fissile batch GA 6151-17-20 and a thermosetting matrix.^bTime averaged from plots shown in Fig. 8.

Table 27. Summary of Capsule HRB-11 Metallographic Results

Fuel Rods	Metallographic Observations
1-3	No failures; some fission product-SiC interaction; no amoeba
4-6	Not examined ^a
7	No failures; no fission product attack of SiC; no amoeba
8-11	Not examined ^a
12-15	To be reported by General Atomic Company
16	No failures, some fission product-SiC interaction; no amoeba
17-18	Not examined ^a
19	No failures, no fission product-SiC interaction; no amoeba
20	Not examined ^a
21	No failures, some fission product-SiC interaction; no amoeba
22-25	To be reported by General Atomic Company

^aThese rods will be examined by the Irradiated Microsphere Gamma Analyzer system.

Table 28. Features of HRB-12 Fuel Rods to Be Related to Metallographic Observations^a

Fuel Rod	Fissile Batch	Fissile Kernel Composition	Con- version (%)	Irradiation Temperature, °C				Special Features
				Average ^b		Peak		
				Rod Surface	Rod Center	Rod Surface	Rod Center	
1	8-HT	UC _{4.60} O _{1.10}	45					ZrC coating instead of SiC
2	9-HT	UC _{4.60} O _{1.10}	45	1100	970	1290	1090	ZrC coating followed by ZrC-doped OLTi
3	10-HT	UC _{4.60} O _{1.10}	45					ZrC coating followed by Zr-C-C coating 25.9 μm thick followed by ZrC-doped OLTi
4	OR-2486-H	UC _{4.58} O _{1.13}	44	1220	1090	1360	1170	SiC deposited at 0.90 μm/min
5	OR-2494-H	UC _{4.58} O _{1.13}	44	1260	1070	1400	1190	SiC deposited at 0.52 μm/min
6	OR-2480-H	UC _{4.58} O _{1.13}	44					Biso-coated fissile particle
7	8-HT	UC _{4.60} O _{1.10}	45	1250	1080	1310	1150	See position 1 above, same as rod 1
8	9-HT	UC _{4.60} O _{1.10}	45	1260	1090	1330	1160	See position 2 above, same as rod 2
9	10-HT	UC _{4.60} O _{1.10}	45					See position 3 above, same as rod 3
10	OR-2493-H	UC _{4.60} O _{1.10}	45					SiC deposited at 0.21 μm/min
11	OR-2497-H	UC _{4.58} O _{1.13}	44					SiC deposited at 0.24 μm/min
12 ^a				1320	1120	1450	1180	
13 ^a				1320	1110	1430	1180	
16	OR-2458-H	UC _{4.83} O _{1.09}	46					SiC deposited at 0.40 μm/min
17	OR-2486-H	UC _{4.58} O _{1.13}	44					SiC deposited at 0.90 μm/min
18	OR-2497-H	UC _{4.58} O _{1.13}	44	1230	1040	1300	1080	SiC deposited at 0.24 μm/min
19	OR-2320-H	UC _{5.12} O _{1.54}	23					Low kernel conversion
20	OR-2493-H	UC _{4.60} O _{1.10}	45					SiC deposited at 0.21 μm/min
21	OR-2320-H	UC _{5.12} O _{1.54}	23	1220	1030	1310	1080	Low kernel conversion

^aRods 8-11 and 22-25 were prepared by GA from its fissile batch GA 6151-17-020 and a thermosetting matrix.^bTime averaged from plots shown in Fig. 9.

Table 29. Summary of Capsule HRB-12 Metallographic Results

Fuel Rods	Metallographic Observations
1	3 failed fissile particles; some ZrC layer corrosion
2	9 failed fissile particles out of 20 in plane of polish
3	All fissile particles in plane of polish had failed
4-5	No fissile failures; some fission product-SiC interaction
6-11	Not examined ^a
12-15	To be reported by General Atomic Company
16-17	Not examined ^a
18	No failures; little fission product-SiC interaction
19	Not examined ^a
20	No failures; little fission product-SiC interaction
21	No failures; significant fission product-SiC interaction, probably due to chlorine in kernel
22-25	To be reported by General Atomic Company

^aThese rods will be examined by the Irradiated Microsphere Gamma Analyzer system.

Electron Microprobe Examination

Limited electron microprobe work was done to investigate specific areas observed during the metallographic examination of the HRB-12 rods. Sufficient electron microprobe work had been done with previous experiments^{1-3,10,15,16} to predict the fission product behavior in the remainder of the HRB-11 and -12 rods from the results of the metallographic examinations.

Particles from fuel rod HRB-12-3 were examined with the microprobe because they were the best performing fissile particles of those containing ZrC coatings in place of SiC. The microprobe work was done to determine the influence of the ZrC coating on fission product behavior within the particle. In addition, particles from rods HRB-12-4 and HRB-12-5 were examined with the microprobe. The SiC coating deposition rates in these rods were 0.90 and 0.52 $\mu\text{m}/\text{min}$, respectively. These examinations were to determine the influence of SiC coating rate on fission product retention, and fission product interactions with SiC.

The particle examined from fuel rod HRB-12-3 is shown in Fig. 40. Of greatest interest was the behavior of high-yield, rare earth fission products (i.e., Nd, Ce, Pr, and La). An earlier irradiation test,² using identical UC_2 kernels in SiC- and ZrC-coated particles, showed SiC corrosion by rare earths, whereas no ZrC corrosion was observed under similar conditions. These results led to the speculation that the rare earths were able to diffuse through the ZrC. Figure 48 is the microprobe display for the particle shown in Fig. 40. It shows the distributions of uranium and the rare earth fission products in this ZrC-coated particle. As shown, the rare earths are associated with the uranium-bearing kernel phases and are also in the densified buffer layer. These results are identical to other electron microprobe studies^{10,16} on WAR-derived particles with comparable oxygen contents. No rare earth accumulations were

Y-160657

Fig. 48. X-Ray Displays from Fissile Particle from Rod HRB-12-3 (same rod shown in Fig. 40) (a) Backscattered electron image. (b) Nd L α . (c) Ce L α . (d) U M β . (e) Pr L α . (f) La L α .

observed at the ZrC coating inner surface. Chlorine was also detected in the particle with the rare earth concentrations, but the count rate was too low to obtain an acceptable x-ray display.

Figure 49 shows the Zr, Cs, and Xe distributions within the particle. The graded ZrC-C outer coating is clearly visible. The cesium and xenon are located in the densified buffer layer and inner LTI coating. These results indicate that the particle remained intact during irradiation. However, since the x-ray displays are only qualitative, it is not conclusive as to a small rare earth loss through the ZrC, since most of the rare earths were retained in the kernel. Results from IMCA analysis comparing these particles with SiC-coated particles should quantitatively determine the rare earth behavior in the ZrC-coated particle. This will be done by observing the behavior of ^{144}Ce and ^{154}Eu . No definitive indication of the rare earth behavior was seen in the gamma scans of the empty graphite sleeve.

Examination of the SiC-fission product interactions in the particles from rods HRB-12-4 and -5 showed palladium (major constituent) and the rare earths in the corrosion areas. Cesium in very small concentrations was also observed. These results are summarized in the line scans in Fig. 50 and were the first indication that palladium was a problem with HEU (high-enriched uranium) fuel particles.

Considering that the particles from rod HRB-12-18 (SiC coated at $0.2 \mu\text{m}/\text{min}$) showed very little SiC corrosion, it might be very easy to conclude that the palladium and rare earth corrosions depend on the SiC deposition rate. However, other irradiation test results^{15,17} (with LEU - low-enriched uranium - fuels) have shown severe corrosion by palladium on SiC with deposition rates of 0.23 and $0.25 \mu\text{m}/\text{min}$, with temperature as the predominant factor in the corrosion rate. Thus, other properties of the SiC were responsible for the different SiC-fission product interactions observed. An extensive study is now examining SiC properties and fission product interactions.

Y-160656

Fig. 49. X-Ray Displays from Fissile Particle from Rod HRB-12-3 (same rod shown in Fig. 40). (a) Backscattered electron image. (b) Zr La. (c) Cs La. (d) Xe La.

(a)

(b)

Fig. 50. X-Ray Line Scans of Fissile Particles from HRB-12 Showing Concentration Profiles of Si, Pd, Nd, and Cs Across the SiC Layer. (a) Particle 1300 μ m from the outer edge of rod 4, operated at an average temperature of 1155°C and average temperature gradient of 410°C/cm. (b) Particle from rod 5 shown in Fig. 43.

DISCUSSION

The results of the HRB-11 and -12 experiments are discussed below in terms of the seven experimental objectives:

Objective 1 was to supplement the data from the HRB-9 and -10 experiments relative to the effects of initial kernel oxygen-to-uranium ratio (O/U) on WAR fuel performance. The HRB-11 and -12 experiments confirmed the conclusion reached from the HRB-9 and -10 data; that is, that the capability of the kernel to retain rare earth fission products decreases with increasing level of conversion from oxide to carbide. Particles with conversion levels ranging from 12 to 77% were irradiated in Capsule HRB-11. The specimens containing the 12 and the 77%-converted fissile fuel were not examined metallographically but will be examined with the IMGA system. These fissile batches were also irradiated in the OF-2 Capsule¹⁰ and showed performance trends similar to those observed³ in the HRB-9 and -10 experiment relative to initial O/U and fission product retention. The HRB-11 specimens examined metallographically contained WAR-derived fissile particles ranging in level of conversion from 18 to 69%. From the metallographic and microprobe examinations it has been concluded that the range of conversion level from 15 to 60% results in good fissile particle performance, relative to fission product-SiC interaction. Figure 51 shows particles containing 30, 60, and 70%-converted kernels. A large buildup of fission products at the inner LTI-SiC interface can be seen for the particle containing the 70%-converted kernel. This comparison can be seen better in Fig. 52. Here fission product penetration of the SiC layer of up to 50% of the layer thickness is noted for the 50 and 60%-converted fuels, and a large concentration of fission products at the inner LTI-SiC interface is visible under polarized light. Very little fission product accumulation at this interface was noted in particles with kernel conversion levels below 50%, and little fission product penetration into the SiC. Identification of 15 to 60% conversion as acceptable is a tentative conclusion and must be verified by measurement of actual fission product inventories using the IMGA system.

	(a)	(b)	(c)
Rod	HRB-11-19	HRB-11-1	HRB-11-21
Distance from outer surface, μm	0	1000	1100
Average temperature, $^{\circ}\text{C}$	1150	1070	1220
Average temperature gradient, $^{\circ}\text{C}/\text{cm}$	790	450	580
Hot side of particle	Bottom	Top	Bottom
Kernel conversion, %	30	60	70

Fig. 51. Comparison of Visual Appearance of Particles Containing 30, 60, and 70%-Converted Kernels.

Fig. 52. Polarized Light View of 50, 60, and 70%-Converted Fuel Particles from HRB-11 Showing Fission Product Penetration of the SiC Layer. The hot sides of the particles are to the left. (a) 1600 μm from outer surface of rod 16, average temperature 1250°C, average temperature gradient 540°C/cm, 50% conversion. (b) On outer surface of rod 2, 1000°C, 670°C/cm, 60%. (c) 1100 μm from outer surface of rod 21, 1220°C, 580°C/cm, 70%.

Objective 2 was to obtain performance data on a second resin. All irradiation experience with Weak-Acid Resin (WAR) fuels before HRB-11 and -12 has been on kernels fabricated from Amberlite IRC-72 resin. Typical behavior^{3,10} showed the kernel and buffer layer densifying together while pulling away from the inner LTI layer. Frequently the densified buffer and kernel were shown attached to one side of the particle. With the second resin, Duolite C-464 (tested in HRB-11), densification of the kernel occurred to a greater extent than with the Amberlite resin because of the lower initial kernel density. Figure 53 compares particles containing 15%-converted kernels and irradiated under similar conditions. Another difference between the two resins is that for particles containing Duolite kernels with low conversion levels (below 30%) the inner LTI is shown pulled away from the SiC layer and densified with the kernel and buffer. The tendency for this behavior appears to diminish as the conversion level of the kernel increases, as shown by comparing Figs. 27 (p. 68), 33 (p. 75), and 22 (p. 61). Figure 27 shows the same 15% converted WAR-derived (Duolite resin) particle shown in Fig. 53, but with both bright field and polarized light illumination. The inner LTI layer has pulled away from the SiC layer and densified with the kernel and buffer. In Fig. 33 (30%-converted WAR-derived particle) the inner LTI has separated from the SiC but has not become homogenized with the kernel and buffer as was the case for the 15%-converted fuel. In Fig. 22 (60%-converted WAR-derived particle) the inner LTI has not separated from the SiC. The appearance of this particle is typical of particles fabricated from Amberlite resin. The difference in behavior under irradiation of the two resins is not expected to influence overall fuel performance. But this is a preliminary conclusion that must be verified with IMGA analysis to determine the relative abilities of the particles to retain fission products.

Objective 3 was to determine whether the minimum thickness buffer layer currently specified in the Fuel Product Specification for fission fragment recoil shielding can be reduced in WAR fuels obtained from the porous Duolite resin. To achieve this objective identical kernels were coated with nominally 0, 25, and 50 μm buffer thickness. All three performed well. The kernels were nominally 46%-converted for each case.

Fig. 53. Comparison of Irradiation Shrinkage of 15%-Converted Kernels Made with Duolite C-464 and Amberlite IRC-72 Resins. Greater shrinkage is noted with the Duolite resin (left) because of its lower starting density. The particle on the left is from rod HRB-11-7, was located 800 μm from the outside of the rod, and operated at an average temperature of 1200°C and an average temperature gradient of 550°C/cm. The hot side of the particle was on the top. The particle on the right (Amberlite resin) is from the outside of rod OF-2-A-1-3. The hot side of the rod was on the right.

An example particle with no buffer layer is shown in Fig. 24 (p. 64). Some "thinning" of the inner LFI layer is evident in the polarized light view, but this does not seem to influence performance. Examples of the half-thickness buffer and full-thickness buffer particles are shown in Fig. 54. The preliminary conclusion drawn from this comparison is that buffer thickness design for WAR fissile fuels allows a great deal of latitude. This is important because thinner buffers enable higher heavy metal loadings in the fuel rods. Statistical determination of any performance differences must await IMGA results.

Objective 4 was to test the influence of SiC coating deposition rate on fission product retention. Metallographic results indicate greater fission product penetration of the SiC layer associated with higher deposition rates for the SiC. Rates of 0.21, 0.24, 0.52 and 0.90 $\mu\text{m}/\text{min}$ were used in fabricating fissile batches associated with this objective. The low-deposition-rate coatings (0.21 and 0.24 $\mu\text{m}/\text{min}$) showed very little fission product penetration. The higher deposition rate coatings showed greater penetration, up to 60% of the coating thickness. A comparison is shown in Fig. 55. Note the increasing fission product penetration of the SiC layer with increasing SiC coating rate. This is best shown in the polarized light portion of the figure.

Objective 5 was to test fuel produced in the 0.13-m coating furnace with a fritted gas distributor and compare the performance of this fuel with the fuel coated with a conical gas distributor. This objective has not yet been completed for the fuel irradiated in HRB-11 and -12. No metallography or microprobe work was done on the fuel fabricated in the 0.13-m coater because only one of each type specimen was included in the experiment, and these were reserved for IMGA analysis. However, as noted earlier, the batches of fissile particles fabricated in the 0.13-m coater were included also in the OF-2 capsule. In OF-2 the fuel fabricated with the fritted gas distributor performed significantly better than the fuel fabricated with the conical distributor. The irradiation conditions in the HRB-11 and -12 capsules were about 30% greater than in the OF-2 capsule, so it will be interesting to see if the trends identified in OF-2 hold for HRB-11. Fissile batches A-601 and A-611 (the frit-coated particles used in HRB-11-5 and -6) will also be irradiated in the Fort St.

Fig. 54. Postirradiation Appearance of HRB-11 Particles with 25- and 50- μ m-Thick Buffer Layers. Both particles contained 46%-converted kernels made with Duolite resin. The irradiation performance appears to be very similar. Hot sides of particles are to the left. Left particle 1600 μ m from outside of rod 6, average temperature 1250°C, average temperature gradient 540°C/cm. Right particle from outside of rod 3, 1050°C, 650°C/cm.

Bright Field

Polarized Light

R-74349

Particle 1.3 mm from outside of rod 4, coated at 0.9 $\mu\text{m}/\text{min}$ Particle from center of rod 5, coated at 0.5 $\mu\text{m}/\text{min}$ Particle 2.6 mm from outside of rod 18, coated at 0.2 $\mu\text{m}/\text{min}$

Top: Average temperature 1165°C, gradient 355°C/cm, hot side toward bottom

Middle: 1260°C, 0, no hot side

Bottom: 1155°C, 410°C/cm, hot side toward bottom

Fig. 55. Postirradiation Appearance of SiC Layers Deposited at Different Rates. Particles from HRB-12. Deposition at rates above 0.5 $\mu\text{m}/\text{min}$ increased susceptibility to fission product corrosion.

Vrain Test Element Program under real-time HTGR irradiation conditions. Therefore, the performance of the same batches of fissile particles can be studied under three different burnup-to-fast-fluence ratios.

Objective 6 was to test fuel fabricated by General Atomic Company using thermosetting matrix materials. The GA fuel was examined at the GA hot cells in San Diego, California, and the results of those examinations will be reported separately.

Objective 7 was to test fuel fabricated by Los Alamos Scientific Laboratory using ZrC coatings in place of SiC in the Triso particle. Coated particles from LASL had been irradiated in a number of capsules at ORNL over the past several years.¹⁸⁻²⁰ In addition to the LASL particles tested, Triso-coated particles with ZrC instead of SiC, fabricated by General Atomic Company, were irradiated² in Capsules HRB-7 and -8. The performance of ZrC coatings was unclear until the HRB-7 and -8 experiment, because no definitive technique was available to measure the capability of the ZrC coatings to retain fission products. In several of the experiments (HT-28, -29, -31, and OF-2) the ZrC coatings were used in particles containing inert kernels. Although the coatings performed well in these experiments relative to resisting damage from neutron exposure, nothing could be learned about fission product retention. In HRB-7 and -8 the coatings looked good under metallographic examination, although there was a "peppery" appearance, which was attributed to chemically induced porosity due to residual chlorine from the coating run. Microprobe analysis of the HRB-7 and -8 particles showed rare earth fission products on the outside of the ZrC coating, but all the cesium was retained inside the ZrC. Further, the inner LTI coating was not graphitized by fission products in the HRB-7 and -8 particles containing ZrC coatings. Fissile particles containing dense UC₂ kernels coated with SiC show severe graphitization of the inner LTI in regions associated with rare-earth fission product accumulation at the inner-SiC interface. In HRB-12 the ZrC coatings performed poorly. There was evidence of higher fission product activity in the upper portion of the sleeve where the fuel rods containing ZrC-coated fissile particles were located. In addition, each of these rods contained a number of failed ZrC-coated fissile particles. Since no failed SiC-coated fissile particles were observed during

metallographic examination, the performance of the ZrC-coated particles appears to be poor by comparison. Examination by IMGA to determine relative fission product retentive capabilities of both SiC- and ZrC-coated fissile particles will be performed soon. The results of these examinations should be very valuable in assessing the future potential for ZrC coatings.

Metallographic examination of rods HRB-12-1 and -2 revealed that the ZrC-coated fissile particles appeared to have failed by pressure vessel rupture. Perhaps the ZrC coatings were underdesigned or the strength was low. Also, the outer LTI coatings failed from fast-neutron-induced damage, which would reduce the combined strength of the multiple coatings. Of the three types of ZrC-coated particles used in HRB-12, the type irradiated in rods HRB-12-3 and -9 (same fissile batch) appeared to have the highest failure rate, according to stereo examination of those irradiated rods. This batch had the SiC layer replaced with ZrC followed by ZrC-C, and the outer layer was ZrC-doped PyC. Finally, there was no evidence of palladium attack on any of the ZrC layers.

CONCLUSIONS

The conclusions reached in the HRB-11 and -12 experiments are listed below:

Fissile fuel particles that contain WAR-derived kernels with initial O/U values between 1.0 and 1.7 give acceptable performance to full burnup for HEU fuel. Fuel particles with initial O/U below 1.0 show excessive chemical interaction between rare earth fission products and the SiC layer. This conclusion has been reached on the basis of metallographic and microprobe examination. Examination of these particles with the IMGA system will provide additional information on fission product retention as influenced by initial kernel composition. An O/U value of 1.0 corresponds to 50% conversion from oxide to carbide; O/U of 1.7 corresponds to 15% conversion.

Some difference noted between the appearance of irradiated fissile particles fabricated from Duolite resin compared with particles fabricated from Amberlite. Greater kernel shrinkage was observed with the Duolite

resin, and at lower conversion levels the inner LTI layer was also observed to pull away from the SiC layer in particles fabricated from the Duolite resin. This difference in appearance is not expected to influence fission product retention, but more information on this will be provided by IMGA examination.

Thinner buffer layers than called for in the current HEU fuel product specification (40 μm) appear to be adequate for the Triso-coated WAR particle. Particles of buffer thickness 40, 25, and 0 μm were tested in HRB-11 and -12. Aside from a slight thinning of the inner LTI layer with no buffer, no differences in performance were noted. Examination by IMGA will provide additional information on fission product retention.

Fission product attack of the SiC layer appears to increase with increasing SiC layer deposition rate for Triso-coated WAR particles. The lowest SiC corrosion rates in HRB-11 and -12 were observed in the particles with lowest SiC deposition rate. However, other capsule experiments used SiC deposition rates lower than anything used in HRB-11 and -12, and high SiC attack rates were observed. Therefore, this conclusion needs to be weighed carefully.

The ZrC coatings produced by LASL were not effective in retaining fission products. It is not clear whether this is due to the high failure rate noted in the metallographic examination, diffusion of fission products through the ZrC layer, or both. Examination by IMGA of intact particles will provide additional information.

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APPENDIX A

Thermal Analysis

The thermal analysis of Capsules HRB-11 and -12 was done with the ECNTRK code.¹ The procedures used were identical to those used with the last four HRB Capsules (see Appendix A in Refs. 2 and 3). As before, the thermal analysis of HRB-11 and -12 relied heavily upon the readings of eight Chromel vs Alumel (C/A) thermocouples located in the graphite sleeve. The centerline thermocouples included in these capsules did not produce useful information, and the data collected by using these thermocouples were not considered in the thermal analysis. The descriptions of the centerline thermocouples and their performance are given in Appendix B. The locations of the eight C/A thermocouples were verified by x radiographs of the assembled capsules (see Fig. 2, p. 7, in text).

Temperature control in the HRB capsules is maintained by varying the mixture of helium and neon in the sweep gas, which passes between the capsule wall and the graphite sleeve and between the graphite sleeve and the fuel rods. Three parameters are used in the calculation of the fuel operating temperatures. These are the graphite sleeve midwall temperature (measured with C/A thermocouples), the fuel rod linear heat rates, and the sweep gas composition. If any two of these parameters are known, the third can be calculated by using the ECNTRK code. The graphite midwall temperatures are measured, and the sweep gas composition is switched to pure helium for short periods of time throughout each 23-d HFIR cycle. By using this technique, a curve of fuel rod heat rate vs time during each cycle can be drawn (see Figs. 6 and 7, pp. 29 and 30, in the body of this report). Then, by using the curves of fuel rod heat rate vs time and the known graphite midwall temperatures the composition of the sweep gas can be calculated for each day during each 23-d HFIR cycle. Now, knowing all three parameters we can calculate the fuel rod operating temperatures. The fuel rod temperatures were presented in Figs. 8 and 9 (pp. 31 and 32) in the body of this report.

Additional data needed for the temperature calculations include the dimensional changes in the fuel rods and in the graphite sleeve as functions of time during the capsule irradiation. The graphite sleeve data are shown in Figs. A1 and A2. The swelling shown was assumed to occur linearly with time during the irradiation.

Poor performance of the centerline thermocouples included in these capsules precluded checking the accuracy of the temperature calculations. The precision of the calculation can be checked roughly, though, by comparing the calculated sweep gas compositions for each fuel rod considered in the thermal analysis. The sweep gas composition is calculated from the measured graphite midwall temperature and the curve of fission heat rate vs time. This calculation is made for each fuel rod located adjacent to a C/A thermocouple in the graphite sleeve. Since the sweep gas composition is constant throughout the capsule, the calculated plots should agree

ORNL-DWG 79-8850

Fig. A1. Dimensional Change Data from HRB-11 Graphite Sleeve. To convert, 1 in. = 25.4 mm.

Fig. A2. Dimensional Change Data from HRB-12 Graphite Sleeve. To convert, 1 in. = 25.4 mm.

well. These plots are shown in Figs. A3 and A4. As can be seen, the agreement is good, giving us confidence in the shape of the heat rate vs time plots shown in Figs. 6 and 7 (pp. 29 and 30). This indicates that any errors in the calculated fuel temperatures are due only to uncertainties in the thermal conductivity of the fuel rods.

The following problems have been identified for the thermal analysis of these capsules:

1. At the beginning of cycle 5 in HRB-11 there was a problem with the recording of temperatures from thermocouple 3 (between fuel rods 7 and 8).
 2. In the middle of cycle 6 for all HRB-11 rods there was an error associated with recording of the time for given thermocouple readings.
 3. For HRB-12 data were lost at the beginning of cycle 1 because of a failure of the instrumentation during that period.
- None of these problems are of serious consequence.

Fig. A3. Calculation of Sweep Gas Composition vs Time for Capsule HRB-11, Based on Thermal

B-11, Based on Thermal Analysis of (a) Rod 2, (b) Rod 4, (c) Rod 5, (d) Rod 7, (e) Rod 8, (f) Rod 12, (g)

ORNL-DWG 80-8074

4, (c) Rod 5, (d) Rod 7, (e) Rod 8, (f) Rod 12, (g) Rod 13, (h) Rod 18, and (i) Rod 21.

Fig. A4. Calculation of Sweep Gas Composition vs Time for Capsule HRB-12, Based on Thermal Analysis

on Thermal Analysis of (a) Rod 2, (b) Rod 4, (c) Rod 5, (d) Rod 7, (e) Rod 8, (f) Rod 12, (g) Rod 13, (h) 1

(b) Rod 4, (c) Rod 5, (d) Rod 7, (e) Rod 8, (f) Rod 12, (g) Rod 13, (h) Rod 18, and (i) Rod 21.

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APPENDIX B

Capsule Centerline Thermometry

Description

The HRB-11 capsule contained an Al_2O_3 -insulated Pt-5% Mo vs Pt-0.1% Mo thermocouple, which was enclosed within a 1.6-mm-OD platinum sheath and wrapped in a 60- μm -thick rhenium foil.^{1,2} The 1.5-m-long thermocouple was connected to a stainless-steel-sheathed pair of Chromel vs Alumel thermocouples. These were used for extension wires for measuring the reference junction temperature of the platinum-molybdenum and its loop resistance.

The HRB-12 capsule contained a dual element 18-rhenium resistor Johnson Noise Power Thermometer (JNT), insulated with BeO and enclosed in a 3.33-mm-OD ZrC-coated rhenium sheath. The sensor design, shown in Fig. B1, was to permit measurement of noise voltage on one resistor simultaneously with noise current on the other, reducing the signal acquisition time from 40 to 10 s and providing sensor redundancy when operated in the commutating mode.

Each of the centerline thermometers was placed with its junction at the interface between fuel rods 7 and 8. A schematic view of the sensor placement is shown in Fig. 1, p. 5, in the text. The x radiographs of the capsules (Fig. 2, p. 7, in text), show the actual sheathed thermometers in place inside the annular fuel rods. These are the actual positions during irradiation.

Performance

The platinum-molybdenum thermocouple in HRB-11 was irradiated for 6559 h at an approximate temperature of 1300°C [see Fig. 8(d) and (e), p. 31, in text]. It accumulated a thermal neutron fluence of 3.3×10^{26} n/m² and a fast fluence (>29 fJ) of 9.1×10^{25} n/m². The thermocouple exhibited progressive degradation of loop resistance and indicated temperature. At the end of the irradiation the temperature readings were about 200°C low (compared with calculated temperatures). In-pool calibration tests conducted after 6000 h of irradiation showed the

Fig. B1. Dual-Sensor Johnson Noise Power Thermometer for Capsule HRB-12. Dimensions are in inches; multiply by 0.0254 to convert to meters.

platinum-molybdenum thermocouple to be sensitive to temperature gradient and predicted errors of as much as -245°C at a true temperature of 100°C .

The dual-element JNT used in HRB-12 was irradiated for 6602 h in a temperature range from 1250 to 1300°C [see Fig. 9(d) and (e) p. 32 of text]. It accumulated a thermal neutron fluence of $3.3 \times 10^{26} \text{ n/m}^2$ and a fast fluence ($>20 \text{ fJ}$) of $9.2 \times 10^{25} \text{ n/m}^2$. At the beginning of irradiation the JNT indicated 1145°C compared with a temperature of 1170°C indicated by the platinum-molybdenum thermocouple in the nearly identical HRB-11 capsule. After 4 d irradiation the JNT indicated temperatures 100 to 200°C higher than the platinum-molybdenum thermocouple had indicated in HRB-11. The temperature difference then became progressively higher and the indicated temperatures unstable. During reactor shutdown periods after the first HFIR irradiation cycle, the JNT-indicated temperature was observed to be influenced by the main water pump operation. The thermocouple showed a drop from 305 to 105°C when the pump was turned off, and then increased 200°C when the pump was again turned on. This behavior was examined by vibrating a similar sensor at 60 to 80 Hz with a $0.25g$ acceleration. This simulation produced an increased electrical noise (at 80 Hz) corresponding to a 50% increase in absolute temperature while the system was actually at room temperature. This microphonic behavior was found in other sensors with loosely fitting, hard-fired insulators. Both rhenium resistors failed (open circuit) after 3780 h of irradiation.

Postirradiation Examination

The rhenium-foil-wrapped platinum sheath of the HRB-11 thermocouple assembly was severely affected during the 1300°C irradiation. Coated particles had reacted with and stuck to the foil, and the foil had alloyed with the platinum sheath where the two touched. The reaction between the particles and the thermocouple assembly could possibly account for the increase in fission-gas release rates during the late stages of the irradiation. A portion of the thermocouple is shown in Fig. B2. Melting of the sheath was probably caused by the transmutation of rhenium to osmium (estimated to be about 80%) and the formation of a Re-Os-Pt ternary compound.

Fig. B2. Portion of Rhenium-Foil-Wrapped Platinum Central Thermocouple Assembly from Capsule HRB-11. The foil had reacted with coated particles.

Postirradiation examination of the HRB-12 capsule showed the ZrC-coated rhenium sheath of the JNT to have survived the 6602-h irradiation (at 1350°C) without visible degradation. The sheath had, however, become brittle during irradiation and was recovered in three sections during capsule disassembly. One portion of the sheath about 100 mm from the closed end contained two small longitudinal cracks. Portions of the 80- μ m-diam rhenium wire resistor coils were still attached to the 0.4-mm-diam lead wires; thus, the open circuit failures of the resistors did not occur at the welds.

Two fuel rods, 4 and 9, were stuck on the rhenium sheath of the HRB-12 thermocouple. After removal of the two fuel rods the dimensions of the sheath were measured in two places corresponding to the locations of rods 4 and 9. The outer diameter of the sheath was 3.212 to 3.271 mm near the tip (fuel rod 9 location) and 3.119 mm at 100 mm from the tip (fuel rod 4 location), neither significantly different from the preirradiation measurements of 3.277 mm maximum outer diameter. Fuel rods 4 and 9

inner diameters were checked with ground pins 3.327 and 3.378 mm in diameter. Fuel rod 4 allowed the 3.378-mm-diam pin to pass through its central hole; fuel rod 9 did not but would pass a 3.327-mm-diam pin. Preirradiation test showed all rods passing 3.380-mm-diam pins. Clearly, the fuel rods shrank about 3% as shown by these tests; therefore, the inner diameter was reduced to very nearly the maximum diameter of the sheath.

A transverse section through the ZrC-coated rhenium sheath and BeO insulator was taken about 30 mm from the tip of the assembly and examined metallographically. Examination of the section showed that, although the ZrC coating remained firmly attached to the rhenium sheath, both the coating and sheath contained numerous fine cracks (see Fig. B3). The radial cracks in the ZrC were indicative of a brittle material. The cracks in the rhenium sheath resulted in grain boundary separation, which was caused by the collection of bubbles on grain interfaces. The rhenium sheath was large grained with single grains spanning the entire wall thickness. The cracks in the ZrC coating probably occurred as a result of the grain boundary separation of the sheath. At present the source of bubbles is not known, but similar results were noted³ during the examination of the rhenium ultrasonic thermometers in HRB-5 and -6.

No evidence of incompatibility between any of the materials in the thermometer assembly nor between the assembly and the fuel rods was observed.

References

1. R. L. Shepard et al., "Capsule Thermometry," *HTGR Base Technology Program Prog. Rep. July 1, 1975, through Dec. 31, 1976*, ORNL-5274, pp. 309-26.
2. M. J. Kania et al., "Capsule Thermometry," *HTGR Base Technology Program Annu. Prog. Rep. Dec. 31, 1977*, ORNL-5412, pp. 109-21.
3. R. L. Shepard and B. H. Montgomery, "Thermometry in HRB Capsules," *HTGR Base Technology Program Prog. Rep. Jan. 1, 1974, through June 30, 1975*, ORNL-5108, pp. 418-25.

Fig. B3. Transverse Section Through the ZrC-Coated Rhenium Thermometer Sheath from HRB-12. (a) ZrC, rhenium sheath, and BeO insulator, 100 $\times$. (b) Intergranular separation of the rhenium sheath was the result of accumulation of bubbles along grain boundaries. Swelling of the rhenium caused cracks to develop in the ZrC. 250 $\times$.

APPENDIX C

Gamma Scan Data from Graphite Sleeves and Fuel Rods from Capsules HRB-11 and -12

Gamma spectra from Capsules HRB-11 and -12 are tabulated in this appendix. Annex C1 lists the spectra acquired from the empty sleeve from HRB-11. The spectra were acquired by using a collimator 3.2 mm wide. The first entry in this tabulation is the cell background data. Annex C2 lists the spectra from the HRB-11 fuel rods after they had been removed from the graphite sleeve. These spectra were obtained by using a collimator 0.25 mm wide, which is considerably smaller than the collimator used for the empty sleeve. The smaller collimator was used for the fuel rods because the activity was so much higher than for the sleeve that the detector would have been "flooded" had the same collimator width been used. No direct comparisons between the two sets of data (Annex C1 and Annex C2) can be made, but qualitative interpretations are possible. The scans tabulated in this Appendix were made by placing the graphite sleeve or fuel rods in an aluminum tube and slowly moving the sample past the collimator and simultaneously recording the spectrum. This technique was used to minimize fuel inhomogeneity effects (such as those shown in Fig. 14, p. 45, in the body of this report). Since the spectra are collected by "collecting" gamma signals of varying energies over a period of time, this technique serves to smear the total collection over the entire fuel rod.

Annex C3 lists gamma spectra from the empty graphite sleeve from HRB-12. Annex C4 is the tabulation from the HRB-12 fuel rods. The same comments made earlier for Annexes C1 and C2 apply to C3 and C4. Care must be exercised in comparing the data from HRB-11 and -12 because the HRB-11 spectra were acquired about 26 d after the capsule was discharged from the reactor, while the HRB-12 spectra were acquired about 90 d after discharge.

Definitions for the column headings used in Annexes C1 through C4 are given on the following page:

F. P.	The chemical symbol and isotope number of all emitters in the isotope table that are identified with the peak.
ENERGY (KEV)	The energy (in keV) that corresponds to the peak centroid.
PEAK CHNL	The channel number of the peak centroid (not the channel containing the peak number of counts as the name implies).
CPS	The rate, in counts per second and, at which characteristic gamma rays having the centroid energy are detected via a full energy mechanism.
GAMMA/SEC	This number is simply the CPS corrected for amplifier pulse pileup losses.
ERR (%)	This number is an estimate of the statistical uncertainty (due to the random nature of the radioactive decay process) that should be associated with the measurement of CPS (and therefore with GAMMA/SEC as well). The best interpretation is to assume that there is a 68% probability that the true value of CPS deviates from the listed value by less than the listed error.
BASE WIDTH	The number of histogram channels involved in the calculation of CPS.
MU	The order of the multiplet of which the listed peak is a member. This number includes all local maxima that were detected in the base width even though some of them may not have satisfied the necessary criteria for being listed as a separate peak.
FWHM (KEV)	The peak's Full Width at Half Maximum (in keV). This number is useful for spotting unresolved multiplets, which often have abnormally high FWHMs. If the program cannot calculate the FWHM (which, for example, sometimes occurs for the central peak of a triplet), a zero will be printed in this column.
PK	A sequential number assigned to each peak.

Some additional information is given below to clarify the tabulations of gamma spectra in this Appendix:

1. The symbol "???" under F.P. indicates that a peak was located at the energy listed, but this peak was not in the library of long-lived fission product gamma peaks. Such peaks are due to (1) activation

products from contamination in the graphite (e.g., ^{125}Sb and ^{46}Sc), (2) short-lived fission products not listed in the library (e.g., ^{156}Eu , ^{140}La , and ^{140}Ba), (3) cell background (^{60}Co), and (4) fluorescent x-rays (e.g., Pb).

2. The number at the top of each spectrum listing is the time (24-h system) and day the spectrum was acquired (i.e., 1108.32 is 11:08 AM).

3. The number of peaks listed for the various scans is not constant. The same peak-searching procedure was used in all scans, but the number of peaks varied with the type of scan (sleeve or fuel rod) and on the number of fission products present and their concentration. The concentration of fission products in turn depends upon burnup and the elapsed time since discharge from the reactor.

4. The gamma scans for the empty sleeve of HRB-11 (Annex C1) began with rod 21 and ended with rod 7. Thirteen scan positions were used (see Fig. 13, p. 44, in the body of this report). Sleeve positions adjacent to rods 1-6 and 22-25 were not scanned because of the low gross gamma activity in these regions.

5. Some lines have a fission product listed but no other entries (for example, the ^{155}Eu peak between 88.18 and 93.86 keV on the second page of Annex C1). This means that the peak for this fission product is very close to the peak of the fission product just ahead of it in the listing (^{233}Pa in the example given) and resolution of the two peaks was not possible. Therefore, both peaks that may contribute to the CPS at the particular energy are listed.

6. The identification of more gamma peaks with the scans from HRB-11 (as compared with HRB-12) is attributable to the decay times involved. HRB-11 was examined about 26 days after irradiation, while HRB-12 was examined about 90 days after removal from the reactor. Thus, many of the short-lived isotopes were not detected in HRB-12.

7. With the recent interest in fuel using low-enriched uranium, the behavior of the $^{110\text{m}}\text{Ag}$ fission product is of importance. It was detected in the graphite sleeve with the greatest concentrations in the middle portion of the sleeve for both HRB-11 and HRB-12. These were also the areas of highest heavy metal burnup and irradiation temperature. No $^{110\text{m}}\text{Ag}$ was detected in any of the fuel rod scans; however, this cannot be interpreted

to mean that no ^{110m}Ag was present in the rods. Problems with detection of ^{110m}Ag arise because the very high activity emanating from the fuel rods causes the lower limits of detection to increase relative to the lower limits of detection for the sleeve. In addition, the major peak of ^{110m}Ag occurs at 657 keV and large quantities of ^{137}Cs (major peak at 661 keV) cover it up. Thus, while the retention of ^{110m}Ag in the fuel rods is uncertain, its presence in the graphite sleeve indicates that this fission product is released to an extent that it appears to depend on the fuel burnup and irradiation temperature.

Annex C1. Gamma Spectra Acquired from Empty Sleeve
of Capsule HRB-11

10 -21 -1976 1136.22
HRB-11 CELL BACKGROUND 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	74.26	106.08	2.2325	2.254E+00	23.08	18	2	2.18	1
CE144	81.25	116.07	2.8297	2.857E+00	9.15	14	2	2.44	2
???	84.07	120.10	6.3790	6.441E+00	6.00	14	2	2.69	3
???	163.75	233.93	1.2517	1.263E+00	17.14	6	1	2.29	4
???	207.21	296.02	22.315	2.253E+01	2.33	24	1	5.83	5
SB125	608.52	869.32	.09525	9.617E-02	40.20	6	1	1.79	6
RU103									
CS137	660.74	943.92	.30075	3.036E-01	13.83	7	1	2.14	7
???	1171.77	1673.95	1.9495	1.968E+00	2.20	12	1	2.44	8
???	1330.76	1901.08	2.3678	2.390E+00	1.66	15	1	2.56	9
???	1367.54	1953.62	.01663	1.678E-02	28.00	5	1	1.50	10
???	1406.26	2008.94	.04350	4.392E-02	17.41	6	1	1.99	11
???	1458.80	2084.00	.16475	1.663E-01	7.11	9	1	2.63	12

10 -21 -1976 932.20
HRB-11; EMPTY SLEEVE; POS. 1=ROD 20; 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	74.35	106.21	6.3277	6.584E+00	19.70	7	1	1.65	1
CE144	81.18	115.98	15.787	1.642E+01	7.78	35	5	3.25	2
???	83.39	119.12	19.156	1.993E+01	6.91	35	5	0.00	3
PA233	88.18	125.97	65.296	6.794E+01	4.30	35	5	1.83	4
EUI55									
PA233	93.86	134.09	22.097	2.299E+01	6.31	35	5	1.87	5
PA233	97.69	139.56	32.645	3.397E+01	5.27	35	5	1.80	6
TE125	110.11	157.30	9.2055	9.578E+00	19.72	11	2	1.97	7
PA233									
CE141	144.73	206.76	6.1652	6.415E+00	19.11	7	1	1.78	8
SB125	175.94	251.35	6.7277	7.000E+00	17.96	8	1	1.71	9
???	198.84	284.06	25.707	2.675E+01	7.96	25	2	2.51	10
???	203.31	290.44	50.436	5.248E+01	5.58	25	2	5.50	11
???	272.86	389.79	4.7305	4.922E+00	16.77	7	1	1.61	12
PA233	299.37	427.67	9.0555	9.422E+00	9.54	8	1	1.61	13
PA233	311.18	444.54	60.680	6.314E+01	1.84	10	1	1.94	14
???	328.03	468.62	7.9666	8.289E+00	10.98	8	1	1.77	15
PA233	339.82	485.45	22.102	2.299E+01	4.66	10	1	1.91	16
PA233	415.33	593.33	2.1305	2.216E+00	26.81	6	1	2.16	17
???	476.18	694.54	15.343	1.596E+01	4.84	9	1	1.96	18
???	536.45	766.35	7.2875	7.583E+00	7.68	7	1	1.78	19
CS134	562.27	803.25	9.9032	1.030E+01	6.66	18	2	2.15	20
CS134	568.42	812.03	18.368	1.911E+01	5.22	18	2	2.14	21
???	598.78	855.40	6.9884	7.271E+00	6.32	17	2	2.67	22
CS134	603.88	862.68	113.57	1.181E+02	1.18	17	2	2.06	23
???	645.35	921.92	16.591	1.726E+01	3.71	9	1	1.96	24
AG110M	656.67	938.10	4.5037	4.686E+00	7.87	15	2	2.24	25
CS137	660.74	943.92	35.739	3.718E+01	2.50	15	2	1.97	26
ZR95	722.53	1032.19	16.955	1.764E+01	3.40	10	1	2.37	27

EUI 54									
ZR95	755.62	1079.46	2.3500	2.445E+00	18.62	8	1	1.81	28
EUI 54									
NR95	764.69	1092.41	7.8763	8.195E+00	7.32	11	1	2.34	29
AGI 10M									
CS134	794.82	1135.45	76.408	7.950E+01	1.42	20	2	2.28	30
CS134	800.85	1144.07	8.8918	9.252E+00	4.69	20	2	1.99	31
???	810.67	1158.10	20.574	2.140E+01	3.21	21	3	2.26	32
???	814.83	1164.04	6.6004	6.868E+00	5.94	21	3	2.36	33
???	817.49	1167.84	16.887	1.757E+01	3.50	21	3	2.31	34
???	866.17	1237.38	4.5000	4.682E+00	10.36	10	1	2.93	35
AGI 10M	883.37	1261.96	2.9383	3.057E+00	12.30	15	2	2.44	36
???	888.07	1268.67	6.0769	6.323E+00	8.78	15	2	2.35	37
???	943.35	1347.65	2.4569	2.556E+00	13.72	7	1	2.15	38
???	959.21	1370.30	2.3722	2.468E+00	16.05	9	1	2.34	39
???	1046.80	1495.43	11.600	1.207E+01	3.56	10	1	2.38	40
???	1063.90	1519.85	8.1750	8.506E+00	5.11	11	1	2.16	41
???	1077.62	1539.45	10.063	1.047E+01	4.91	14	1	2.71	42
???	1119.23	1598.90	4.3861	4.564E+00	8.28	11	1	2.17	43
???	1152.31	1646.15	18.609	1.936E+01	2.46	11	1	2.46	44
???	1171.83	1674.04	2.3138	2.407E+00	13.34	10	1	2.53	45
???	1229.20	1756.01	12.641	1.315E+01	3.60	16	2	2.47	46
???	1233.96	1762.81	2.6032	2.708E+00	9.16	16	2	2.17	47
???	1241.00	1772.86	9.3944	9.775E+00	4.29	12	1	2.39	48
EUI 54	1275.87	1822.67	4.4319	4.611E+00	6.20	9	1	2.46	49
???	1330.73	1901.05	3.3152	3.449E+00	7.72	9	1	2.46	50
CS134	1364.26	1948.94	4.2638	4.436E+00	6.46	10	1	3.15	51
???	1594.21	2277.44	13.322	1.386E+01	2.60	12	1	2.71	52
???	1874.53	2677.89	1.4041	1.461E+00	13.00	9	1	2.05	53
???	1934.92	2764.16	2.1750	2.263E+00	9.79	13	1	2.51	54
???	1963.15	2804.50	4.3944	4.572E+00	4.95	12	1	2.90	55
???	2023.89	2891.27	3.3166	3.451E+00	5.64	11	1	2.69	56
???	2094.84	2992.63	3.8277	3.983E+00	4.65	12	1	3.01	57
???	2177.98	3111.39	1.8985	1.975E+00	8.41	21	2	2.91	58
???	2183.65	3119.50	3.5084	3.650E+00	5.44	21	2	2.89	59
???	2200.99	3144.27	2.5935	2.698E+01	20.29	11	2	1.34	60
???	2202.28	3146.11	4.3371	4.513E+01	16.10	11	2	2.95	61
???	2267.41	3239.16	4.8611	5.058E+01	17.19	6	1	1.42	62

10 -21 -1976 948.32
 HRB-11; EMPTY SLEEVE; POS.2=ROD 19; 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	47.89	68.41	4.0597	4.247E+00	19.91	5	1	1.75	1
???	66.07	94.39	6.2000	6.487E+00	17.00	6	1	1.78	2
CE144	79.90	114.15	13.293	1.390E+01	8.96	20	3	1.88	3
???	83.97	119.96	20.809	2.177E+01	6.60	20	3	0.00	4
PA233	88.14	125.92	64.636	6.763E+01	4.08	20	3	1.85	5
EUI 55									
PA233	93.88	134.11	16.128	1.687E+01	9.32	19	3	1.90	6
PA233	97.68	139.54	24.532	2.566E+01	8.30	19	3	1.71	7
TE125	110.34	157.62	14.100	1.475E+01	14.19	12	2	2.11	8
PA233									
CE141	144.73	206.75	9.3611	9.794E+00	12.99	7	1	2.12	9
???	152.68	218.12	4.4583	4.664E+00	24.53	6	1	2.07	10
???	162.44	232.05	7.3083	7.646E+00	14.69	6	1	1.72	11

SB125	176.05	251.50	9.5722	1.001E+01	13.29	8	1	1.79	12
???	203.35	290.50	38.050	3.981E+01	5.77	14	1	4.50	13
???	272.87	389.81	6.5888	6.894E+00	14.55	8	1	2.22	14
PA233	299.41	427.73	12.930	1.352E+01	10.77	13	2	1.89	15
PA233	311.16	444.52	54.150	5.665E+01	2.24	10	1	1.98	16
???	328.00	468.57	16.730	1.750E+01	6.34	9	1	1.93	17
PA233	339.76	485.37	27.184	2.844E+01	3.87	9	1	2.01	18
CS134	474.48	677.83	2.5944	2.714E+00	27.43	8	1	2.25	19
???	486.17	694.53	25.938	2.714E+01	3.72	11	1	1.97	20
???	536.51	766.44	10.979	1.148E+01	6.95	9	1	1.86	21
CS134	562.30	803.28	13.313	1.393E+01	5.92	9	1	1.96	22
CS134	568.43	812.04	23.983	2.509E+01	3.46	9	1	2.04	23
???	598.62	855.17	5.8232	6.093E+00	8.06	17	2	2.24	24
CS134	603.65	862.64	157.74	1.650E+02	0.99	17	2	2.08	25
???	645.37	921.96	16.005	1.674E+01	4.36	10	1	2.08	26
AG110M	656.67	938.09	4.6252	4.839E+00	8.09	15	2	1.88	27
CS137	660.72	943.89	49.102	5.137E+01	2.07	15	2	2.01	28
ZR95	722.48	1032.11	13.963	1.461E+01	4.36	10	1	2.26	29
EUI54									
ZR95	755.61	1079.45	2.5916	2.711E+00	15.81	7	1	1.78	30
EUI54									
NB95	764.51	1092.15	6.0166	6.295E+00	8.09	8	1	2.31	31
AG110M									
CS134	794.70	1135.28	109.58	1.146E+02	1.08	19	2	2.21	32
CS134	800.89	1144.13	12.512	1.309E+01	3.73	19	2	1.95	33
???	810.66	1158.09	19.772	2.068E+01	3.11	20	3	2.20	34
???	814.84	1164.06	9.5326	9.974E+00	4.69	20	3	2.43	35
???	817.42	1167.75	24.100	2.521E+01	2.64	20	3	2.30	36
???	866.17	1237.39	5.4152	5.666E+00	8.31	9	1	2.69	37
AG110M	883.75	1262.49	2.0777	3.073E+00	12.56	14	2	2.15	38
???	888.18	1268.61	5.5534	5.857E+00	9.25	14	2	2.29	39
???	943.10	1347.29	2.1332	2.232E+00	18.20	8	1	2.06	40
???	959.33	1370.47	2.9055	3.040E+00	12.49	6	1	2.23	41
???	1046.66	1495.22	15.168	1.587E+01	3.16	11	1	2.40	42
???	1063.86	1519.80	8.1166	8.492E+00	5.05	10	1	2.33	43
???	1075.24	1536.06	3.3757	3.532E+00	8.53	13	2	2.73	44
???	1077.91	1539.87	7.4298	7.774E+00	5.55	13	2	2.03	45
???	1119.19	1598.84	5.2638	5.507E+00	6.28	9	1	2.24	46
???	1152.26	1646.08	17.219	1.801E+01	2.68	11	1	2.55	47
???	1171.85	1674.08	2.0638	2.159E+00	15.14	9	1	2.35	48
???	1229.18	1755.97	12.186	1.275E+01	3.73	16	2	2.30	49
???	1233.67	1762.39	3.5075	3.670E+00	7.47	16	2	2.53	50
???	1240.99	1772.84	9.3222	9.754E+00	3.87	10	1	2.27	51
EUI54	1275.96	1822.79	3.8097	3.986E+00	7.80	9	1	2.40	52
???	1330.72	1901.03	3.2791	3.431E+00	8.44	9	1	2.96	53
CS134	1364.08	1948.69	4.1111	4.301E+00	7.72	10	1	2.83	54
???	1594.19	2277.42	21.750	2.275E+01	2.13	16	1	2.77	55
???	1874.53	2677.90	1.8222	1.906E+00	9.50	9	1	2.84	56
???	1935.02	2764.32	2.1666	2.267E+00	7.62	8	1	3.10	57
???	1963.19	2804.55	3.6055	3.772E+00	5.66	11	1	2.77	58
???	2023.71	2891.01	3.0388	3.179E+00	6.02	11	1	2.69	59
???	2094.88	2992.68	3.8111	3.937E+00	4.49	12	1	2.98	60
CE144	2183.97	3119.96	1.3444	1.406E+00	18.34	12	1	2.19	61
???	2201.72	3145.31	.64722	6.772E-01	13.02	10	2	1.34	62
???	2266.49	3237.84	.97778	1.023E+00	9.37	12	1	2.47	63

10 -21 -1976 954.04
 HRB-11;EMPTY SLEEVE;POS-3=ROD 18;1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	66.15	94.50	5.4388	5.647E+00	20.92	7	1	1.63	1
PA233	93.85	134.08	15.605	1.620E+01	7.46	13	2	1.77	2
PA233	97.68	139.54	22.453	2.331E+01	6.46	13	2	1.72	3
TE125	110.20	157.42	6.5291	6.779E+00	22.87	9	1	1.89	4
PA233									
CE141	144.69	206.70	6.2805	6.521E+00	16.45	6	1	1.66	5
???	152.66	218.08	5.5486	5.761E+00	21.15	7	1	1.89	6
???	162.53	232.19	6.7166	6.974E+00	19.10	8	1	2.39	7
SB125	176.00	251.43	9.7805	1.015E+01	11.19	7	1	1.71	8
???	203.34	290.48	45.016	4.674E+01	4.64	14	1	4.84	9
???	273.01	390.01	6.3777	6.622E+00	14.13	8	1	1.81	10
PA233	299.32	427.60	7.2458	7.523E+00	13.13	9	1	1.77	11
PA233	311.17	444.52	46.286	4.806E+01	2.39	10	1	1.93	12
???	328.06	468.66	11.409	1.184E+01	8.68	9	1	1.93	13
PA233	339.84	485.49	26.377	2.739E+01	5.56	15	2	1.97	14
CS134	474.54	677.91	3.5666	3.703E+00	16.18	7	1	1.86	15
???	486.29	694.70	18.100	1.879E+01	4.07	9	1	2.14	16
???	536.31	766.16	7.2888	7.568E+00	9.41	9	1	2.09	17
CS134	562.41	803.44	14.014	1.155E+01	4.74	18	2	1.90	18
CS134	568.41	812.01	25.827	2.681E+01	3.75	18	2	2.12	19
CS134	603.87	862.67	153.34	1.592E+02	0.80	12	1	2.08	20
???	645.43	922.04	3.1027	3.221E+00	13.64	7	1	2.75	21
AG110M	656.77	938.24	5.6297	5.845E+00	6.36	16	2	2.24	22
CS137	660.72	943.89	53.686	5.574E+01	1.76	16	2	2.09	23
ZR95	722.75	1032.50	4.6555	4.834E+00	8.63	8	1	2.06	24
EUI54									
ZR95	755.51	1079.30	2.5888	2.688E+00	14.75	8	1	2.31	25
EUI54									
NB95	764.59	1092.27	5.3500	5.555E+00	7.49	8	1	2.12	26
AG110M									
CS134	794.81	1135.44	109.37	1.135E+02	1.00	20	2	2.19	27
CS134	820.90	1144.14	11.763	1.221E+01	3.59	20	2	2.02	28
???	810.71	1158.16	4.2229	4.384E+00	7.14	19	3	1.91	29
???	814.85	1164.07	6.1028	6.337E+00	5.63	19	3	2.31	30
???	817.43	1167.76	22.496	2.335E+01	2.97	19	3	2.30	31
???	866.60	1237.99	2.0527	2.131E+00	13.57	7	1	2.27	32
AG110M	883.51	1262.15	3.1238	3.243E+00	9.43	15	2	2.21	33
???	888.18	1268.84	6.5955	6.848E+00	6.61	15	2	2.02	34
???	924.02	1320.02	1.5819	1.642E+00	15.83	7	1	1.85	35
AG110M	936.37	1337.67	1.3305	1.381E+00	19.30	7	1	2.23	36
???	959.10	1370.15	.89028	9.244E-01	19.97	5	1	1.14	37
CS134	1036.78	1481.12	.88611	9.201E-01	22.24	6	1	1.69	38
???	1046.81	1495.44	15.702	1.630E+01	2.61	11	1	2.35	39
???	1075.41	1536.30	1.8833	1.955E+00	14.15	7	1	2.14	40
???	1119.18	1598.83	4.6138	4.790E+00	6.31	10	1	2.21	41
???	1152.43	1646.33	4.1388	4.297E+00	6.22	9	1	2.72	42
CS134	1166.72	1666.74	1.9856	2.061E+00	11.54	17	2	2.23	43
???	1171.79	1673.99	3.3657	3.494E+00	8.83	17	2	2.46	44
???	1229.19	1755.99	2.7337	2.808E+00	8.72	16	2	2.21	45
???	1233.91	1762.73	3.2496	3.374E+00	8.06	16	2	2.24	46

???	1240.90	1772.72	2.1611	2.244E+00	9.48	8	1	2.34	47
EUI54	1275.99	1822.84	.78889	8.191E-01	21.27	7	1	2.53	48
???	1330.89	1901.28	3.7250	3.867E+00	6.36	10	1	2.72	49
CS134	1363.68	1948.12	2.5652	2.663E+00	7.93	7	1	2.28	50
???	1594.21	2277.44	15.055	1.563E+01	2.31	14	1	2.74	51
???	1874.21	2677.44	.44306	4.600E-01	20.82	11	1	3.27	52
???	1963.44	2804.91	.87361	9.071E-01	11.60	11	1	2.78	53
???	2022.41	2889.16	.27280	2.832E-01	18.76	11	2	1.40	54
???	2024.23	2891.76	.55498	5.762E-01	13.21	11	2	1.98	55
???	2093.76	2991.09	.41212	4.279E-01	14.06	11	2	1.91	56
???	2095.12	2993.02	.44066	4.575E-01	13.58	11	2	2.79	57
???	2178.32	3111.89	.46568	4.835E-01	13.49	22	4	3.69	58
???	2182.64	3118.05	.51757	5.374E-01	12.72	22	4	2.37	59
CE144	2184.02	3120.03	.69730	7.240E-01	10.54	22	4	4.44	60
???	2343.71	3348.16	.15000	1.557E-01	21.28	8	1	1.12	61

10 -21 -1976 959.48
 HRB-11; EMPTY SLEEVE; POS. 8=ROD 17; 1/8 IN. SLIT
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F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	66.24	94.62	6.2347	6.485E+00	18.57	7	1	1.62	1
???	74.21	106.01	4.0000	4.160E+00	27.46	6	1	1.19	2
PA233	93.84	134.06	12.139	1.262E+01	9.83	13	2	1.88	3
PA233	97.74	139.63	17.307	1.800E+01	8.56	13	2	1.78	4
TE125	110.43	157.75	5.6763	5.904E+00	26.80	9	2	2.49	5
PA233									
CE141	144.50	206.43	4.2500	4.420E+00	31.03	8	2	1.38	6
???	152.84	218.34	7.2083	7.498E+00	14.76	6	1	1.29	7
???	162.36	231.95	11.640	1.210E+01	12.31	9	1	2.19	8
SB125	175.92	251.31	9.4541	9.834E+00	11.89	7	1	1.68	9
???	198.23	283.18	10.079	1.048E+01	16.66	16	2	1.42	10
???	202.96	289.94	39.814	4.141E+01	6.26	16	2	4.94	11
???	272.90	389.85	7.1500	7.437E+00	11.78	7	1	1.79	12
PA233	299.38	427.69	6.4208	6.679E+00	12.77	7	1	2.07	13
PA233	311.17	444.53	4.0044	4.300E+01	2.73	10	1	1.88	14
???	328.00	468.57	22.598	2.350E+01	5.34	11	1	1.92	15
PA233	339.86	485.52	27.844	2.896E+01	3.95	10	1	2.06	16
???	431.91	617.01	2.7736	2.885E+00	22.94	7	1	2.04	17
CS134	474.56	677.95	3.0222	3.143E+00	21.87	8	1	1.34	18
???	486.16	694.51	30.222	3.143E+01	2.83	10	1	1.94	19
???	536.43	766.33	13.048	1.357E+01	6.40	11	1	2.06	20
CS134	562.36	803.37	14.433	1.501E+01	4.68	8	1	2.02	21
CS134	568.45	812.08	23.811	2.476E+01	3.51	10	1	2.01	22
CS134	603.87	862.67	163.33	1.699E+02	0.76	12	1	2.04	23
AG110M	606.70	938.14	5.2310	5.441E+00	6.80	15	2	2.00	24
CS137	660.73	943.90	57.403	5.971E+01	1.64	15	2	2.07	25
ZR95	722.97	1032.81	3.1333	3.259E+00	12.25	8	1	2.31	26
EUI54									
???	750.74	1072.48	1.8805	1.956E+00	14.62	5	1	2.01	27
NB95	764.45	1092.07	4.7777	4.969E+00	8.36	8	1	2.51	28

AG110M

CS134	794.80	1135.43	113.16	1.177E+02	0.96	19	2	2.25	29
CS134	800.87	1144.10	12.723	1.323E+01	3.42	19	2	1.91	30
???	810.70	1158.14	2.0385	2.120E+00	12.49	17	3	1.58	31
???	814.85	1164.07	10.967	1.140E+01	3.85	17	3	2.39	32
???	817.44	1167.78	25.482	2.650E+01	2.51	17	3	2.36	33
???	866.60	1238.00	2.8055	2.918E+00	11.42	8	1	2.08	34
AG110M	883.59	1262.28	3.2327	3.362E+00	9.79	15	2	2.18	35
???	888.19	1268.85	5.8700	6.106E+00	7.35	15	2	2.27	36
???	924.05	1320.07	2.8555	2.970E+00	10.34	8	1	1.73	37
CS134	1037.16	1481.65	.86111	8.957E-01	23.62	6	1	1.74	38
???	1046.65	1495.21	15.744	1.637E+01	3.07	14	2	2.37	39
???	1075.33	1536.19	2.6444	2.750E+00	10.33	8	1	2.32	40
???	1119.21	1598.87	5.4388	5.657E+00	5.25	9	1	2.18	41
???	1152.17	1645.95	1.4888	1.548E+00	12.96	6	1	1.96	42
CS134	1166.65	1666.65	1.8740	1.949E+00	12.30	18	2	2.79	43
???	1171.73	1673.90	4.1148	4.280E+00	8.64	18	2	2.16	44
???	1233.95	1762.79	2.8277	2.941E+00	8.94	8	1	2.13	45
???	1330.90	1901.33	3.7527	3.903E+00	7.46	10	1	2.47	46
CS134	1363.43	1947.76	3.0347	3.156E+00	8.13	9	1	2.71	47
???	1594.21	2277.45	26.694	2.776E+01	1.57	15	1	2.73	48
???	2023.89	2891.27	.34444	3.582E-01	17.71	9	1	1.96	49
???	2095.03	2992.90	.45139	4.695E-01	14.16	9	1	2.89	50

10 -21 -1976 1006.41

HRB-111; EMPTY SLEEVE/POS.5=ROD 16;1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	66.08	94.40	10.266	1.092E+01	14.75	8	1	1.68	1
PA233	88.22	126.02	29.227	3.111E+01	6.16	8	1	1.34	2
EUI55									
PA233	93.81	134.01	18.202	1.937E+01	7.98	14	2	1.84	3
PA233	97.63	139.47	25.511	2.715E+01	7.03	14	2	1.78	4
TE125	110.18	157.40	8.4111	8.954E+00	14.82	6	1	1.52	5
PA233									
CE141	144.69	206.69	7.9791	8.494E+00	16.89	7	1	2.01	6
???	152.61	218.01	11.644	1.239E+01	18.50	12	2	1.71	7
???	162.76	232.52	10.472	1.114E+01	14.37	8	1	2.27	8
SB125	175.95	251.36	21.800	2.320E+01	6.73	8	1	1.79	9
???	198.20	283.14	2.7486	2.920E+00	38.20	5	1	0.89	10
???	203.65	290.93	34.445	3.666E+01	6.68	13	1	4.88	11
???	272.94	389.92	14.863	1.582E+01	8.72	9	1	1.85	12
PA233	299.34	427.62	7.2472	7.715E+00	13.96	7	1	1.77	13
???	304.24	434.63	2.6055	2.773E+00	29.18	5	1	1.16	14
PA233	311.12	444.46	51.700	5.503E+01	2.71	10	1	1.96	15
???	328.07	468.68	14.994	1.596E+01	7.70	8	1	2.06	16
PA233	339.74	485.35	53.502	5.695E+01	2.63	10	1	2.01	17
???	363.64	519.49	6.7305	7.165E+00	13.94	7	1	1.82	18
CS134	474.30	677.57	7.1666	7.629E+00	12.42	8	1	2.58	19
???	486.14	694.48	26.508	2.821E+01	3.79	9	1	2.05	20
RU103	496.64	709.48	1.6277	1.732E+00	41.13	6	1	1.92	21
???	536.30	766.15	11.800	1.256E+01	10.01	12	1	2.24	22
CS134	562.28	803.25	26.674	2.839E+01	3.83	21	3	2.04	23
CS134	568.37	811.96	48.256	5.137E+01	3.12	21	3	2.05	24
SB125	598.85	855.50	7.3906	7.867E+00	8.08	21	3	2.03	25
CS134	603.84	862.62	294.10	3.130E+02	0.77	21	3	2.13	26

???	645.37	921.95	15.426	1.642E+01	5.03	9	1	2.04	27
AG110M	657.24	938.92	6.5559	6.979E+00	7.04	15	2	3.27	28
CS137	660.66	943.81	101.97	1.085E+02	1.30	15	2	2.12	29
AG110M	705.99	1008.55	1.6635	1.770E+00	25.21	10	2	1.83	30
???	708.83	1012.62	1.8503	1.969E+00	24.07	10	2	1.55	31
ZR95	722.49	1032.13	16.008	1.704E+01	4.12	9	1	2.12	32
EUI54									
ZR95	755.79	1079.69	2.8638	3.048E+00	20.67	9	1	2.24	33
EUI54									
NB95	764.50	1092.14	5.8138	6.189E+00	8.94	7	1	2.43	34
AG110M									
CS134	794.67	1135.25	208.24	2.216E+02	0.73	19	2	2.23	35
CS134	800.83	1144.04	21.455	2.284E+01	2.72	19	2	2.17	36
???	810.68	1158.11	24.711	2.630E+01	2.88	21	2	2.10	37
???	817.43	1167.76	58.296	6.206E+01	1.89	21	2	2.26	38
???	866.18	1237.40	4.7722	5.080E+00	10.06	8	1	2.39	39
AG110M	883.67	1262.38	4.6081	4.905E+00	10.62	15	2	2.53	40
???	888.10	1268.72	6.3654	6.776E+00	9.14	15	2	2.32	41
???	918.44	1312.06	1.0055	1.070E+00	33.39	6	1	1.45	42
???	924.08	1320.11	1.8083	1.925E+00	19.33	6	1	1.59	43
AG110M	936.28	1337.54	1.4638	1.558E+00	23.18	6	1	1.71	44
CS134	1038.04	1482.91	2.8111	2.992E+00	14.15	9	1	3.58	45
???	1046.62	1495.17	34.634	3.687E+01	1.79	11	1	2.34	46
???	1063.70	1519.57	9.3805	9.986E+00	4.68	10	1	2.30	47
???	1077.05	1538.64	12.309	1.310E+01	4.49	13	1	4.16	48
???	1119.01	1598.58	5.8777	6.257E+00	6.63	10	1	2.57	49
???	1152.25	1646.07	19.501	2.076E+01	2.54	11	1	2.56	50
CS134	1166.43	1666.33	2.6137	2.782E+00	14.57	16	2	2.41	51
???	1171.66	1673.80	2.3639	2.516E+00	15.05	16	2	2.61	52
???	1229.13	1755.90	12.339	1.313E+01	3.94	17	2	2.36	53
???	1233.69	1762.41	7.2719	7.741E+00	5.15	17	2	2.36	54
???	1240.78	1772.54	9.6388	1.026E+01	4.09	10	1	2.37	55
EUI54	1275.93	1822.75	4.1347	4.401E+00	7.80	9	1	2.35	56
???	1330.72	1901.03	3.1347	3.337E+00	9.49	9	1	2.64	57
CS134	1363.87	1948.39	7.1319	7.592E+00	5.24	11	1	2.68	58
???	1594.16	2277.37	20.655	2.198E+01	2.03	12	1	2.61	59
???	1935.13	2764.47	1.7152	1.826E+00	10.77	9	1	2.73	60
???	1963.15	2804.49	4.3333	4.613E+00	5.44	12	1	2.92	61
???	2023.79	2891.13	3.4000	3.619E+00	6.15	12	1	3.33	62
???	2094.83	2992.61	3.8388	4.086E+00	4.74	12	1	3.02	63
???	2177.87	3111.25	2.1675	2.307E+00	7.93	19	2	3.33	64
???	2183.40	3119.14	3.4893	3.714E+00	5.52	19	2	3.24	65
???	2202.09	3145.84	.58001	6.174E-01	15.36	11	2	2.28	66
???	2204.18	3148.83	.28666	3.051E-01	21.98	11	2	1.16	67
???	2266.71	3238.16	1.0277	1.094E+00	9.50	11	1	3.71	68

10 -21 -1976 1012.43
 HRB-11; EMPTY SLEEVE/POS.6=RODIS 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	65.98	94.25	8.0319	9.162E+00	23.86	7	1	1.50	1
???	74.20	106.00	52.729	6.014E+01	4.96	9	1	1.88	2
CE144	79.98	114.25	17.643	2.012E+01	9.50	16	2	1.95	3
PA233	85.51	122.16	94.134	1.073E+02	4.40	16	2	1.90	4
EUI55									
PA233	93.74	133.91	442.71	5.050E+02	0.79	23	3	2.01	5

PA233	97.43	139.19	693.78	7.914E+02	0.67	23	3	2.02	6
PA233	103.00	147.14	36.825	4.200E+01	3.91	23	3	1.81	7
TE125	110.05	157.21	263.61	3.007E+02	1.36	16	2	2.33	8
PA233									
PA233	113.59	162.28	96.042	1.095E+02	2.20	16	2	2.79	9
CE144	132.51	189.31	20.005	2.282E+01	10.88	8	1	2.00	10
CE141	144.34	206.21	243.54	2.778E+02	1.62	15	2	1.62	11
???	152.53	217.90	12.888	1.470E+01	17.50	8	1	2.32	12
???	162.16	231.66	23.901	2.726E+01	10.32	9	1	2.29	13
SB125	175.76	251.09	22.627	2.581E+01	8.94	8	1	1.77	14
???	203.01	290.01	48.795	5.566E+01	7.45	17	1	5.06	15
???	271.85	388.35	31.294	3.569E+01	7.25	12	1	4.42	16
PA233	299.09	427.27	245.69	2.802E+02	1.15	14	2	2.06	17
PA233	310.91	444.16	1362.7	1.554E+03	0.28	15	1	2.03	18
???	327.73	468.19	53.068	6.053E+01	3.16	9	1	2.00	19
PA233	339.52	485.03	197.02	2.247E+02	1.14	12	1	2.03	20
???	363.45	519.22	39.408	4.495E+01	4.27	10	1	2.02	21
PA233	374.42	534.89	21.002	2.395E+01	5.94	7	1	1.84	22
PA233	397.55	567.92	42.047	4.796E+01	3.97	10	1	1.97	23
PA233	414.73	592.47	49.036	5.593E+01	3.38	10	1	2.22	24
???	431.30	616.14	3.1138	3.552E+00	31.77	6	1	1.45	25
CS134	474.18	677.40	4.8722	5.557E+00	16.96	5	1	1.77	26
???	485.93	694.18	84.880	9.682E+01	1.83	10	1	2.16	27
RU103	496.09	708.70	56.258	6.417E+01	2.64	10	1	2.16	28
???	536.23	766.05	34.394	3.923E+01	4.16	10	1	2.08	29
CS134	562.18	803.12	28.775	3.282E+01	4.37	18	2	2.00	30
CS134	568.29	811.84	48.738	5.559E+01	3.58	18	2	2.15	31
CS134	603.57	862.24	311.59	3.554E+02	0.66	13	1	2.20	32
AG110M	656.61	938.01	6.2958	7.181E+00	9.12	15	2	1.71	33
CS137	660.59	943.69	110.78	1.263E+02	1.50	15	2	2.21	34
ZR95	722.98	1032.83	75.577	8.621E+01	1.57	12	1	2.29	35
EUI54									
???	750.76	1072.51	5.2595	5.999E+00	9.86	16	2	2.54	36
ZR95	755.41	1079.16	90.123	1.028E+02	1.60	16	2	2.29	37
EUI54									
NB95	764.48	1092.11	175.19	1.998E+02	0.81	13	1	2.27	38
AG110M									
CS134	794.58	1135.11	222.62	2.539E+02	0.79	20	2	2.27	39
CS134	800.71	1143.87	23.600	2.692E+01	2.81	20	2	2.23	40
???	810.53	1157.89	3.4534	3.939E+00	12.69	19	3	2.26	41
???	814.81	1164.01	31.253	3.565E+01	2.63	19	3	2.82	42
???	816.98	1167.11	55.058	6.280E+01	2.04	19	3	2.88	43
???	866.41	1237.73	6.4000	7.300E+00	8.88	8	1	2.24	44
AG110M	882.95	1261.36	2.0041	2.286E+00	18.95	5	1	1.35	45
???	888.13	1268.75	4.1972	4.787E+00	14.64	9	1	2.22	46
???	918.04	1311.49	1.8333	2.091E+00	27.64	8	1	2.18	47
???	923.76	1319.66	7.1166	8.118E+00	7.18	8	1	2.50	48
???	1046.55	1495.07	37.327	4.258E+01	1.95	12	1	2.52	49
???	1075.27	1536.11	2.9555	3.371E+00	16.96	10	1	2.23	50
???	1118.98	1598.55	5.1000	5.817E+00	9.23	10	1	2.43	51
???	1152.02	1645.74	3.1222	3.561E+00	11.86	8	1	2.98	52
CS134	1166.04	1665.77	2.5666	2.927E+00	11.92	6	1	1.59	53
???	1171.63	1673.75	1.3388	1.527E+00	28.66	8	1	1.63	54
???	1233.80	1762.57	5.1722	5.899E+00	9.63	10	1	2.49	55
???	1330.72	1901.03	2.3333	2.661E+00	13.38	6	1	2.38	56
CS134	1363.30	1947.57	5.4361	5.201E+00	8.55	10	1	3.00	57
???	1594.04	2277.20	71.051	8.104E+01	1.03	17	1	2.80	58
???	1962.93	2804.19	.48056	5.481E-01	20.22	5	1	1.27	59
???	2023.51	2890.73	.30833	3.517E-01	32.96	7	1	2.12	60
???	2095.02	2992.88	.72778	8.301E-01	18.11	12	2	2.78	61
???	2183.46	3119.23	.67222	7.668E-01	16.09	8	1	2.46	62
???	2345.10	3350.14	.46944	5.354E-01	16.21	11	3	1.38	63

10 -21 -1976 1019.30
 HRB-11; EMPTY SLEEVE; POS. ?= ROD ? 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FTHM (KEV)	PK #
???	66.05	94.35	15.202	1.721E+01	12.10	7	1	1.62	1
???	74.20	126.00	36.543	4.138E+01	7.91	11	1	1.94	2
CE144	80.10	114.43	19.112	2.164E+01	9.91	17	2	2.57	3
PA233	85.47	122.10	73.252	8.294E+01	5.47	17	2	1.98	4
EUI55									
PA233	93.76	133.94	255.23	2.890E+02	1.23	23	3	1.96	5
PA233	97.46	139.23	390.35	4.420E+02	1.07	23	3	1.95	6
PA233	103.02	147.18	19.644	2.224E+01	6.47	23	3	1.38	7
TE125	110.05	157.22	157.93	1.788E+02	2.16	16	2	2.30	8
PA233									
PA233	113.51	162.16	54.240	6.142E+01	3.58	16	2	2.74	9
CE144	132.61	189.44	12.222	1.384E+01	24.02	12	2	1.77	10
CE141	144.55	206.50	171.05	1.936E+02	1.59	10	1	1.96	11
???	152.52	217.89	21.426	2.426E+01	8.94	7	1	2.02	12
???	162.25	231.78	24.495	2.773E+01	9.48	9	1	2.25	13
SB125	175.77	251.10	33.500	3.793E+01	5.89	8	1	1.80	14
???	203.29	290.42	43.386	4.912E+01	7.51	15	1	5.23	15
???	272.66	389.51	28.961	3.279E+01	6.81	10	1	2.05	16
PA233	299.11	427.31	141.32	1.600E+02	2.08	15	2	2.08	17
???	304.01	434.31	7.5788	8.582E+00	13.55	15	2	2.01	18
PA233	310.94	444.20	801.91	9.080E+02	0.39	13	1	2.01	19
???	327.80	468.28	46.455	5.260E+01	3.98	10	1	2.01	20
PA233	339.57	485.10	160.46	1.817E+02	1.40	12	1	2.00	21
???	363.47	519.25	39.125	4.430E+01	4.49	10	1	2.06	22
PA233	374.42	534.89	8.7777	9.939E+00	16.27	8	1	2.01	23
PA233	397.57	567.96	21.479	2.432E+01	7.33	9	1	1.93	24
PA233	414.57	592.24	34.730	3.932E+01	4.95	10	1	2.18	25
CS134	474.42	677.75	8.6750	9.823E+00	12.90	7	1	2.32	26
???	485.94	694.21	71.172	8.059E+01	2.21	10	1	2.12	27
RUI03	496.11	708.72	48.588	5.502E+01	3.09	10	1	2.12	28
???	536.22	766.03	26.576	3.009E+01	5.09	9	1	2.04	29
CS134	562.18	803.11	42.633	4.827E+01	3.11	18	2	2.08	30
CS134	568.29	811.85	74.230	8.405E+01	2.51	18	2	2.14	31
CS134	603.58	862.25	460.53	5.214E+02	0.50	13	1	2.19	32
SB125	635.59	907.98	3.7083	4.199E+00	21.66	7	1	2.27	33
???	645.17	921.67	2.3861	2.701E+00	28.80	6	1	1.63	34
AG110M	656.62	938.02	6.3846	7.229E+00	9.54	16	2	2.20	35
CS137	660.59	943.70	169.68	1.921E+02	1.13	16	2	2.22	36
ZR95	722.99	1032.84	57.745	6.538E+01	1.94	11	1	2.21	37
EUI54									
???	750.33	1071.90	3.8421	4.350E+00	13.43	16	2	2.94	38
ZR95	755.44	1079.20	69.935	7.919E+01	2.25	18	2	2.24	39
EUI54									
NB95	764.53	1092.18	128.16	1.451E+02	1.05	13	1	2.25	40
AG110M									
CS134	794.59	1135.12	322.78	3.655E+02	0.62	21	2	2.26	41
CS134	800.72	1143.90	33.600	3.804E+01	2.24	21	2	2.29	42
???	810.67	1158.11	3.6960	4.185E+00	17.14	19	2	2.15	43
???	817.13	1167.32	98.633	1.116E+02	1.66	19	2	2.64	44
???	866.48	1237.83	5.2333	5.926E+00	11.05	8	1	1.96	45
???	888.11	1268.73	4.2611	4.825E+00	14.98	9	1	2.34	46
???	918.25	1311.78	2.3124	2.618E+00	19.95	17	2	1.97	47
???	923.84	1319.77	6.2611	7.089E+00	12.00	17	2	2.33	48
???	1046.52	1495.03	55.654	6.302E+01	2.25	25	3	2.31	49
???	1056.06	1508.66	0.64167	7.266E-01	42.16	5	1	0.87	50
???	1063.49	1519.28	1.1972	1.355E+00	27.70	6	1	2.40	51

???	1075.20	1535.99	4.1000	4.642E+00	10.88	8	1	1.81	52
???	1119.07	1598.68	5.1203	5.784E+00	8.68	9	1	2.25	53
???	1151.93	1645.61	2.9194	3.305E+00	12.09	7	1	1.70	54
CS134	1166.38	1666.25	3.9041	4.420E+00	11.37	9	1	2.46	55
???	1171.71	1673.87	2.1458	2.429E+00	16.24	7	1	2.00	56
???	1229.09	1755.85	1.8739	2.122E+00	16.33	16	2	3.86	57
???	1233.66	1762.37	11.653	1.319E+01	5.54	16	2	2.50	58
???	1240.80	1772.57	1.3861	1.569E+00	20.14	6	1	1.81	59
???	1330.70	1901.00	3.0347	3.436E+00	10.76	7	1	2.20	60
CS134	1363.33	1947.61	7.7944	8.826E+00	6.36	11	1	2.86	61
???	1594.07	2277.25	61.044	6.912E+01	1.11	16	1	2.77	62
???	2094.76	2992.51	.59722	6.762E-01	17.68	10	1	3.26	63
???	2177.79	3111.13	.26389	2.988E-01	33.26	7	1	2.55	64
???	2344.23	3348.90	.30972	3.507E-01	24.07	9	1	2.18	65

10 -21 -1976 1026.37
HRB-11; EMPTY SLEEVE; POS. 8= ROD₁? 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	65.95	94.22	22.994	2.686E+01	9.80	8	1	1.99	1
???	74.18	105.98	40.855	4.773E+01	7.18	28	3	2.05	2
CE144	79.90	114.14	20.613	2.408E+01	10.18	28	3	1.90	3
PA233	85.44	122.06	84.358	9.855E+01	5.99	28	3	1.93	4
EU155									
PA233	93.71	133.87	322.23	3.764E+02	1.31	39	5	2.03	5
PA233	97.38	139.12	525.99	6.145E+02	1.15	39	5	2.00	6
TE125	109.96	157.08	166.26	1.942E+02	1.64	39	5	2.13	7
PA233									
PA233	113.48	162.11	58.033	6.779E+01	2.99	39	5	2.58	8
CE144	132.55	189.36	17.088	1.996E+01	13.25	8	1	1.84	9
CE141	144.44	206.34	204.09	2.384E+02	1.45	10	1	2.03	10
???	152.31	217.58	25.366	2.963E+01	9.20	8	1	1.89	11
???	162.36	231.94	32.100	3.750E+01	9.39	11	2	2.85	12
SB125	175.70	251.01	38.491	4.496E+01	6.76	10	1	1.81	13
???	200.34	286.20	14.441	1.687E+01	15.34	13	2	1.41	14
???	202.36	289.08	26.168	3.057E+01	10.72	13	2	6.40	15
???	272.50	389.28	40.068	4.681E+01	5.93	11	1	2.46	16
PA233	299.03	427.19	172.69	2.017E+02	1.49	11	1	2.07	17
PA233	310.86	444.09	1032.9	1.206E+03	0.37	15	1	2.05	18
???	327.75	468.21	49.250	5.753E+01	4.86	12	1	2.09	19
PA233	339.52	485.02	205.26	2.398E+02	1.25	12	1	2.04	20
???	363.42	519.17	42.205	4.930E+01	4.70	10	1	2.03	21
PA233	374.39	534.84	14.700	1.717E+01	9.91	7	1	2.03	22
PA233	397.51	567.87	31.327	3.659E+01	6.29	10	1	2.25	23
PA233	414.56	592.23	38.669	4.517E+01	4.67	9	1	2.07	24
???	436.47	623.53	3.7236	4.350E+00	27.16	5	1	1.40	25
CS134	474.22	677.45	12.433	1.452E+01	11.41	8	1	2.59	26
???	485.91	694.16	77.608	9.066E+01	2.28	10	1	2.18	27
RU103	495.96	708.52	55.408	6.473E+01	3.08	10	1	2.27	28
???	536.16	765.94	31.475	3.677E+01	4.86	9	1	2.11	29
CS134	562.10	803.00	54.810	6.403E+01	2.83	19	2	2.17	30
CS134	568.26	811.80	98.986	1.156E+02	2.26	19	2	2.15	31
CS134	603.52	862.18	602.75	7.041E+02	0.44	13	1	2.21	32
CS137	660.45	943.50	225.05	2.629E+02	0.91	15	1	2.31	33
ZR95	722.94	1032.78	73.427	8.578E+01	2.00	14	1	2.26	34
EU154									
???	750.37	1071.95	5.5462	6.479E+00	10.71	17	2	1.94	35

ZR95	755.37	1079.10	78.984	9.227E+01	2.18	17	2	2.30	36
EUI54									
NB95	764.45	1092.07	154.38	1.803E+02	0.95	12	1	2.31	37
AG110M									
CS134	794.53	1135.05	428.22	5.302E+02	0.55	21	2	2.29	38
CS134	800.66	1143.81	42.952	5.018E+01	2.04	21	2	2.34	39
???	817.12	1161.31	127.61	1.467E+02	1.23	15	1	2.54	40
???	866.40	1237.71	7.2000	8.411E+00	10.07	9	1	2.31	41
AG110M	883.39	1261.99	4.3357	5.065E+00	15.45	15	2	2.31	42
???	887.78	1268.25	5.3962	6.304E+00	14.11	15	2	2.46	43
???	923.72	1319.60	6.8194	7.967E+00	10.66	10	1	2.34	44
CS134	1037.07	1481.53	3.5500	4.147E+00	14.30	8	1	2.32	45
???	1046.51	1495.01	68.719	8.028E+01	1.41	13	1	2.39	46
???	1077.12	1535.89	4.8000	5.607E+00	10.49	8	1	1.85	47
???	1118.84	1598.34	4.7236	5.518E+00	10.77	9	1	2.57	48
???	1152.07	1645.81	3.1000	3.621E+00	12.73	7	1	2.31	49
CS134	1166.28	1666.11	4.9111	5.737E+00	9.39	8	1	2.07	50
???	1228.59	1755.13	7.0000	8.177E+01	42.11	5	1	1.97	51
???	1233.56	1762.23	12.075	1.410E+01	5.16	11	1	2.26	52
???	1330.57	1900.81	2.6305	3.073E+00	13.59	7	1	2.32	53
CS134	1363.31	1947.59	10.230	1.195E+01	4.95	10	1	2.87	54
???	1593.79	2276.85	67.431	7.877E+01	1.06	15	1	2.79	55
???	2094.49	2992.12	5.5333	6.230E+01	19.38	7	1	1.14	56

10 -21 -1976 1033.57

HRB-11; EMPTY SLEEVE; POS. 9= ROD 11 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	65.93	94.18	24.155	2.696E+01	8.63	9	1	1.83	1
???	74.25	106.07	8.3402	9.308E+00	16.58	5	1	2.26	2
PA233	85.43	122.05	43.655	4.872E+01	4.50	33	5	3.43	3
EUI55									
PA233	88.15	125.93	85.979	9.596E+01	3.39	33	5	2.39	4
EUI55									
PA233	93.77	133.96	67.379	7.520E+01	3.69	33	5	2.01	5
PA233	97.41	139.16	101.36	1.131E+02	3.20	33	5	1.60	6
TE125	110.44	157.78	30.773	3.434E+01	9.53	16	3	2.76	7
PA233									
PA233	113.55	162.22	10.893	1.215E+01	14.71	16	3	1.50	8
CE141	144.73	206.76	31.219	3.484E+01	7.34	10	2	2.28	9
???	152.51	217.86	27.276	3.044E+01	9.23	11	1	1.99	10
???	162.61	232.30	20.718	2.312E+01	10.11	9	1	2.28	11
SB125	175.78	251.12	49.405	5.514E+01	4.50	10	1	2.05	12
???	198.13	283.05	15.552	1.735E+01	13.39	15	2	2.02	13
???	202.58	289.41	28.324	3.161E+01	9.63	15	2	4.01	14
???	227.59	325.12	3.6861	4.114E+00	35.18	6	1	1.91	15
???	272.78	389.69	30.490	3.403E+01	5.69	9	1	1.97	16
PA233	299.25	427.50	26.927	3.005E+01	5.77	8	1	1.97	17
PA233	310.97	444.24	171.59	1.915E+02	1.17	10	1	1.96	18
???	327.81	468.30	19.422	2.167E+01	10.03	11	1	2.01	19
PA233	339.63	485.19	116.45	1.299E+02	1.76	11	1	2.01	20
???	363.55	519.35	21.604	2.411E+01	8.69	11	1	2.10	21
PA233	397.65	568.07	3.8694	4.318E+00	29.40	6	1	2.09	22
PA233	414.59	592.28	10.408	1.161E+01	15.05	9	1	2.43	23
CS134	474.44	677.77	12.472	1.392E+01	10.01	8	1	2.28	24
???	486.02	694.31	34.941	3.899E+01	3.94	9	1	2.13	25
RUI03	496.24	708.91	5.4590	6.082E+00	19.35	7	1	2.18	26

???	536.24	766.05	13.004	1.451E+01	9.95	9	1	2.10	27
CS134	562.20	803.15	51.958	5.799E+01	2.66	19	2	2.13	28
CS134	568.32	811.89	93.893	1.047E+02	2.13	19	2	2.11	29
???	598.55	855.08	11.241	1.254E+01	7.18	18	2	2.27	30
CS134	603.59	862.28	594.01	6.629E+02	0.50	18	2	2.18	31
???	645.26	921.80	23.395	2.611E+01	4.48	9	1	2.19	32
AG110M	656.66	938.09	6.3533	7.091E+00	9.62	15	2	1.88	33
CS137	660.60	943.71	203.38	2.269E+02	0.95	15	2	2.17	34
EUI54	694.44	992.06	6.6500	7.422E+00	11.81	8	1	2.53	35
AG110M	708.62	1012.31	1.9833	2.213E+00	38.73	8	1	2.40	36
ZR95	722.47	1032.09	26.200	2.924E+01	3.76	10	1	2.29	37
EUI54									
ZR95	755.50	1079.28	10.944	1.221E+01	6.96	8	1	2.08	38
EUI54									
NB95	764.50	1092.14	22.911	2.557E+01	4.11	10	1	2.23	39
AG110M									
CS134	794.61	1135.15	419.76	4.685E+02	0.55	22	2	2.25	40
CS134	800.71	1143.87	40.731	4.546E+01	2.03	22	2	2.34	41
???	810.62	1158.03	35.865	4.003E+01	2.51	20	2	2.22	42
???	817.23	1167.47	112.29	1.253E+02	1.37	20	2	2.42	43
???	833.68	1190.97	5.1305	5.726E+00	11.96	7	1	2.35	44
???	865.32	1236.17	6.2125	6.933E+00	9.35	7	1	3.75	45
AG110M	883.49	1262.13	4.4176	4.930E+00	14.87	15	2	2.89	46
???	888.00	1268.57	6.2420	6.966E+00	12.60	15	2	2.65	47
???	923.43	1319.19	3.5583	3.971E+00	14.41	7	1	3.53	48
???	959.18	1370.26	4.2166	4.706E+00	17.82	12	2	2.30	49
CS134	1036.84	1481.20	2.3138	2.582E+00	15.61	5	1	1.19	50
???	1046.57	1495.10	71.105	7.936E+01	1.27	12	1	2.35	51
???	1063.69	1519.56	11.233	1.253E+01	5.57	11	1	2.38	52
???	1075.25	1536.07	6.9753	7.785E+00	6.57	12	2	2.22	53
???	1077.94	1539.91	9.9580	1.111E+01	5.42	12	2	2.09	54
???	1119.01	1598.59	4.8611	5.425E+00	8.90	8	1	2.19	55
???	1152.18	1645.97	27.183	3.033E+01	2.34	11	1	2.45	56
CS134	1166.50	1666.42	6.4453	7.193E+00	9.82	16	2	2.75	57
???	1171.64	1673.77	2.3046	2.572E+00	16.75	16	2	2.79	58
???	1228.96	1755.65	18.138	2.024E+01	3.50	19	2	2.62	59
???	1233.61	1762.30	14.136	1.577E+01	4.00	19	2	2.74	60
???	1240.79	1772.56	14.477	1.615E+01	2.63	11	1	2.51	61
EUI54	1275.68	1822.41	6.4569	7.206E+00	6.16	9	1	2.87	62
CS134	1363.61	1948.02	-12.400	1.383E+01	3.96	11	1	3.10	63
AG110M	1382.91	1975.59	.78889	8.804E-01	25.73	5	1	1.67	64
???	1594.07	2277.25	28.358	3.165E+01	1.88	13	1	2.83	65
???	1874.53	2677.89	1.9888	2.219E+00	9.93	7	1	2.28	66
???	1935.00	2764.29	2.7666	3.087E+00	8.87	10	1	3.37	67
???	1963.16	2804.51	6.1680	6.884E+00	4.37	11	1	2.96	68
???	2023.67	2890.96	4.9083	5.478E+00	5.42	13	1	2.57	69
???	2094.72	2992.46	5.5888	6.237E+00	3.92	12	1	2.81	70
???	2177.98	3111.40	2.7666	3.087E+00	7.57	21	2	3.00	71
???	2183.58	3119.39	4.8833	5.450E+00	5.22	21	2	3.11	72
???	2202.26	3146.08	.69028	7.704E-01	16.07	7	2	1.37	73
???	2264.66	3235.23	.47403	5.290E-01	17.24	10	2	1.46	74
???	2266.83	3238.33	.92596	1.033E+00	11.30	10	2	3.12	75

10 -21 -1976 1044.53
 HRB-11; EMPTY SLEEVE; POS. 10= ROD10 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FVHM (KEV)	PK #
???	66.11	94.44	15.466	1.655E+01	10.26	8	1	1.78	1
???	74.45	106.36	4.7027	5.032E+00	24.70	5	1	1.62	2
CE144	80.53	115.04	13.717	1.468E+01	10.16	20	4	2.13	3
???	83.99	119.98	17.412	1.863E+01	8.89	20	4	0.00	4
PA233	85.46	122.08	24.941	2.669E+01	7.58	20	4	2.59	5
EUI55									
PA233	88.16	125.95	17.117	1.831E+01	8.93	20	4	1.80	6
EUI55									
PA233	93.85	134.08	29.014	3.105E+01	5.31	14	2	1.93	7
PA233	97.64	139.49	41.910	4.485E+01	4.58	14	2	1.89	8
TE125	110.08	157.25	11.455	1.225E+01	14.56	8	1	1.93	9
PA233									
CE141	144.86	206.95	10.180	1.089E+01	12.46	6	1	1.52	10
???	152.61	218.01	15.566	1.665E+01	9.53	7	1	1.71	11
???	163.07	232.95	13.640	1.459E+01	10.56	7	1	2.17	12
SB125	175.82	251.17	31.586	3.380E+01	5.42	9	1	1.74	13
???	202.78	289.69	29.250	3.130E+01	6.72	10	1	4.07	14
???	272.86	389.80	22.748	2.434E+01	6.04	9	1	1.94	15
PA233	299.28	427.55	12.827	1.372E+01	9.41	8	1	1.80	16
PA233	311.12	444.45	81.275	8.697E+01	2.03	11	1	1.96	17
???	328.06	468.66	10.311	1.103E+01	10.51	7	1	1.63	18
PA233	339.82	485.46	72.527	7.761E+01	2.70	14	1	2.02	19
???	363.56	519.38	15.422	1.650E+01	7.40	8	1	2.16	20
CS134	474.41	677.73	7.0388	7.532E+00	13.56	8	1	1.88	21
???	486.19	694.56	16.116	1.724E+01	6.33	9	1	2.27	22
???	536.30	766.15	6.5333	6.991E+00	10.96	6	1	2.14	23
CS134	562.27	803.24	33.218	3.554E+01	3.10	19	2	2.15	24
CS134	568.38	811.97	63.659	6.812E+01	2.42	19	2	2.04	25
CS134	603.74	862.49	386.53	4.136E+02	0.49	12	1	2.15	26
???	645.30	921.86	4.9763	5.325E+00	12.32	7	1	2.24	27
AG110M	656.71	938.16	6.7839	7.259E+00	6.90	15	2	1.57	28
CS137	660.68	943.83	129.51	1.386E+02	1.10	15	2	2.12	29
ZR95	722.69	1032.41	6.8694	7.351E+00	9.06	9	1	2.53	30
EUI54									
ZR95	755.49	1079.28	3.2722	3.501E+00	16.71	8	1	2.10	31
EUI54									
NB95	764.64	1092.34	10.401	1.113E+01	5.88	9	1	2.60	32
AG110M									
CS134	794.65	1135.22	271.82	2.908E+02	0.62	21	2	2.24	33
CS134	800.81	1144.01	28.352	3.034E+01	2.28	21	2	2.25	34
???	810.65	1158.08	6.8634	7.345E+00	6.46	21	2	2.21	35
???	817.42	1167.74	75.524	8.082E+01	1.66	21	2	2.22	36
???	833.68	1190.97	5.8777	6.290E+00	8.90	9	1	2.33	37
AG110M	883.47	1262.10	3.9927	4.272E+00	10.54	15	2	2.16	38
???	888.01	1268.58	6.1377	6.568E+00	8.73	15	2	2.36	39
???	959.18	1370.25	6.1250	6.554E-01	39.85	5	1	1.31	40

CS134	1036.83	1481.19	2.5111	2.687E+00	16.69	11	2	1.43	41
???	1046.61	1495.16	46.409	4.966E+01	1.47	13	1	2.40	42
???	1063.78	1519.68	2.0944	2.241E+00	13.09	7	1	2.39	43
???	1075.30	1536.15	7.6611	8.198E+00	5.69	12	1	2.15	44
???	1119.15	1598.79	5.5722	5.963E+00	6.37	10	1	2.36	45
???	1152.27	1646.10	5.2083	5.573E+00	6.50	10	1	2.23	46
CS134	1166.32	1666.18	4.2804	4.580E+00	8.85	17	2	2.22	47
???	1171.74	1673.92	2.6251	2.809E+00	10.94	17	2	2.33	48
???	1229.23	1756.04	3.4670	3.710E+00	7.70	16	2	2.43	49
???	1233.79	1762.56	9.9718	1.067E+01	4.27	16	2	2.38	50
???	1240.93	1772.76	2.8986	3.102E+00	11.98	13	1	2.28	51
???	1330.66	1900.95	3.4958	3.741E+00	7.15	9	1	2.33	52
CS134	1363.57	1947.96	7.0986	7.596E+00	4.46	11	1	2.71	53
???	1594.14	2277.35	13.306	1.424E+01	2.47	13	1	2.79	54
???	1874.56	2677.95	.56389	6.034E-01	20.32	10	1	3.06	55
???	2022.32	2889.03	.49421	5.288E-01	17.17	15	3	1.78	56
???	2024.45	2892.07	.60718	6.497E-01	15.73	15	3	5.72	57
???	2094.75	2992.50	1.2097	1.294E+00	8.86	11	1	1.77	58
???	2177.86	3111.23	.43889	4.696E-01	23.03	8	1	2.85	59
???	2183.70	3119.57	.77222	8.264E-01	13.67	8	1	3.08	60
???	2201.78	3145.39	.12222	1.307E-01	40.21	5	1	1.24	61

10 -21 -1976 1050.35

HRB-11; EMPTY SLEEVE; POS. 11= ROD 9 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	66.15	94.50	8.2527	8.650E+00	15.21	7	1	1.74	1
???	74.40	106.28	7.7194	8.091E+00	17.70	7	1	1.76	2
CE144	80.46	114.94	5.9421	6.228E+00	22.71	10	2	2.39	3
???	83.66	119.52	5.5772	5.845E+00	23.66	10	2	1.16	4
PA233	93.84	134.06	30.385	3.184E+01	4.88	15	2	1.81	5
PA233	97.71	139.58	41.189	4.317E+01	4.36	15	2	1.80	6
TE125	110.28	157.54	19.388	2.032E+01	10.18	11	2	2.02	7
PA233									
CE141	144.65	206.65	12.827	1.344E+01	11.23	8	1	1.66	8
???	152.55	217.93	10.473	1.097E+01	12.63	7	1	1.99	9
SB125	176.02	251.46	15.338	1.607E+01	8.77	8	1	1.76	10
???	203.28	290.40	32.384	3.394E+01	5.75	11	1	4.68	11
???	272.96	389.94	11.162	1.169E+01	10.09	9	1	1.89	12
PA233	299.29	427.56	15.727	1.648E+01	6.30	8	1	1.88	13
PA233	311.16	444.51	90.869	9.524E+01	1.44	10	1	1.95	14
???	319.30	456.15	3.0152	3.160E+00	21.11	5	1	1.32	15
PA233	339.83	485.47	43.655	4.575E+01	2.79	10	1	2.01	16
???	363.76	519.65	13.781	1.444E+01	7.13	9	1	2.07	17
PA233	397.58	567.97	2.9500	3.092E+00	25.82	7	1	2.17	18
PA233	414.93	592.76	2.9777	3.121E+00	25.70	7	1	1.68	19
CS134	474.57	677.96	3.9666	4.157E+00	14.76	6	1	2.04	20
???	486.13	694.47	7.5694	7.933E+00	11.56	10	1	2.22	21
RU103	496.22	708.97	2.0500	2.148E+00	33.90	8	1	2.15	22
???	536.26	766.08	3.4583	3.624E+00	23.73	10	2	1.42	23
CS134	562.27	803.24	17.930	1.879E+01	4.63	9	1	1.88	24
CS134	568.42	812.03	32.419	3.398E+01	2.88	10	1	1.96	25
CS134	603.85	862.64	203.01	2.127E+02	0.69	12	1	2.09	26
???	645.41	922.02	5.4305	5.692E+00	16.21	15	3	2.73	27
AG110M	656.81	938.30	6.9224	7.255E+00	5.84	16	2	2.25	28
CS137	660.69	943.84	66.155	6.934E+01	1.64	16	2	2.03	29

EUI54	693.80	991.15	.73194	7.671E-01	40.17	5	1	1.03	30
AG110M	705.68	1008.12	1.0847	1.136E+00	27.86	5	1	1.19	31
ZR95	722.78	1032.55	6.6583	6.978E+00	8.13	10	1	2.03	32
EUI54									
ZR95	755.69	1079.56	3.0166	3.161E+00	15.98	9	1	1.87	33
EUI54									
NB95	764.66	1092.37	11.847	1.241E+01	4.21	9	1	2.39	34
AG110M									
CS134	794.70	1135.28	142.94	1.498E+02	0.86	20	2	2.19	35
CS134	800.83	1144.05	15.436	1.617E+01	3.08	20	2	2.17	36
???	810.60	1158.00	5.2737	5.527E+00	6.83	18	2	2.21	37
???	817.45	1167.78	41.890	4.390E+01	2.07	18	2	2.13	38
???	833.71	1191.21	4.3888	4.600E+00	10.45	10	1	2.18	39
AG110M	883.50	1262.14	4.8531	5.086E+00	7.69	15	2	2.03	40
???	888.03	1268.61	6.3509	6.656E+00	6.78	15	2	2.38	41
AG110M	936.27	1337.53	2.0111	2.107E+00	22.54	13	2	2.12	42
???	1046.66	1495.22	24.916	2.611E+01	2.41	12	1	2.35	43
???	1063.94	1519.91	2.1611	2.265E+00	11.07	8	1	2.39	44
???	1075.58	1536.55	3.2666	3.423E+00	8.29	7	1	2.55	45
???	1119.11	1598.73	5.5000	5.764E+00	5.00	9	1	2.54	46
???	1152.24	1646.05	3.5972	3.770E+00	8.21	10	1	2.37	47
CS134	1166.45	1666.35	2.0579	2.157E+00	11.42	17	2	2.54	48
???	1171.72	1673.88	3.9281	4.117E+00	8.17	17	2	2.37	49
???	1229.20	1756.00	3.7355	3.915E+00	6.58	17	2	2.16	50
???	1233.80	1762.56	5.2520	5.504E+00	5.42	17	2	2.79	51
???	1240.76	1772.52	2.4055	2.521E+00	7.94	8	1	2.55	52
EUI54	1276.04	1822.92	.89444	9.375E-01	20.00	8	2	2.12	53
???	1330.69	1940.99	3.4555	3.621E+00	6.68	10	1	2.42	54
CS134	1363.58	1947.98	3.9000	4.087E+00	6.34	11	1	2.67	55
???	1381.36	1973.37	.31657	3.318E-01	22.36	7	2	1.33	56
AG110M	1382.71	1975.30	.65982	6.915E-01	15.75	7	2	1.47	57
???	1502.88	2146.97	.61111	6.405E-01	19.12	10	1	2.66	58
???	1594.14	2277.34	7.2750	7.625E+00	3.42	13	1	2.77	59
???	1963.16	2804.52	.98889	1.036E+00	9.60	8	1	3.13	60
???	2023.94	2891.34	.84861	8.894E-01	11.48	11	1	2.41	61
???	2094.89	2992.70	1.0055	1.053E+00	9.64	11	1	2.70	62
???	2177.89	3111.27	.43334	4.542E-01	19.40	19	2	3.71	63
???	2183.45	3119.21	.96805	1.014E+00	11.29	19	2	3.33	64
???	2202.92	3147.03	.26944	2.824E-01	17.14	11	2	4.44	65
???	2267.18	3238.83	.23611	2.474E-01	19.51	10	2	3.59	66

10 -21 -1976 1055.06

HRB-11; EMPTY SLEEVE; POS. 12= ROD 8 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	65.99	94.28	4.4763	4.663E+00	26.65	7	1	1.74	1
PA233	93.92	134.17	26.461	2.756E+01	5.05	15	2	1.80	2
PA233	97.70	139.57	42.964	4.475E+01	4.24	15	2	1.78	3
TE125	110.43	157.75	14.354	1.495E+01	11.57	12	2	2.13	4
PA233									
PA233	114.18	163.11	6.2791	6.541E+00	16.96	12	2	1.57	5
CE141	144.67	206.68	10.611	1.105E+01	13.10	8	1	1.51	6
???	152.46	217.80	4.3194	4.499E+00	29.44	7	1	1.68	7
SB125	176.04	251.48	10.305	1.073E+01	17.28	12	2	2.01	8
???	203.28	290.40	53.300	5.552E+01	4.88	18	1	5.46	9
???	272.88	389.83	7.9763	8.309E+00	10.57	7	1	1.90	10

PA233	299.33	427.62	14.850	1.546E+01	7.42	10	1	1.81	11
PA233	311.15	444.51	91.041	9.483E+01	1.44	11	1	1.94	12
???	319.39	456.28	3.1555	3.287E+00	18.89	5	1	1.51	13
???	328.02	468.60	9.2333	9.618E+00	9.82	8	1	1.76	14
PA233	339.86	485.51	33.827	3.523E+01	3.26	10	1	1.93	15
???	363.91	519.87	14.113	1.470E+01	8.39	13	2	2.13	16
PA233	414.97	592.81	2.8638	2.983E+00	23.99	7	1	1.78	17
???	486.21	694.58	12.627	1.315E+01	5.86	9	1	1.85	18
???	536.48	766.39	6.0000	6.250E+00	10.42	8	1	2.04	19
CS134	562.31	803.29	12.894	1.343E+01	5.09	18	2	2.08	20
CS134	568.45	812.06	25.167	2.621E+01	3.95	18	2	1.92	21
CS134	603.86	862.66	150.99	1.572E+02	0.82	12	1	2.05	22
AG110M	656.77	938.25	8.0012	8.335E+00	4.99	15	2	2.17	23
CS137	660.72	943.89	49.979	5.206E+01	1.79	15	2	2.11	24
ZR95	722.82	1032.61	6.5333	6.805E+00	7.45	10	1	2.53	25
EUI54									
ZR95	755.70	1079.58	4.5777	4.768E+00	8.82	8	1	1.79	26
EUI54									
NB95	764.69	1092.42	10.552	1.099E+01	5.15	11	1	2.23	27
AG110M									
CS134	794.71	1135.30	105.93	1.103E+02	1.01	20	2	2.23	28
CS134	800.86	1144.08	12.200	1.270E+01	3.47	20	2	2.04	29
???	810.62	1158.03	4.1041	4.275E+00	8.11	18	2	1.78	30
???	817.45	1167.78	30.734	3.201E+01	2.57	18	2	2.10	31
???	833.66	1190.94	4.5250	4.713E+00	9.15	10	1	1.87	32
???	866.56	1237.94	2.0458	2.131E+00	18.55	11	2	2.45	33
AG110M	883.50	1262.14	4.6295	4.822E+00	7.76	15	2	1.99	34
???	888.12	1268.75	5.4398	5.666E+00	7.21	15	2	2.10	35
AG110M	936.24	1337.48	2.1055	2.193E+00	13.17	8	1	1.71	36
???	1046.63	1495.18	18.588	1.936E+01	2.34	12	1	2.34	37
???	1064.15	1520.22	1.6333	1.701E+00	14.38	8	1	1.50	38
???	1075.20	1536.01	1.9958	2.079E+00	12.39	7	1	2.22	39
???	1119.05	1598.65	5.7611	6.001E+00	4.98	10	1	2.38	40
???	1152.23	1646.04	3.0750	3.203E+00	7.84	9	1	2.48	41
CS134	1166.28	1666.11	1.1222	1.169E+00	15.86	6	1	2.50	42
???	1171.85	1674.07	3.9083	4.071E+00	7.25	10	1	2.27	43
???	1229.20	1756.00	1.9971	2.080E+00	9.95	16	2	2.32	44
???	1233.85	1762.64	3.8917	4.054E+00	7.17	16	2	2.35	45
???	1240.88	1772.68	1.7666	1.840E+00	10.56	8	1	2.72	46
???	1330.90	1901.28	4.5319	4.720E+00	5.60	11	1	2.88	47
CS134	1363.61	1948.01	3.1527	3.284E+00	6.46	9	1	3.27	48
???	1473.90	2105.57	.34444	3.588E-01	24.74	7	1	1.87	49
???	1594.17	2277.39	12.152	1.265E+01	2.48	15	1	2.73	50
???	1934.82	2764.02	.26528	2.763E-01	27.47	9	1	2.65	51
???	1963.20	2804.57	.50972	5.309E-01	14.81	5	1	1.68	52
???	2023.74	2891.05	.49444	5.150E-01	16.34	10	1	2.45	53
???	2094.82	2992.60	.69028	7.190E-01	10.66	9	1	2.55	54
???	2177.62	3110.88	.26641	2.775E-01	20.64	22	4	3.38	55
???	2178.99	3112.84	.26557	2.766E-01	20.74	22	4	6.13	56
???	2183.26	3118.94	.54302	5.656E-01	13.43	22	4	2.46	57

10 -21 -1976 1059.37
 HRB-11; EMPTY SLEEVE; POS. 13= ROD 7 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	66.09	94.42	4.0666	4.210E+00	24.78	6	1	1.95	1
???	74.26	106.09	8.7111	9.019E+00	19.18	10	2	1.32	2
PA233	93.90	134.15	27.758	2.873E+01	5.38	19	-	1.86	3
PA233	97.72	139.61	44.740	4.632E+01	4.65	19	3	1.73	4
TE125	110.30	157.57	21.011	2.175E+01	9.40	12	2	1.94	5
PA233									
CE141	144.65	206.64	13.147	1.361E+01	11.16	9	1	1.66	6
???	152.54	217.91	2.3136	2.395E+00	40.88	5	1	0.95	7
???	157.56	225.08	9.4208	9.753E+00	16.15	9	1	1.68	8
SB125	175.99	251.42	9.4055	9.736E+00	12.79	8	1	1.75	9
???	202.70	289.58	32.688	3.384E+01	5.67	12	1	4.24	10
???	273.04	390.06	7.4777	7.742E+00	14.61	11	1	1.78	11
PA233	299.49	427.84	16.487	1.707E+01	7.36	13	2	1.87	12
PA233	311.17	444.54	85.377	8.839E+01	1.34	10	1	1.90	13
???	319.34	456.21	3.7111	3.842E+00	18.76	7	1	2.05	14
PA233	339.85	485.50	26.800	2.981E+01	3.42	10	1	1.97	15
???	363.68	519.55	10.868	1.127E+01	7.42	9	1	1.93	16
PA233	415.15	593.08	2.5666	2.657E+00	21.33	6	1	1.69	17
CS134	474.40	677.72	2.6444	2.737E+00	19.55	7	1	2.20	18
???	486.16	694.51	5.8055	6.010E+00	9.67	8	1	2.27	19
CS134	562.32	803.31	10.807	1.118E+01	5.67	19	2	2.03	20
CS134	568.47	812.10	20.223	2.093E+01	4.43	19	2	2.09	21
CS134	603.86	862.66	117.18	1.213E+02	0.92	12	1	2.09	22
AG110M	656.78	938.26	4.7211	4.887E+00	6.72	15	2	1.97	23
CS137	660.72	943.89	36.609	3.790E+01	2.17	15	2	2.03	24
ZR95	723.03	1032.90	4.6555	4.820E+00	8.33	9	1	2.44	25
EU154									
ZR95	755.69	1079.55	4.2777	4.429E+00	8.21	8	1	2.20	26
EU154									
NB95	764.69	1092.42	10.552	1.092E+01	4.18	10	1	2.32	27
AG110M									
CS134	794.72	1135.32	81.460	8.434E+01	1.13	19	2	2.22	28
CS134	800.84	1144.06	8.5132	8.814E+00	4.20	19	2	2.21	29
???	817.55	1167.92	22.416	2.320E+01	3.28	20	2	2.40	30
???	833.72	1191.04	4.8055	4.975E+00	7.79	10	1	1.99	31
AG110M	883.49	1262.13	2.8269	2.926E+00	10.30	17	2	1.92	32
???	888.22	1268.89	5.2008	5.384E+00	8.01	17	2	2.21	33
AG110M	936.39	1337.70	1.0791	1.117E+00	19.21	7	1	2.36	34
???	1046.70	1495.28	13.886	1.437E+01	2.61	11	1	2.24	35
???	1119.22	1598.88	5.2750	5.461E+00	4.92	10	1	2.11	36
???	1152.56	1646.51	1.4361	1.486E+00	10.86	7	1	2.55	37
CS134	1166.95	1667.07	1.1666	1.207E+00	14.02	19	3	3.27	38
???	1171.77	1673.96	4.7833	4.952E+00	6.64	19	3	2.40	39
???	1229.22	1756.03	4.5833	4.745E-01	30.87	6	1	1.65	40
???	1233.72	1762.45	1.7805	1.843E+00	11.75	9	1	1.96	41
???	1240.98	1772.83	6.6389	6.873E-01	18.62	7	1	2.09	42
???	1330.89	1901.26	4.8111	4.981E+00	4.44	12	1	2.80	43
CS134	1363.66	1948.09	2.0916	2.165E+00	7.79	9	1	2.75	44
AG110M	1382.44	1974.91	6.1389	6.355E-01	16.96	7	1	2.14	45
???	1503.23	2147.47	2.7222	2.818E-01	32.07	8	1	2.46	46
???	1594.16	2277.38	4.6027	4.765E+00	4.00	11	1	2.89	47
???	2023.88	2891.26	2.7083	2.804E-01	22.26	13	3	1.42	48
???	2094.94	2992.77	2.6806	2.775E-01	19.83	7	1	2.08	49

Annex C2. Gamma Spectra Acquired from HRR-11 Fuel Rods

10 -20 -1976 1407.08
 HRB-11-1 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.13	133.05	35.911	4.755E+01	9.56	15	2	2.52	1
PA233	97.25	138.93	73.450	9.726E+01	7.02	15	2	2.07	2
TE125	109.62	156.60	22.387	2.964E+01	15.51	7	1	1.85	3
PA233									
CE144	132.35	189.07	19.785	2.619E+01	15.82	6	1	1.76	4
CE141	144.25	206.08	156.96	2.078E+02	3.30	10	1	2.05	5
???	161.45	230.65	19.225	2.545E+01	19.73	7	1	2.03	6
???	270.37	386.24	38.610	5.112E+01	10.33	10	1	2.19	7
PA233	298.94	427.05	974.60	1.290E+03	0.56	38	2	2.26	8
PA233	310.75	443.92	5711.1	7.562E+03	0.24	38	2	2.23	9
???	327.59	467.98	112.11	1.484E+02	3.47	11	1	2.14	10
PA233	339.35	484.79	627.81	8.313E+02	0.79	13	1	2.26	11
???	363.28	518.97	105.97	1.403E+02	3.47	11	1	2.26	12
PA233	374.19	534.56	88.315	1.169E+02	3.78	10	1	2.31	13
PA233	397.27	567.53	174.73	2.313E+02	2.12	11	1	2.30	14
PA233	414.50	592.14	224.06	2.967E+02	1.77	12	1	2.29	15
???	431.24	616.06	14.480	1.917E+01	14.14	6	1	1.93	16
???	485.77	693.95	217.29	2.877E+02	1.91	13	1	2.30	17
RUI03	495.85	708.35	268.43	3.554E+02	1.50	12	1	2.39	18
???	536.09	765.84	84.835	1.123E+02	3.87	10	1	2.36	19
CS134	568.05	811.50	5.9275	7.849E+00	37.85	7	1	1.97	20
CS134	603.31	861.88	47.410	6.278E+01	5.35	9	1	2.40	21
RUI06	621.18	887.39	20.745	2.747E+01	11.89	10	1	4.32	22
CS137	660.39	943.41	22.950	3.039E+01	7.76	8	1	2.63	23
CE144	695.37	993.39	9.3225	1.234E+01	23.17	11	1	5.08	24
ZR95	722.76	1032.52	389.29	5.155E+02	0.85	14	1	2.59	25
EUI54									
ZR95	755.29	1078.99	475.87	6.301E+02	0.79	37	3	2.51	26
EUI54									
NB95	764.39	1091.98	1087.4	1.440E+03	0.54	37	3	2.52	27
AG110M									
CS134	794.44	1134.91	39.130	5.181E+01	4.71	10	1	2.32	28
???	810.06	1157.23	7.0575	9.345E+00	16.86	17	2	1.16	29
???	814.42	1163.45	82.800	1.096E+02	3.50	17	2	2.55	30
???	866.20	1237.43	17.170	2.273E+01	7.72	8	1	2.79	31
???	923.37	1319.09	22.585	2.990E+01	10.90	18	2	2.14	32
???	1063.36	1519.08	2.5750	3.409E+00	31.92	6	1	1.64	33
???	1593.69	2276.71	192.51	2.549E+02	0.89	17	1	2.88	34
???	2343.79	3348.27	1.1450	1.516E+00	19.35	10	2	1.40	35

10 -20 -1976 1401.58
 HRB-11-2 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.19	133.12	32.011	4.152E+01	10.64	16	2	2.12	1
PA233	97.28	138.97	60.618	7.863E+01	8.37	16	2	2.10	2
TE125	109.67	156.67	26.167	3.394E+01	12.82	7	1	2.28	3

PA233									
CE144	132.35	189.07	20.945	2.717E+01	16.32	7	1	2.27	4
CE141	144.30	206.14	163.99	2.127E+02	3.26	11	1	2.22	5
???	206.83	295.47	13.620	1.766E+01	19.16	6	1	1.73	6
???	270.35	386.21	39.592	5.136E+01	9.03	9	1	2.16	7
PA233	298.95	427.07	818.94	1.062E+03	0.72	13	1	2.23	8
PA233	310.77	443.96	1999.3	6.485E+03	0.23	26	1	2.22	9
???	327.62	468.03	107.34	1.392E+02	3.50	11	1	2.23	10
PA233	339.38	484.82	567.84	7.366E+02	0.88	14	1	2.23	11
???	363.32	519.04	103.92	1.348E+02	3.37	11	1	2.31	12
PA233	374.33	534.75	74.557	9.672E+01	4.68	11	1	2.18	13
PA233	397.29	567.56	166.78	2.163E+02	2.26	12	1	2.23	14
PA233	414.51	592.16	200.68	2.603E+02	2.15	14	1	2.26	15
???	422.29	603.27	7.3300	9.509E+00	27.21	6	1	1.35	16
???	431.07	615.81	6.8400	8.873E+00	32.70	7	1	2.10	17
???	485.75	693.98	186.56	2.420E+02	1.89	11	1	2.24	18
RU103	495.86	708.37	244.00	3.165E+02	2.00	17	2	2.38	19
???	536.09	765.84	78.090	1.013E+02	4.04	10	1	2.25	20
CS134	603.42	862.02	50.767	6.586E+01	6.85	16	2	2.38	21
RU103	609.02	870.03	13.332	1.729E+01	12.85	16	2	2.02	22
CS137	660.23	943.19	19.170	2.486E+01	8.97	8	1	2.18	23
ZR95	722.79	1032.56	368.47	4.780E+02	0.93	16	1	2.50	24
EUI54									
ZR95	755.31	1079.01	426.43	5.532E+02	0.82	34	3	2.44	25
EUI54									
NB95	764.40	1091.99	1002.3	1.300E+03	0.55	34	3	2.42	26
AGI 10M									
CS134	794.38	1134.83	39.117	5.074E+01	4.20	9	1	2.63	27
???	814.46	1163.51	72.212	9.368E+01	3.10	13	1	2.57	28
???	866.25	1237.51	15.190	1.970E+01	8.28	8	1	2.64	29
???	923.66	1319.51	12.400	1.608E+01	11.62	10	1	2.22	30
???	1593.72	2276.74	175.63	2.278E+02	0.94	16	1	2.93	31
???	1962.86	2804.08	93500	1.212E+00	25.36	6	1	1.85	32

10 -20 -1976 1356.51

HRB-11-3 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.68	133.83	34.195	4.476E+01	11.42	20	3	3.51	1
PA233	97.28	138.97	70.924	9.285E+01	8.93	20	3	2.16	2
TE125	109.83	156.91	18.012	2.358E+01	23.46	9	1	1.98	3
PA233									
CE144	132.78	189.68	19.110	2.501E+01	20.33	8	2	2.17	4
CE141	144.27	206.10	165.04	2.160E+02	3.32	11	1	2.14	5
???	227.51	325.01	7.1575	9.370E+00	31.17	5	1	1.01	6
???	270.39	386.27	32.895	4.306E+01	12.06	10	1	2.04	7
???	282.54	403.63	7.0525	9.233E+00	31.78	5	1	1.62	8
PA233	298.93	427.04	929.53	1.216E+03	0.73	16	1	2.26	9
PA233	310.75	443.93	5303.4	6.943E+03	0.21	24	1	2.24	10
???	327.57	467.96	109.71	1.436E+02	3.51	11	1	2.32	11
PA233	339.36	484.80	593.06	7.764E+02	0.82	13	1	2.24	12
???	363.30	519.01	108.46	1.420E+02	4.02	14	2	2.26	13
PA233	374.17	534.52	81.442	1.066E+02	4.35	11	1	2.34	14
PA233	397.28	567.54	167.67	2.195E+02	2.15	11	1	2.46	15
PA233	414.48	592.12	203.47	2.663E+02	2.15	14	1	2.33	16
???	485.75	693.93	201.29	2.635E+02	1.89	12	1	2.25	17
RU103	495.75	708.21	242.29	3.172E+02	1.61	12	1	2.35	18

???	529.36	756.23	11.820	1.547E+01	19.23	7	1	2.21	19
???	535.96	765.66	85.607	1.120E+02	3.41	9	1	2.52	20
CS134	603.39	861.98	43.120	5.645E+01	6.19	10	1	2.22	21
RU103	609.33	870.47	12.445	1.629E+01	13.69	6	1	1.96	22
RU106	621.32	887.59	6.6200	8.667E+00	36.13	10	1	1.67	23
CS137	660.24	943.19	14.370	1.881E+01	14.55	10	1	2.44	24
ZR95	722.75	1032.51	362.47	4.745E+02	0.88	14	1	2.60	25
EUI54									
ZR95	755.29	1078.98	448.85	5.876E+02	0.84	40	3	2.51	26
EUI54									
NB95	764.38	1091.97	981.12	1.284E+03	0.59	40	3	2.54	27
AG110M									
CS134	794.42	1134.88	37.592	4.974E+01	5.07	11	1	2.46	28
???	814.36	1163.37	87.147	1.140E+02	3.15	17	1	2.80	29
???	866.17	1237.39	17.722	2.320E+01	7.98	9	1	2.65	30
???	923.45	1319.22	18.503	2.422E+01	9.00	12	1	2.30	31
???	1228.79	1755.41	3.6975	4.840E+00	19.89	7	1	2.08	32
???	1593.68	2276.69	186.40	2.440E+02	0.94	18	1	3.00	33

10 -20 -1976 1351.43
HRB-11-4 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.13	133.05	37.054	4.857E+01	9.46	15	2	2.55	1
PA233	97.27	138.96	74.490	9.764E+01	6.92	15	2	2.27	2
TE125	109.72	156.75	25.070	3.286E+01	15.29	8	1	2.29	3
PA233									
CE144	132.35	189.07	17.140	2.246E+01	24.93	9	1	2.35	4
CE141	144.28	206.11	161.65	2.119E+02	2.91	9	1	2.13	5
???	270.30	386.14	41.330	5.417E+01	10.38	11	1	2.15	6
???	282.79	403.98	8.0650	1.057E+01	27.83	5	1	1.20	7
PA233	298.93	427.04	945.87	1.239E+03	0.57	41	2	2.25	8
PA233	310.75	443.93	5450.4	7.144E+03	0.26	41	2	2.24	9
???	327.60	468.00	110.83	1.452E+02	3.49	11	1	2.20	10
PA233	339.35	481.79	602.99	7.904E+02	0.97	17	1	2.30	11
???	363.28	505.97	102.91	1.349E+02	3.49	11	1	2.14	12
PA233	374.17	520.52	87.155	1.142E+02	3.74	10	1	2.37	13
PA233	397.26	547.52	164.34	2.154E+02	2.05	10	1	2.27	14
PA233	414.49	572.13	212.71	2.788E+02	1.70	11	1	2.32	15
???	436.13	623.04	5.5500	7.275E+00	31.08	5	1	1.02	16
???	485.78	693.97	205.90	2.699E+02	1.74	11	1	2.32	17
RU103	495.74	708.19	249.61	3.272E+02	1.57	12	1	2.35	18
???	529.77	756.81	7.1450	9.366E+00	28.26	6	1	1.64	19
???	536.06	765.80	82.005	1.075E+02	3.90	10	1	2.38	20
CS134	603.41	862.02	40.005	5.244E+01	6.69	10	1	2.06	21
RU103	609.31	870.44	13.620	1.785E+01	15.80	8	1	2.50	22
CS137	660.25	943.22	16.105	2.111E+01	12.91	10	1	2.10	23
ZR95	722.75	1032.50	370.58	4.857E+02	0.90	15	1	2.59	24
EUI54									
ZR95	755.29	1078.99	436.40	5.720E+02	0.82	33	3	2.47	25
EUI54									
NB95	764.38	1091.97	943.47	1.236E+03	0.57	33	3	2.53	26
AG110M									
CS134	794.43	1134.89	33.250	4.358E+01	5.40	10	1	2.44	27
???	810.26	1157.51	7.5464	9.892E+00	16.39	18	2	2.03	28
???	814.38	1163.40	77.958	1.021E+02	3.83	16	2	2.57	29
???	866.22	1237.46	16.810	2.203E+01	9.12	10	1	2.56	30

???	917.71	1311.02	4.8200	6.318E+00	24.41	8	2	1.70	31
???	923.67	1319.53	17.942	2.352E+01	7.50	9	1	2.48	32
???	982.78	1403.97	2.7250	3.572E+00	29.62	6	1	1.28	33
???	1043.02	1494.31	5.8025	7.636E+00	15.83	7	1	1.98	34
???	1152.14	1645.91	5.2500	6.882E+00	13.46	6	1	2.49	35
???	1593.69	2276.70	189.59	2.485E+02	0.88	15	1	2.96	36

10 -20 -1976 1346.28
HRB-11-5 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.10	133.00	30.361	4.037E+01	11.33	15	2	2.52	1
PA233	97.20	138.86	66.223	8.741E+01	7.96	15	2	2.38	2
TE125	109.87	156.96	19.670	2.596E+01	23.49	10	1	2.14	3
PA233									
CE144	132.20	188.86	17.320	2.286E+01	17.79	6	1	2.29	4
CE141	144.20	206.04	173.90	2.295E+02	3.16	11	1	2.32	5
???	206.59	295.13	11.742	1.550E+01	25.78	7	1	2.14	6
???	270.46	386.37	38.600	5.095E+01	8.66	8	1	2.52	7
???	263.34	404.77	5.5200	7.286E+00	41.23	5	1	1.46	8
PA233	298.88	426.90	907.60	1.198E+03	0.62	40	2	2.39	9
PA233	310.71	443.87	5280.2	6.970E+03	0.27	40	2	2.37	10
???	327.54	467.92	101.70	1.342E+02	3.33	9	1	2.17	11
PA233	339.22	484.60	576.94	7.615E+02	0.90	14	1	2.41	12
???	363.24	518.91	105.85	1.397E+02	3.47	11	1	2.34	13
PA233	374.08	534.40	80.320	1.060E+02	4.15	10	1	2.46	14
PA233	397.23	567.48	163.59	2.159E+02	2.40	12	1	2.44	15
PA233	414.46	592.06	200.33	2.644E+02	1.85	11	1	2.45	16
???	422.64	603.77	12.725	1.679E+01	18.46	7	1	2.11	17
???	485.73	693.90	201.50	2.659E+02	1.95	12	1	2.45	18
RU103	495.71	708.15	244.54	3.227E+02	1.65	12	1	2.46	19
???	529.25	756.07	7.1350	9.418E+00	28.90	6	1	1.59	20
???	535.91	765.58	79.530	1.049E+02	4.43	11	1	2.37	21
CS134	567.80	811.14	8.4150	1.110E+01	26.43	7	1	2.10	22
CS131	603.34	861.91	45.235	5.971E+01	6.13	10	1	2.45	23
???	644.94	921.34	6.3250	8.349E+00	23.31	6	1	2.21	24
CS137	660.21	943.16	16.610	2.192E+01	11.02	8	1	2.24	25
ZR95	722.72	1032.46	369.26	4.874E+02	0.93	15	1	2.66	26
EUI54									
ZR95	755.29	1078.98	427.07	5.637E+02	0.87	33	3	2.70	27
EUI54									
NB95	764.38	1091.97	950.12	1.254E+03	0.60	33	3	2.70	28
AGI 10M									
CS134	794.33	1134.76	39.432	5.205E+01	5.14	11	1	2.69	29
???	810.00	1157.14	11.529	1.521E+01	11.77	17	2	1.18	30
???	814.36	1163.37	83.340	1.100E+02	3.48	17	2	2.66	31
???	866.17	1237.39	15.755	2.379E+01	9.62	9	1	2.54	32
???	923.62	1319.46	18.277	2.412E+01	7.69	9	1	2.24	33
???	1046.45	1494.93	6.6225	8.741E+00	14.42	7	1	2.53	34
???	1593.65	2276.65	184.33	2.433E+02	0.96	17	1	2.99	35
???	2094.54	2992.19	1.0600	1.399E+00	25.49	8	1	2.75	36

10 -20 -1976 1340.58
HRB-11-6 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.70	133.86	31.842	4.373E+01	10.76	15	2	4.18	1
PA233	97.22	138.88	86.194	1.183E+02	6.75	15	2	2.13	2
TE125	109.72	156.74	32.093	4.406E+01	11.36	7	1	2.11	3
PA233									
CE144	132.33	189.04	18.010	2.473E+01	18.18	6	1	1.99	4
CE141	144.20	206.00	187.52	2.575E+02	2.90	10	1	2.12	5
???	270.19	385.98	39.530	5.428E+01	8.96	8	1	2.17	6
PA233	298.86	426.94	1064.8	1.462E+03	0.57	41	2	2.37	7
PA233	310.68	443.83	6125.3	8.411E+03	0.25	41	2	2.5	8
???	327.49	467.84	120.99	1.661E+02	3.25	10	1	2.36	9
PA233	339.18	484.55	686.48	9.427E+02	0.92	17	1	2.44	10
???	363.22	518.09	120.92	1.660E+02	3.49	12	1	2.49	11
PA233	374.08	534.40	98.245	1.349E+02	3.62	10	1	2.49	12
PA233	397.22	567.45	197.16	2.707E+02	2.40	14	1	2.47	13
PA233	414.41	592.01	236.24	3.244E+02	1.79	12	1	2.39	14
???	430.82	615.46	10.640	1.461E+01	28.95	9	1	2.11	15
???	485.72	693.88	239.12	3.283E+02	1.98	14	1	2.44	16
RUI33	495.65	708.07	280.23	3.848E+02	1.54	12	1	2.36	17
???	529.74	756.77	9.5900	1.317E+01	26.06	7	1	2.44	18
???	535.89	765.55	94.000	1.290E+02	4.33	12	1	2.41	19
CS134	603.29	861.85	47.015	6.456E+01	5.79	9	1	2.34	20
SB125	635.23	907.43	7.5100	1.031E+01	18.97	5	1	1.66	21
CS137	660.11	943.41	21.392	2.937E+01	9.99	9	1	2.66	22
ZR95	722.69	1032.41	418.14	5.742E+02	0.88	15	1	2.62	23
EUI54									
ZR95	755.26	1078.94	494.41	6.789E+02	0.62	34	3	2.73	24
EUI54									
W395	764.35	1091.94	1065.1	1.462E+03	0.50	34	3	2.79	25
AG110M									
CS134	794.24	1134.62	39.220	5.386E+01	5.19	10	1	2.65	26
???	814.19	1163.12	87.060	1.195E+02	2.34	12	1	2.46	27
???	866.10	1237.28	17.942	2.464E+01	9.06	9	1	3.06	28
???	917.78	1311.12	4.9250	6.763E+00	21.83	6	1	2.33	29
???	923.55	1319.36	20.010	2.747E+01	8.25	10	1	2.73	30
???	1045.26	1493.23	3.1900	4.380E+00	25.66	5	1	1.25	31
???	1593.62	2276.60	219.57	3.015E+02	0.86	16	1	3.11	32

10 -20 -1976 1334.33
HRB-11-7 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.30	133.28	32.408	4.398E+01	10.56	15	2	2.74	1
PA233	97.19	138.84	76.721	1.041E+02	7.23	15	2	2.19	2
TE125	109.73	156.75	20.427	2.772E+01	17.69	7	1	2.06	3
PA233									
CE141	144.20	206.01	196.83	2.671E+02	0.72	10	1	2.23	4
???	160.56	229.37	7.0925	9.625E+00	42.85	5	1	1.22	5
???	270.28	386.11	46.745	6.343E+01	6.69	7	1	2.24	6
PA233	298.88	426.96	1024.2	1.390E+03	0.56	38	2	2.34	7

PA233	316.70	443.85	5894.7	7.999E+03	0.25	38	2	2.32	8
???	327.54	467.92	124.35	1.687E+02	3.31	11	1	2.28	9
PA233	339.20	484.57	651.96	8.847E+02	0.83	14	1	2.41	10
???	363.21	518.87	128.53	1.744E+02	3.19	12	1	2.38	11
PA233	374.14	534.49	88.682	1.203E+02	4.26	11	1	2.40	12
PA233	397.19	567.41	178.42	2.421E+02	2.16	11	1	2.37	13
PA233	414.43	592.04	222.22	3.015E+02	1.87	12	1	2.33	14
???	422.64	603.77	11.192	1.518E+01	21.99	7	1	2.12	15
???	430.62	615.17	8.7350	1.185E+01	21.44	5	1	1.49	16
???	485.72	693.88	240.90	3.269E+02	1.99	27	2	2.33	17
RU103	495.68	708.11	289.09	3.923E+02	1.88	27	2	2.34	18
???	535.92	765.60	93.712	1.271E+02	3.93	11	1	2.51	19
CS134	603.37	861.95	51.726	7.019E+01	7.54	17	2	2.34	20
RU103	609.33	870.48	16.850	2.286E+01	12.65	17	2	2.73	21
CS137	660.14	943.06	18.297	2.483E+01	11.38	9	1	2.49	22
ZR95	722.70	1032.43	410.96	5.577E+02	0.87	15	1	2.62	23
EU154									
???	750.19	1071.70	18.810	2.552E+01	7.70	33	3	2.53	24
ZR95	755.24	1078.91	470.34	6.383E+02	0.84	33	3	2.52	25
EU154									
NB95	764.20	1091.72	1021.1	1.385E+03	0.59	33	3	2.52	26
AG110M									
CS134	794.29	1134.71	37.717	5.118E+01	5.67	11	1	2.60	27
???	810.53	1157.91	11.621	1.577E+01	13.11	19	2	2.15	28
???	814.38	1163.40	92.371	1.253E+02	3.66	19	2	2.81	29
???	866.20	1237.43	20.230	2.745E+01	8.46	10	1	3.01	30
???	923.45	1319.22	17.210	2.335E+01	9.40	10	1	2.24	31
???	1228.43	1754.90	5.5550	7.538E+00	14.87	7	1	2.96	32
???	1486.94	2124.20	1.5125	2.052E+00	28.24	5	1	1.13	33
???	1593.65	2276.64	209.96	2.849E+02	0.86	15	1	3.11	34
???	1962.13	2803.04	.77500	1.051E+00	36.86	6	1	2.10	35
???	2093.74	2991.05	1.5000	2.035E+00	19.32	8	1	2.83	36
???	2182.62	3118.03	2.1000	2.849E+00	14.00	8	1	2.92	37

10 -20 -1976 1329.11

HRB-11-8 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.20	133.14	40.148	5.488E+01	9.33	16	2	2.12	1
PA233	97.22	138.88	75.361	1.030E+02	7.29	16	2	2.11	2
TE125	109.82	156.89	34.314	4.690E+01	13.01	12	2	2.37	3
PA233									
PA233	113.44	162.06	17.396	2.377E+01	17.80	12	2	0.91	4
CE141	144.20	205.99	195.77	2.676E+02	3.19	12	1	2.19	5
???	206.58	295.11	8.1250	1.110E+01	30.04	5	1	0.95	6
???	270.24	336.06	42.270	5.778E+01	8.29	8	1	2.47	7
PA233	298.85	426.93	1045.0	1.428E+03	0.57	40	2	2.38	8
PA233	310.68	443.82	5988.0	8.185E+03	0.25	40	2	2.38	9
???	327.51	467.87	122.61	1.676E+02	3.68	12	1	2.38	10
PA233	339.17	484.52	648.51	8.864E+02	0.81	13	1	2.49	11
???	363.21	518.87	121.10	1.655E+02	3.46	12	1	2.45	12
PA233	374.11	534.44	88.800	1.213E+02	4.00	10	1	2.42	13
PA233	397.20	567.43	188.44	2.575E+02	2.36	13	1	2.38	14
PA233	414.41	592.01	227.92	3.115E+02	1.96	13	1	2.42	15
???	431.17	615.95	15.842	2.165E+01	15.59	7	1	2.52	16
???	485.69	693.84	240.02	3.280E+02	1.73	12	1	2.47	17

RUI03	495.66	708.09	275.96	3.772E+02	1.54	12	1	2.43	18
???	535.91	765.58	97.430	1.331E+02	4.12	12	1	2.65	19
CS134	603.21	861.72	53.408	7.300E+01	7.27	17	2	2.49	20
SB125	608.89	869.84	20.734	2.834E+01	11.43	17	2	3.06	21
RUI03									
CS137	660.11	943.02	15.050	2.057E+01	12.86	8	1	2.45	22
ZR95	722.68	1032.40	417.90	5.712E+02	0.95	17	1	2.65	23
EUI54									
ZR95	755.26	1078.94	422.70	6.598E+02	0.83	33	3	2.90	24
EUI54									
NB95	764.35	1091.93	1041.4	1.423E+03	0.57	33	3	2.81	25
AGI10M									
CS134	794.20	1134.57	33.550	4.586E+01	5.99	10	1	2.71	26
???	814.32	1163.31	105.84	1.446E+02	3.67	22	2	2.81	27
???	866.03	1237.19	20.945	2.863E+01	8.36	10	1	2.35	28
???	917.98	1311.39	6.3525	8.683E+00	15.03	5	1	1.88	29
???	923.54	1319.34	18.252	2.495E+01	8.44	9	1	2.43	30
???	1593.62	2276.60	215.57	2.946E+02	0.88	16	1	3.04	31
???	2023.66	2890.95	.74500	1.018E+00	31.87	5	1	0.93	32
???	2181.95	3117.07	1.2250	1.674E+00	18.24	5	1	1.22	33
???	2343.69	3348.12	.73000	9.978E-01	24.09	5	1	1.13	34

10 -20 -1976 1324.31
HRB-11-9 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

[illegible]

NB95	764.36	1091.94	988.36	1.331E+03	0.62	36	4	2.76	26
AG110M									
CS134	794.42	1134.88	34.530	4.652E+01	5.74	10	1	2.44	27
???	814.30	1163.28	81.585	1.099E+02	3.14	13	1	2.63	28
???	866.19	1237.41	19.690	2.653E+01	7.28	8	1	2.66	29
???	923.53	1319.33	17.715	2.387E+01	9.15	10	1	2.59	30
???	1046.07	1494.39	4.2150	5.679E+00	21.69	6	1	2.15	31
???	1228.48	1754.98	4.1000	5.524E+00	22.48	8	1	2.37	32
???	1593.62	2276.60	205.83	2.773E+02	0.89	16	1	3.05	33

10 -20 -1976 1318.54

HRB-11-10 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	97.25	138.93	67.840	9.053E+01	12.62	20	3	2.17	1
TE125	109.41	156.30	16.142	2.154E+01	26.70	9	1	2.46	2
PA233									
CE141	144.22	206.03	175.26	2.338E+02	3.21	11	1	2.32	3
???	206.69	295.28	9.9500	1.327E+01	34.41	8	1	2.60	4
EUI54	246.66	352.37	8.6750	1.157E+01	26.24	5	1	1.53	5
???	270.28	386.12	32.427	4.327E+01	15.81	13	2	2.13	6
???	282.99	404.28	6.5950	8.800E+00	40.72	6	1	1.94	7
PA233	298.88	426.97	926.33	1.236E+03	0.76	16	1	2.33	8
PA233	310.71	443.87	5352.1	7.142E+03	0.20	22	1	2.23	9
???	327.56	467.95	115.79	1.545E+02	3.23	10	1	2.29	10
PA233	339.20	484.57	606.40	8.092E+02	0.87	14	1	2.42	11
???	363.23	518.90	115.34	1.539E+02	3.25	11	1	2.29	12
PA233	374.15	534.49	82.185	1.096E+02	4.14	10	1	2.51	13
PA233	397.21	567.45	168.24	2.245E+02	2.23	11	1	2.44	14
PA233	414.44	592.05	209.93	2.801E+02	2.04	13	1	2.34	15
???	422.62	603.74	7.5075	1.001E+01	31.74	7	1	2.05	16
???	431.05	615.78	15.030	2.005E+01	17.64	8	1	2.81	17
???	485.72	693.89	229.28	3.059E+02	1.73	12	1	2.40	18
RU103	495.70	708.14	269.73	3.599E+02	1.60	13	1	2.41	19
???	536.00	765.71	85.070	1.135E+02	4.54	12	1	2.47	20
CS134	603.39	861.98	45.351	6.052E+01	8.27	18	2	2.25	21
RU103	609.12	870.17	18.458	2.463E+01	12.19	18	2	3.07	22
CS137	660.45	943.50	18.170	2.424E+01	10.05	8	1	2.61	23
ZR95	722.71	1032.44	388.06	5.178E+02	0.94	16	1	2.64	24
EUI54									
ZR95	755.28	1078.98	454.23	6.061E+02	0.83	31	3	2.66	25
EUI54									
NB95	764.36	1091.95	950.09	1.267E+03	0.58	31	3	2.72	26
AG110M									
CS134	794.23	1134.61	26.720	3.565E+01	8.24	12	1	2.30	27
???	814.38	1163.40	84.335	1.125E+02	3.09	14	1	2.70	28
???	866.17	1237.38	17.585	2.346E+01	9.44	10	1	2.39	29
???	923.42	1319.17	18.095	2.414E+01	8.72	10	1	2.24	30
???	1046.06	1494.37	4.9900	6.659E+00	17.64	6	1	2.06	31
???	1228.65	1755.22	4.0075	5.347E+00	20.26	7	1	2.25	32
???	1593.63	2276.62	208.27	2.779E+02	0.91	18	1	3.06	33

10 -20 -1976 1313.51
HRB-11-11 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.11	133.01	34.982	4.716E+01	10.12	15	2	3.23	1
PA233	97.18	138.83	78.460	1.057E+02	6.99	15	2	2.22	2
CE144	132.28	188.96	13.840	1.865E+01	23.09	6	1	1.92	3
CE141	144.23	206.05	184.98	2.493E+02	3.10	11	1	2.27	4
???	161.32	230.45	9.2875	1.252E+01	32.26	5	1	1.50	5
???	206.98	295.69	8.8650	1.195E+01	31.23	6	1	1.57	6
EU154	247.11	353.01	9.8150	1.323E+01	23.66	5	1	1.26	7
???	270.20	386.00	37.355	5.036E+01	10.23	9	1	2.24	8
PA233	298.88	426.98	989.11	1.333E+03	0.58	39	2	2.31	9
PA233	310.70	443.86	5688.4	7.669E+03	0.26	39	2	2.30	10
???	327.59	467.98	107.22	1.445E+02	4.70	14	2	2.28	11
PA233	339.21	484.59	626.48	8.446E+02	0.86	14	1	2.39	12
???	363.25	518.92	123.47	1.664E+02	3.07	11	1	2.33	13
PA233	374.12	534.46	85.105	1.147E+02	4.08	10	1	2.40	14
PA233	397.20	567.43	170.72	2.301E+02	2.39	12	1	2.43	15
PA233	414.44	592.06	220.11	2.967E+02	1.85	12	1	2.38	16
???	431.09	615.84	12.867	1.734E+01	18.76	7	1	1.98	17
???	485.73	693.90	242.43	3.268E+02	1.78	13	1	2.43	18
RU103	495.69	708.14	290.22	3.912E+02	1.61	14	1	2.40	19
???	535.90	765.57	99.240	1.337E+02	3.41	10	1	2.48	20
CS134	603.27	861.82	32.880	4.432E+01	7.15	8	1	2.26	21
CS137	660.07	942.95	13.590	1.832E+01	13.68	8	1	2.27	22
ZR95	722.69	1032.42	402.55	5.427E+02	0.86	14	1	2.60	23
EU154									
ZR95	755.27	1078.96	500.81	6.751E+02	0.81	37	3	2.63	24
EU154									
NB95	764.36	1091.95	1033.2	1.392E+03	0.58	37	3	2.72	25
AG110M									
CS134	794.46	1134.94	27.732	3.738E+01	8.49	13	2	2.88	26
???	810.58	1157.97	7.9986	1.078E+01	17.34	18	2	3.13	27
???	814.33	1163.33	94.011	1.267E+02	3.50	18	2	2.65	28
???	866.17	1237.39	19.390	2.614E+01	7.98	9	1	2.34	29
???	917.72	1311.02	7.7680	1.047E+01	16.55	20	3	2.26	30
???	923.36	1319.09	24.202	3.262E+01	10.17	20	3	2.08	31
???	949.16	1355.94	2.3000	3.100E+00	35.56	5	1	0.87	32
???	1046.14	1494.49	4.2200	5.689E+00	18.73	5	1	1.80	33
???	1062.80	1518.29	1.9100	2.575E+00	40.50	5	1	1.19	34
???	1228.72	1755.32	4.1100	5.54.E+00	22.05	8	1	2.92	35
???	1593.86	2276.94	221.64	2.988E+02	0.88	20	2	3.41	36
???	2182.71	3118.16	1.4200	1.914E+00	16.64	5	1	1.47	37

10 -20 -1976 1308.51
HRB-11-16 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

[illegible]

CE141	144.23	206.05	179.79	2.400E+02	2.90	10	1	2.11	5
???	270.33	386.18	37.582	5.018E+01	10.01	9	1	2.15	6
PA233	298.88	426.97	945.17	1.262E+03	0.63	52	3	2.36	7
PA233	310.70	443.86	5497.2	7.340E+03	0.32	52	3	2.32	8
???	327.55	467.93	121.09	1.616E+02	2.31	52	3	2.19	9
PA233	339.20	484.57	603.83	8.062E+02	0.83	13	1	2.36	10
???	363.24	518.91	111.88	1.493E+02	3.11	10	1	2.32	11
PA233	374.13	534.47	81.560	1.389E+02	4.17	10	1	2.36	12
PA233	397.18	567.40	171.28	2.287E+02	2.19	11	1	2.44	13
PA233	414.44	592.06	211.24	2.820E+02	2.02	13	1	2.39	14
???	431.32	616.17	11.270	1.504E+01	18.61	6	1	2.00	15
???	485.72	593.89	225.92	3.016E+02	1.77	12	1	2.43	16
RUI03	495.69	708.13	273.15	3.647E+02	1.50	12	1	2.41	17
???	529.65	756.64	6.4600	8.625E+00	36.92	7	1	1.81	18
???	535.92	765.61	95.165	1.270E+02	3.47	10	1	2.54	19
CS134	603.37	861.96	32.560	4.347E+01	8.61	10	1	2.13	20
CS137	660.16	943.08	19.052	2.544E+01	10.58	9	1	2.32	21
ZR95	722.70	1032.43	390.91	5.219E+02	0.89	15	1	2.58	22
EU154									
ZR95	755.27	1078.96	450.07	6.009E+02	0.84	31	3	2.63	23
EU154									
NB95	764.36	1091.95	956.63	1.277E+03	0.58	31	3	2.69	24
AG110M									
CS134	794.45	1134.93	31.830	4.250E+01	9.82	18	3	2.93	25
???	814.35	1163.36	89.520	1.195E+02	3.07	15	1	2.72	26
???	866.02	1237.17	18.307	2.444E+01	8.31	9	1	2.18	27
???	923.38	1319.11	18.175	2.426E+01	8.66	10	1	2.41	28
???	1152.05	1645.78	6.4000	8.545E+00	17.47	10	1	2.38	29
???	1228.85	1755.50	3.8800	5.180E+00	23.44	8	1	2.50	30
???	1593.61	2276.58	209.01	2.790E+02	0.90	18	1	3.08	31
???	2093.96	2991.37	-90000	1.201E+00	24.44	5	1	1.37	32
???	2182.59	3117.99	1.0850	1.448E+00	34.20	10	1	2.26	33

10 -20 -1976 1304.50

HRB-11-17 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.50	133.56	25.517	2.998E+01	11.03	15	2	2.55	1
PA233	97.43	139.19	49.745	5.845E+01	8.21	15	2	2.16	2
PA233	103.12	147.31	5.1350	6.034E+00	40.00	5	1	1.04	3
TE125	110.11	157.31	15.085	1.772E+01	16.24	6	1	1.72	4
PA233									
CE141	144.64	206.63	121.69	1.430E+02	4.15	13	2	2.05	5
???	207.38	296.25	9.4150	1.106E+01	23.01	6	1	1.44	6
???	270.58	386.54	26.670	3.134E+01	10.03	8	1	1.83	7
PA233	299.01	427.15	485.41	5.704E+02	1.13	16	2	1.91	8
PA233	310.90	444.15	2902.7	3.411E+03	0.27	20	1	2.16	9
???	327.76	468.23	69.310	8.144E+01	4.55	12	1	2.18	10
PA233	339.51	485.01	334.79	3.934E+02	1.10	13	1	2.18	11
???	363.45	519.21	64.507	7.580E+01	4.87	13	1	2.18	12
PA233	374.45	534.93	48.145	5.657E+01	4.70	9	1	2.31	13
PA233	397.50	567.86	95.532	1.122E+02	2.83	11	1	2.20	14
PA233	414.73	592.47	116.49	1.369E+02	2.34	11	1	2.34	15
???	431.55	616.49	6.0775	7.141E+00	28.14	7	1	2.13	16
???	485.93	694.18	119.98	1.409E+02	2.26	11	1	2.24	17
RUI03	496.13	708.76	157.52	1.851E+02	1.90	12	1	2.23	18
RUI06	510.41	729.15	4.0925	4.809E+00	32.21	5	1	1.11	19

???	536.24	766.05	54.617	6.418E+01	4.72	11	1	2.39	20
CS134	603.61	862.30	31.420	3.692E+01	6.41	10	1	2.11	21
CS137	660.59	943.70	14.070	1.653E+01	9.18	8	1	2.25	22
CE144	695.20	993.15	6.7950	7.985E+00	18.96	9	1	2.35	23
ZR95	723.82	1032.89	228.37	2.683E+02	1.09	15	1	2.34	24
EUI54									
???	750.17	1071.67	8.6147	1.212E+01	10.55	17	2	1.72	25
ZR95	755.42	1079.17	260.52	3.061E+02	1.10	17	2	2.39	26
EUI54									
NB95	764.51	1092.16	586.77	6.895E+02	0.53	14	1	2.37	27
AG110M									
CS134	794.57	1135.10	29.075	3.416E+01	4.41	10	1	2.46	28
???	814.53	1163.62	46.060	5.405E+01	3.87	14	1	2.55	29
???	866.49	1237.84	8.7300	1.025E+01	10.52	8	1	1.92	30
???	918.08	1311.55	4.1500	4.876E+00	17.83	7	1	2.66	31
???	923.73	1319.61	10.255	1.205E+01	13.14	14	2	2.44	32
???	1046.57	1495.10	5.9950	7.044E+00	14.62	10	2	1.79	33
???	1064.04	1520.06	2.9800	3.501E+00	23.65	8	1	2.39	34
???	1152.15	1645.93	5.5600	6.533E+00	10.52	7	1	2.42	35
???	1171.79	1673.98	2.6425	3.105E+00	16.17	5	1	1.21	36
???	1240.94	1772.77	2.3625	2.776E+00	23.38	7	1	2.21	37
???	1331.06	1901.51	2.0400	2.397E+00	21.88	5	1	1.51	38
???	1594.05	2277.21	108.82	1.278E+02	1.14	15	1	2.84	39

10 -20 -1976 1300.07

HRB-11-18 FUEL ROD SCAN 1/1 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.14	133.05	26.183	3.686E+01	10.94	15	2	2.77	1
PA233	97.26	138.94	71.519	9.355E+01	7.36	15	2	1.95	2
CE144	132.53	189.33	18.875	2.468E+01	16.24	6	1	1.73	3
CE141	144.26	206.09	184.69	2.415E+02	3.40	13	1	2.29	4
???	227.23	324.61	8.0325	1.050E+01	27.57	5	1	1.75	5
???	270.31	386.16	29.647	3.878E+01	12.28	9	1	2.17	6
PA233	298.92	427.03	901.23	1.178E+03	0.59	37	2	2.30	7
PA233	310.74	443.92	5222.1	6.830E+03	0.26	37	2	2.27	8
???	327.58	467.97	113.55	1.485E+02	3.40	11	1	2.19	9
PA233	339.35	484.79	584.63	7.647E+02	0.91	15	1	2.29	10
???	363.28	518.98	100.64	1.316E+02	3.58	11	1	2.22	11
PA233	374.16	534.51	79.260	1.036E+02	4.44	11	1	2.33	12
PA233	397.25	567.50	163.20	2.134E+02	2.34	12	1	2.34	13
PA233	414.50	592.14	206.74	2.704E+02	1.97	13	1	2.32	14
???	422.43	603.47	9.8875	1.293E+01	23.14	7	1	1.57	15
???	431.21	616.01	10.680	1.396E+01	18.80	6	1	1.58	16
???	485.77	693.96	209.35	2.738E+02	1.95	13	1	2.31	17
RUI03	495.71	708.16	252.52	3.303E+02	1.55	12	1	2.33	18
???	529.21	756.01	8.5700	1.120E+01	29.47	8	1	2.72	19
???	535.94	765.63	92.120	1.204E+02	3.70	11	1	2.42	20
CS134	603.39	861.98	47.858	6.260E+01	7.90	19	2	2.32	21
RUI03	609.30	870.42	18.106	2.368E+01	11.86	19	2	2.80	22
CS137	660.19	943.13	14.470	1.892E+01	14.57	10	1	2.34	23
CE144	694.80	992.57	8.1275	1.063E+01	21.90	9	1	2.44	24
ZR95	722.74	1032.49	371.82	4.863E+02	0.97	17	1	2.61	25
EUI54									
???	750.39	1071.99	16.920	2.214E+01	7.60	32	3	2.67	26
ZR95	755.27	1078.96	421.39	5.512E+02	0.85	32	3	2.47	27
EUI54									
NB95	764.36	1091.94	915.10	1.197E+03	0.59	32	3	2.46	28

AG110M

CS134	794.44	1134.91	34.265	4.482E+01	5.24	10	1	2.32	29
???	809.96	1157.09	9.5979	1.255E+01	13.14	16	2	1.43	30
???	814.36	1163.37	85.432	1.117E+02	3.21	16	2	2.56	31
???	866.13	1237.33	19.265	2.519E+01	7.98	10	1	2.35	32
???	917.88	1311.26	7.9630	1.041E+01	14.58	17	2	2.31	33
???	923.39	1319.13	17.194	2.249E+01	10.63	17	2	2.26	34
???	1074.72	1535.31	1.9075	2.495E+00	35.79	5	1	1.30	35
???	1151.85	1645.50	5.0400	6.592E+00	17.83	8	1	2.61	36
???	1240.65	1772.36	2.5300	3.309E+00	26.42	6	1	2.16	37
???	1593.66	2276.66	188.09	2.460E+02	0.95	17	1	2.89	38
???	1962.11	2803.02	.64500	8.436E-01	40.97	6	1	1.40	39
???	2094.34	2991.92	.93000	1.216E+00	28.43	8	1	2.64	40

10 -20 -1976 1255.17
HRB-11-19 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.11	133.02	36.415	4.690E+01	10.03	16	2	2.64	1
PA233	97.30	138.99	67.494	8.693E+01	7.66	16	2	2.36	2
TE125	109.90	156.99	33.310	4.290E+01	20.00	16	2	2.37	3
PA233									
CE144	132.28	188.97	17.117	2.204E+01	19.68	7	1	1.68	4
CE141	144.26	206.09	167.32	2.155E+02	2.94	10	1	2.26	5
???	161.33	230.47	13.160	1.695E+01	21.21	5	1	1.90	6
???	207.20	296.01	12.730	1.639E+01	23.05	7	1	2.03	7
???	270.32	386.18	40.222	5.180E+01	8.79	9	1	2.24	8
PA233	298.92	427.03	757.22	9.753E+02	0.73	12	1	2.24	9
PA233	310.75	443.93	4646.8	5.985E+03	0.20	18	1	2.27	10
???	327.58	467.97	100.33	1.292E+02	4.02	12	2	2.29	11
PA233	339.35	484.79	532.22	6.855E+02	0.96	15	1	2.33	12
???	363.31	519.02	97.970	1.261E+02	3.82	12	1	2.36	13
PA233	374.15	534.50	71.250	9.177E+01	4.08	9	1	2.31	14
PA233	397.24	567.48	149.38	1.924E+02	2.33	11	1	2.42	15
PA233	414.49	592.13	187.27	2.412E+02	2.00	12	1	2.32	16
???	431.19	615.99	9.1650	1.180E+01	24.11	7	1	2.17	17
???	485.77	693.96	196.55	2.531E+02	1.89	12	1	2.32	18
RU103	495.75	708.21	239.60	3.086E+02	1.79	14	1	2.38	19
???	535.97	765.66	78.105	1.006E+02	4.29	11	1	2.54	20
CS134	603.43	862.05	49.277	6.347E+01	7.14	17	2	2.32	21
RU103	609.22	870.32	15.347	1.976E+01	12.26	17	2	2.90	22
RU106	621.18	887.39	14.115	1.818E+01	12.37	7	1	2.99	23
CS137	660.13	943.04	18.102	2.331E+01	8.40	7	1	2.13	24
ZR95	723.01	1032.88	353.95	4.558E+02	1.10	20	3	3.15	25
EUI54									
???	750.32	1071.88	10.135	1.305E+01	11.96	18	2	2.63	26
ZR95	755.28	1078.97	386.53	4.978E+02	1.03	18	2	2.45	27
EUI54									
NB95	764.37	1091.95	882.40	1.136E+03	0.47	15	1	2.47	28
AG110M									
CS134	794.31	1134.72	33.510	4.316E+01	5.64	11	1	2.61	29
???	814.39	1163.42	71.485	9.207E+01	3.35	14	1	2.63	30
???	866.25	1237.50	17.052	2.196E+01	8.11	9	1	2.77	31
???	917.73	1311.04	5.7950	7.464E+00	15.94	6	1	2.23	32
???	923.75	1319.65	13.540	1.743E+01	10.55	10	1	2.50	33
???	1046.24	1494.63	6.7600	3.707E+00	14.82	8	1	2.40	34
???	1152.11	1645.87	6.2075	7.995E+00	12.62	7	1	2.21	35
???	1593.65	2276.64	181.47	2.337E+02	0.95	19	1	3.03	36

10 -20 -1976 1250.22
 HRB-11-20 FUEL ROD SCAN 1/4 IN CU 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	93.17	133.10	29.907	3.893E+01	12.58	20	3	2.24	1
PA233	97.21	138.87	59.262	7.714E+01	10.30	20	3	2.03	2
TE125	109.64	156.63	25.770	3.354E+01	14.60	8	1	2.46	3
PA233									
CE144	132.50	189.28	15.255	1.985E+01	17.32	5	1	1.32	4
CE141	144.26	206.08	177.32	2.308E+02	3.05	11	1	2.23	5
???	161.64	230.92	14.835	1.931E+01	24.85	7	1	1.88	6
???	206.86	295.51	9.5300	1.240E+01	31.01	7	1	1.83	7
???	270.31	386.16	36.010	4.687E+01	9.09	8	1	2.27	8
PA233	298.89	426.98	900.37	1.172E+03	0.59	38	2	2.28	9
PA233	310.70	443.86	5185.5	6.749E+03	0.26	38	2	2.29	10
???	327.55	467.92	104.36	1.358E+02	3.40	10	1	2.27	11
PA233	339.20	484.57	572.80	7.456E+02	0.92	15	1	2.29	12
???	363.25	518.92	104.94	1.366E+02	3.39	11	1	2.31	13
PA233	374.06	534.37	81.100	1.055E+02	4.30	11	1	2.48	14
PA233	397.21	567.44	159.79	2.080E+02	2.23	11	1	2.33	15
PA233	414.43	592.05	192.02	2.499E+02	2.00	12	1	2.34	16
???	485.76	693.94	202.88	2.640E+02	2.10	14	2	2.54	17
RU103	495.67	708.10	245.38	3.194E+02	1.58	12	1	2.39	18
???	529.62	756.59	8.8525	1.152E+01	25.45	7	1	2.21	19
???	535.83	765.47	85.490	1.112E+02	3.67	10	1	2.53	20
CS134	603.29	861.85	41.287	5.374E+01	5.91	9	1	2.20	21
RU103	609.14	870.20	10.235	1.332E+01	24.67	10	1	2.17	22
CS137	660.28	943.25	19.350	2.518E+01	8.86	8	1	2.68	23
ZR95	722.65	1032.36	359.86	4.684E+02	0.89	14	1	2.54	24
EUI54									
ZR95	755.25	1078.93	425.20	5.534E+02	0.86	36	3	2.76	25
EUI54									
NB95	764.35	1091.92	948.77	1.235E+03	0.59	36	3	2.78	26
AG110M									
CS134	794.14	1134.49	33.547	4.366E+01	5.73	11	1	2.46	27
???	814.30	1163.29	89.207	1.158E+02	3.13	17	1	2.82	28
???	865.91	1237.01	17.107	2.226E+01	11.03	13	2	2.51	29
???	917.98	1311.40	8.1157	1.056E+01	14.38	16	2	1.64	30
???	923.55	1319.36	14.384	1.872E+01	11.33	16	2	2.63	31
???	1046.22	1494.60	4.9650	6.462E+00	18.48	7	1	2.56	32
???	1150.18	1643.11	2.5672	3.341E+00	19.29	7	2	1.41	33
???	1151.57	1645.10	3.3652	4.380E+00	16.98	7	2	2.39	34
???	1228.05	1754.36	2.6250	3.416E+00	22.71	5	1	1.32	35
???	1593.50	2276.43	183.41	2.387E+02	0.93	16	1	3.09	36

10 -20 -1976 1241.38
 HRB-11-21 FUEL ROD SCAN 1/4 IN CU 10 MIL SLOT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	NU	FWHM (KEV)	PK #
PA233	93.41	133.44	25.809	3.385E+01	11.91	15	2	2.62	1
PA233	97.19	138.85	63.413	8.318E+01	8.26	15	2	2.11	2
EU155	103.94	148.48	8.6000	1.128E+01	39.12	7	1	1.92	3
PA233									
TE125	109.91	157.02	30.495	4.000E+01	13.06	11	2	2.48	4
PA233									
PA233	113.60	162.41	16.604	2.178E+01	17.75	11	2	1.60	5
CE144	132.29	188.99	24.897	3.265E+01	13.89	7	1	2.25	6
CE141	144.24	206.06	158.26	2.076E+02	3.47	11	1	2.13	7
???	206.58	295.11	14.280	1.873E+01	23.13	8	1	2.70	8
???	270.26	386.09	36.900	4.840E+01	12.51	12	2	1.96	9
PA233	298.87	426.95	857.77	1.125E+03	0.70	13	1	2.24	10
PA233	310.70	443.85	5315.6	6.972E+03	0.20	22	1	2.27	11
???	327.55	467.93	109.12	1.431E+02	3.30	10	1	2.20	12
PA233	339.20	484.57	600.54	7.877E+02	0.81	13	1	2.33	13
???	363.24	518.92	109.91	1.441E+02	3.27	11	1	2.33	14
PA233	374.38	534.82	80.575	1.056E+02	5.38	14	2	2.93	15
PA233	397.18	567.40	167.38	2.195E+02	2.17	11	1	2.39	16
PA233	414.41	592.02	203.27	2.666E+02	1.80	11	1	2.33	17
???	485.70	693.85	206.63	2.710E+02	1.86	12	1	2.32	18
RU103	495.66	708.09	254.89	3.343E+02	1.72	14	1	2.26	19
RU106	510.33	729.04	11.145	1.461E+01	17.94	6	1	2.63	20
???	535.86	765.52	75.145	9.857E+01	4.65	11	1	2.22	21
CS134	603.26	861.80	53.070	6.961E+01	7.57	16	2	2.23	22
CS137	660.17	943.09	17.790	2.333E+01	9.92	8	1	2.53	23
ZR95	722.64	1032.35	376.86	4.943E+02	0.89	15	1	2.52	24
EU154									
???	749.80	1071.15	17.850	2.341E+01	7.63	35	3	1.65	25
ZR95	755.06	1078.66	441.89	5.796E+02	0.85	35	3	2.52	26
EU154									
NB95	764.14	1091.63	969.34	1.271E+03	0.59	35	3	2.52	27
AG110M									
CS134	794.19	1134.56	35.360	4.638E+01	5.54	11	1	2.71	28
???	814.16	1163.09	82.440	1.081E+02	2.96	4	1	2.54	29
???	865.93	1237.04	17.310	2.270E+01	10.46	12	2	2.65	30
???	917.83	1311.19	4.6650	6.119E+00	20.50	6	1	2.34	31
???	923.48	1319.26	16.750	2.197E+01	8.80	10	1	2.54	32
???	1045.93	1494.19	6.3150	8.283E+00	14.60	7	1	2.14	33
???	1593.47	2276.39	190.88	2.503E+02	0.89	15	1	3.00	34

Annex C3. Gamma Spectra Acquired from Empty Sleeve
of Capsule HRB-12

4 - 7 - 1977 1215.60
HRB-12 ; EMPTY SLEEVE; POS.=ROD#1 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	562.72	803.88	10.521	1.062E+01	5.88	18	2	1.93	1
CS134	568.72	812.45	17.304	1.747E+01	4.78	18	2	1.93	2
CS134	604.11	863.01	104.12	1.051E+02	1.12	11	1	1.95	3
CS137	661.02	944.31	34.550	3.489E+01	1.98	10	1	2.04	4
CS134	795.27	1136.10	74.041	7.476E+01	1.28	19	2	2.02	5
CS134	801.40	1144.86	6.6363	6.703E+00	5.15	19	2	2.25	6
AG110M	936.84	1338.35	.27000	2.727E-01	31.43	5	1	1.14	7
CS134	1038.16	1483.08	.61250	6.186E-01	23.10	9	2	1.12	8
???	1119.98	1599.97	.40500	4.090E-01	33.00	13	2	1.81	9
CS134	1167.47	1667.81	1.1603	1.171E+00	14.84	17	2	2.75	10
???	1172.51	1675.01	.87469	8.834E-01	17.33	17	2	2.47	11
???	1331.74	1902.49	.97250	9.822E-01	11.23	9	1	2.43	12
CS134	1364.46	1949.15	1.8275	1.845E+00	8.00	11	1	2.27	13

4 - 7 - 1977 1229.03
HRB-12; EMPTY SLEEVE; POS.=ROD# 2 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	474.80	678.29	3.2675	3.336E+00	23.48	7	1	1.69	1
CS134	562.61	803.72	23.921	2.442E+01	4.11	19	2	1.95	2
CS134	568.63	812.32	39.683	4.052E+01	3.33	19	2	2.05	3
CS134	604.07	862.96	246.32	2.515E+02	0.73	11	1	1.99	4
CS137	660.98	944.26	78.870	8.053E+01	1.31	10	1	1.97	5
CS134	795.22	1136.03	172.76	1.764E+02	0.84	20	2	2.07	6
CS134	801.35	1144.78	17.202	1.756E+01	3.21	20	2	2.11	7
???	959.26	1370.37	.25750	2.629E-01	38.06	5	1	1.23	8
CS134	1038.01	1482.87	1.5925	1.626E+00	12.34	9	1	1.81	9
???	1119.53	1599.33	.37500	3.829E-01	33.07	6	1	1.56	10
CS134	1167.36	1667.65	2.9478	3.010E+00	8.29	15	2	2.40	11
???	1172.48	1674.97	.93462	9.543E-01	16.21	15	2	2.11	12
???	1331.76	1902.51	.76000	7.760E-01	15.26	9	1	2.44	13
CS134	1364.41	1949.15	4.3075	4.398E+00	4.99	11	1	2.08	14

4 - 7 - 1977 1232.12
HRB-12; EMPTY SLEEVE; POS.=ROD# 3 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	474.73	678.19	4.7900	4.892E+00	15.65	7	1	1.91	1
CS134	562.65	803.78	22.267	2.274E+01	4.28	19	2	1.99	2
CS134	568.71	812.44	39.045	3.988E+01	3.41	19	2	1.94	3
CS134	604.08	862.97	236.96	2.420E+02	0.74	11	1	2.00	4
CS137	660.90	944.15	78.112	7.978E+01	1.50	15	2	1.76	5

CS134	795.22	1136.02	169.97	1.736E+02	0.87	22	2	2.09	6
CS134	801.37	1144.82	16.911	1.727E+01	3.27	22	2	2.10	7
AG110M	883.97	1262.82	1.4225	1.453E+00	14.68	7	1	1.63	8
AG110M	937.11	1338.72	.44250	4.519E-01	41.54	7	1	2.04	9
CS134	1037.81	1482.59	1.7600	1.797E+00	11.91	9	1	1.83	10
CS134	1167.29	1667.56	2.3394	2.389E+00	10.10	16	2	1.80	11
???	1172.61	1675.15	1.0006	1.022E+00	15.09	16	2	1.93	12
???	1331.98	1902.82	1.0525	1.075E+00	11.90	11	1	2.27	13
CS134	1364.53	1949.33	3.8400	3.922E+00	5.71	12	1	2.54	14
AG110M	1383.99	1977.13	.40500	4.135E-01	18.33	9	2	1.33	15

4 - 7 -1977 1235.15
HRB-12; EMPTY SLEEVE; POS.=ROD# 4 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CE141	145.33	207.61	1.9175	1.973E+00	42.25	5	1	1.43	1
CS134	474.59	677.98	6.7975	6.995E+00	12.88	7	1	2.18	2
CS134	562.62	803.75	31.004	3.190E+01	3.64	19	2	2.02	3
CS134	568.61	812.30	53.540	5.510E+01	2.91	19	2	1.97	4
CS134	604.06	862.94	326.94	3.364E+02	0.64	11	1	1.96	5
AG110M	657.21	938.88	3.3305	3.427E+00	11.55	14	2	1.96	6
CS137	660.97	944.24	99.764	1.026E+02	1.33	14	2	1.96	7
CS134	795.21	1136.01	234.08	2.409E+02	0.73	20	2	2.08	8
CS134	801.34	1144.78	22.460	2.311E+01	2.83	20	2	2.06	9
???	810.90	1158.43	1.3175	1.355E+00	19.01	7	1	1.97	10
AG110M	884.05	1262.93	1.8325	1.885E+00	13.28	7	1	1.95	11
CS134	1038.01	1482.87	1.6125	1.659E+00	14.30	7	1	1.81	12
CS134	1167.26	1657.51	4.2586	4.382E+00	7.12	16	2	2.42	13
???	1172.52	1675.03	1.2713	1.308E+00	14.81	16	2	2.67	14
???	1230.40	1757.72	.58750	6.046E-01	26.45	9	2	3.05	15
???	1241.69	1773.84	.58500	6.020E-01	19.18	7	1	2.23	16
EUI54	1274.06	1820.38	.58750	6.046E-01	22.16	7	1	2.10	17
???	1331.40	1901.99	1.1000	1.132E+00	13.61	8	1	1.99	18
CS134	1364.36	1949.09	5.9250	6.097E+00	4.45	11	1	2.37	19

4 - 7 -1977 1238.26
HRB-12; EMPTY SLEEVE; POS.=ROD#5 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	57.26	81.80	2.5300	2.591E+00	29.72	5	1	1.65	1
CE144	132.56	189.36	2.4225	2.481E+00	41.57	7	1	1.50	2
CS134	562.61	803.73	23.569	2.413E+01	4.18	18	2	2.13	3
CS134	568.71	812.45	43.541	4.459E+01	3.21	18	2	1.97	4
CS134	604.07	862.96	261.15	2.674E+02	0.72	11	1	1.91	5
CS137	660.96	944.23	77.950	7.983E+01	1.41	10	1	1.95	6
7395	723.59	1033.70	2.8200	2.888E+00	13.95	8	1	2.02	7
EUI54									
2R95	756.13	1080.19	3.2400	3.318E+00	12.05	8	1	2.32	8
EUI54									
NR95	765.15	1093.07	10.940	1.120E+01	5.45	12	1	1.82	9
AG110M									
CS134	795.21	1136.02	183.28	1.877E+02	0.84	19	2	2.06	10
CS134	801.34	1144.78	17.816	1.824E+01	3.18	19	2	2.01	11

CS134	1166.96	1667.09	2.8055	2.873E+00	10.08	18	3	1.88	12
???	1172.51	1675.01	1.1294	1.156E+00	16.53	18	3	2.19	13
???	1331.60	1902.29	.88000	9.013E-01	12.96	8	1	2.20	14
CS134	1364.52	1949.32	4.4225	4.529E+00	5.23	11	1	2.44	15
AG110M	1383.12	1975.88	.44000	4.506E-01	18.53	6	1	2.32	16

4 - 7 - 1977 1241.36

HRB-12; EMPTY SLEEVE; POS.= ROD# 6 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	562.56	803.65	18.884	1.922E+01	4.48	17	2	1.82	1
CS134	568.64	812.34	30.420	3.097E+01	3.67	17	2	2.35	2
CS134	604.09	862.98	191.46	1.949E+02	0.87	12	1	1.92	3
CS137	661.01	944.30	54.840	5.583E+01	1.73	10	1	1.98	4
CS134	795.24	1136.05	135.83	1.383E+02	0.95	19	2	2.10	5
CS134	801.36	1144.79	12.594	1.282E+01	3.78	19	2	2.07	6
???	834.59	1192.27	.81750	8.321E-01	19.90	5	1	1.26	7
CS134	1037.78	1482.55	1.1400	1.160E+00	16.36	8	1	1.79	8
CS134	1167.35	1667.65	2.2025	2.242E+00	13.26	16	2	2.73	9
???	1172.61	1675.16	1.0374	1.056E+00	15.62	16	2	2.27	10
???	1331.75	1902.51	1.0000	1.018E+00	12.65	8	1	2.66	11
CS134	1364.36	1949.09	3.2550	3.314E+00	5.72	11	1	2.20	12
AG110M	1383.70	1976.71	.37000	3.767E-01	22.12	8	1	1.55	13

4 - 7 - 1977 1244.47

HRB-12; EMPTY SLEEVE; POS.= ROD# 7 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	474.63	678.05	4.8525	4.977E+00	13.17	5	1	1.26	1
CS134	562.61	803.73	26.286	2.696E+01	3.94	18	2	1.95	2
CS134	568.64	812.34	45.168	4.633E+01	3.13	18	2	2.04	3
???	586.71	838.16	1.5250	1.564E+00	37.59	5	1	0.92	4
CS134	604.07	862.05	279.23	2.864E+02	0.69	11	1	2.01	5
AG110M	657.26	938.95	5.5555	5.699E+00	7.70	15	2	2.38	6
CS137	660.98	944.26	81.019	8.208E+01	1.56	15	2	2.02	7
AG110M	706.03	1008.62	1.3950	1.431E+00	22.56	6	1	1.72	8
NB95	764.13	1091.61	1.8100	1.856E+00	23.56	9	1	3.34	9
AG110M									
CS134	795.22	1136.03	196.15	2.012E+02	0.81	21	2	2.06	10
CS134	801.37	1144.81	20.003	2.052E+01	2.97	21	2	1.99	11
???	811.04	1158.63	1.0000	1.025E+00	27.05	8	1	2.36	12
???	834.16	1191.66	2.2900	2.349E+00	11.95	7	1	2.05	13
AG110M	884.06	1262.95	2.9100	2.985E+00	9.31	7	1	1.98	14
CS134	1038.09	1482.98	2.1425	2.197E+00	9.90	7	1	2.48	15
CS134	1167.31	1667.59	3.1550	3.236E+00	8.09	9	1	1.91	16
???	1205.80	1722.57	.24000	2.462E-01	34.61	5	1	1.46	17
???	1230.23	1757.47	.59750	6.129E-01	28.64	11	2	1.81	18
???	1331.82	1902.60	.94000	9.642E-01	13.83	6	1	1.78	19
CS134	1364.55	1949.36	4.7175	4.839E+00	5.13	11	1	2.58	20
AG110M	1383.73	1976.76	.74750	7.668E-01	14.11	9	1	2.19	21

4 - 7 - 1977 1247.55
 HRB-12; EMPTY SLEEVE; POS.= ROD#8 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	65.93	94.18	4.7575	4.948E+00	27.08	7	1	1.79	1
PA233	87.98	125.68	9.8600	1.025E+01	15.03	8	1	1.72	2
EUI55									
EUI54	122.02	174.32	7.3450	7.640E+00	16.56	6	1	1.72	3
CS134	474.59	677.95	8.2300	8.561E+00	12.07	7	1	1.94	4
CS134	562.59	803.70	32.709	3.402E+01	3.64	18	2	2.03	5
CS134	568.60	812.29	58.831	6.119E+01	2.85	18	2	2.00	6
CS134	604.04	862.92	351.62	3.657E+02	0.63	11	1	1.98	7
AG110M	657.94	939.92	5.0587	5.262E+00	9.50	15	2	4.23	8
CS137	660.95	944.21	104.87	1.090E+02	1.43	15	2	2.11	9
ZR95	722.89	1032.69	5.0600	5.263E+00	10.62	8	1	2.33	10
EUI54									
CS134	795.20	1136.00	251.53	2.616E+02	0.73	20	2	2.08	11
CS134	801.30	1144.72	23.512	2.445E+01	2.87	20	2	2.16	12
???	811.17	1158.82	4.0450	4.207E+00	9.55	7	1	2.00	13
???	817.66	1168.02	2.4200	2.517E+00	13.59	6	1	1.73	14
???	834.17	1191.67	3.5700	3.713E+00	11.55	8	1	2.11	15
AG110M	884.18	1263.12	2.2300	2.319E+00	17.48	8	1	1.98	16
???	959.16	1370.23	.68000	7.073E-01	32.74	5	1	1.16	17
CS134	1038.06	1482.94	2.1100	2.194E+00	13.31	7	1	2.10	18
???	1047.36	1496.23	1.1650	1.211E+00	22.77	7	1	1.57	19
???	1078.16	1540.23	1.8675	1.942E+00	16.54	9	1	2.26	20
???	1153.15	1647.36	3.6900	3.838E+00	7.98	9	1	2.61	21
CS134	1167.54	1667.92	3.6016	3.746E+00	10.65	16	2	2.42	22
???	1172.46	1674.94	1.3583	1.412E+00	17.44	16	2	2.10	23
???	1230.01	1757.16	2.1300	2.215E+00	11.41	8	1	2.42	24
???	1241.70	1773.86	2.1950	2.283E+00	11.28	10	1	2.20	25
EUI54	1273.37	1819.10	1.8050	1.877E+00	12.49	15	3	1.22	26
EUI54	1276.88	1824.11	.94244	9.803E-01	16.68	15	3	10.2	27
CS134	1364.48	1949.26	6.6100	6.875E+00	4.76	11	1	2.74	28
AG110M	1383.59	1976.56	.54500	5.669E-01	24.59	7	1	1.98	29

4 - 7 - 1977 1251.09
 HRB-12; EMPTY SLEEVE; POS.= ROD# 9 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CE144	132.67	189.52	9.7900	1.009E+01	13.10	8	1	1.85	1
CS134	474.61	678.01	7.7575	8.001E+00	11.80	7	1	2.02	2
CS134	562.61	803.73	30.353	3.130E+01	3.76	19	2	2.04	3
CS134	568.71	812.44	56.876	5.866E+01	2.92	19	2	1.95	4
CS134	604.07	862.96	345.91	3.568E+02	0.62	11	1	1.94	5
AG110M	657.29	938.99	4.2417	4.375E+00	10.25	15	2	2.70	6
CS137	660.98	944.25	102.27	1.054E+02	1.40	15	2	2.00	7
CS134	795.22	1136.03	245.16	2.528E+02	0.72	20	2	2.10	8
CS134	801.36	1144.80	23.866	2.461E+01	2.78	20	2	2.08	9
???	817.72	1168.16	2.6025	2.684E+00	13.09	9	1	2.39	10
???	834.17	1191.67	4.3825	4.520E+00	8.35	9	1	2.18	11
AG110M	883.95	1262.79	2.3600	2.434E+00	12.81	8	1	2.34	12

AG110M	936.81	1338.30	1.2420	1.279E+00	22.06	8	1	2.05	13
CS134	1037.90	1482.72	2.3800	2.454E+00	9.82	7	1	2.26	14
???	1047.21	1496.01	1.4230	1.464E+00	16.69	8	1	1.92	15
???	1099.61	1570.87	.30250	3.120E-01	42.13	5	1	1.22	16
CS134	1167.42	1667.74	3.1000	3.197E+00	9.17	9	1	2.15	17
???	1172.58	1675.11	.81500	8.406E-01	20.26	6	1	1.47	18
???	1241.58	1773.69	.52000	5.363E-01	27.33	8	1	1.51	19
???	1331.70	1902.42	1.1050	1.139E+00	14.57	10	1	2.01	20
CS134	1364.40	1949.14	6.1450	6.338E+00	4.36	11	1	2.31	21
AG110M	1383.35	1976.22	1.0150	1.046E+00	12.05	7	1	2.14	22

4 - 7 - 1977 1255.09

HRB-12; EMPTY SLEEVE; POS. = ROD#10 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
PA233	87.95	125.65	3.5450	3.665E+00	28.90	6	1	1.55	1
EUI55									
CS134	474.58	677.97	7.3400	7.589E+00	12.93	7	1	1.51	2
CS134	562.61	803.73	33.355	3.448E+01	3.51	18	2	1.94	3
CS134	568.62	812.32	58.814	6.081E+01	2.79	18	2	1.95	4
CS134	604.07	862.95	371.98	3.846E+02	0.60	11	1	1.99	5
AG110M	657.24	938.92	4.6109	4.767E+00	9.75	14	2	1.98	6
CS137	660.97	914.24	110.15	1.138E+02	1.32	14	2	1.99	7
ZR95	722.95	1032.78	1.3900	1.437E+00	26.10	6	1	1.67	8
EUI54									
CS134	795.21	1136.02	262.41	2.713E+02	0.70	20	2	2.09	9
CS134	801.33	1144.75	26.410	2.730E+01	2.04	20	2	2.05	10
???	810.83	1158.33	1.1900	1.230E+00	24.78	7	1	1.77	11
???	817.69	1168.13	2.7325	2.825E+00	11.55	7	1	1.79	12
???	834.30	1191.86	6.2800	6.493E+00	6.21	10	1	1.91	13
AG110M	884.02	1262.88	2.7700	2.864E+00	13.17	9	1	2.43	14
AG110M	936.87	1338.38	1.1900	1.230E+00	23.09	8	1	2.46	15
CS134	1038.04	1482.91	2.1650	2.238E+00	14.44	10	2	2.21	16
???	1047.44	1496.34	1.3325	1.377E+00	17.78	7	1	1.67	17
???	1153.06	1647.23	1.2750	1.318E+00	14.17	6	1	1.95	18
CS134	1167.12	1667.32	2.8700	2.967E+00	11.88	10	1	2.11	19
???	1229.93	1757.05	.62500	6.462E-01	24.33	6	1	1.85	20
???	1331.46	1902.09	1.1200	1.158E+00	12.27	7	1	2.44	21
CS134	1364.36	1949.08	6.3275	6.542E+00	4.66	11	1	2.55	22
AG110M	1383.45	1976.35	.81000	8.374E-01	13.44	6	1	1.64	23

4 - 7 - 1977 1259.53

HRB-12; EMPTY SLEEVE; POS. = ROD# 11 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	474.66	678.08	7.3850	7.628E+00	15.43	9	1	1.76	1
CS134	562.50	803.57	31.425	3.246E+01	3.89	9	1	1.90	2
CS134	568.71	812.44	55.850	5.769E+01	2.56	10	1	1.91	3
CS134	604.06	862.94	364.40	3.764E+02	0.63	13	1	2.01	4
???	645.59	922.28	1.1775	1.216E+00	37.76	5	1	0.97	5
AG110M	657.23	938.89	5.0689	5.236E+00	8.94	18	3	2.30	6

CS137	660.88	944.12	112.62	1.163E+02	1.43	18	3	1.77	7
CS134	795.22	1136.03	254.71	2.631E+02	0.72	21	2	2.08	8
CS134	801.36	1144.80	26.674	2.755E+01	2.61	21	2	2.06	9
???	817.66	1168.09	3.1900	3.295E+00	10.53	8	1	2.49	10
???	834.16	1191.66	5.7075	5.895E+00	6.75	9	1	1.59	11
AG110M	883.93	1262.75	3.0500	3.150E+00	10.77	8	1	2.22	12
CS134	1037.99	1482.85	2.4050	2.484E+00	12.69	10	1	2.13	13
CS134	1167.26	1667.52	3.8567	3.984E+00	7.98	15	2	2.37	14
???	1172.47	1674.96	1.7132	1.769E+00	12.37	15	2	2.44	15
???	1331.55	1902.22	1.4425	1.490E+00	11.67	9	1	2.20	16
CS134	1364.38	1949.11	6.0900	6.290E+00	4.51	12	1	2.37	17
AG110M	1383.34	1976.20	.81500	8.418E-01	17.90	10	2	1.09	18

4 - 7 - 1977 1303.16

HRB-12; EMPTY SLEEVE; POS.= ROD# 12 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	562.68	803.83	18.052	1.838E+01	4.82	18	2	1.90	1
CS134	568.72	812.45	29.027	2.955E+01	3.99	18	2	1.96	2
CS134	604.11	863.01	187.30	1.908E+02	0.85	11	1	1.96	3
AG110M	657.32	939.03	4.1542	4.229E+00	8.80	14	2	1.70	4
CS137	661.01	944.30	58.905	5.997E+01	1.77	14	2	2.04	5
CS134	795.25	1136.07	133.42	1.358E+02	0.96	19	2	2.05	6
CS134	801.32	1144.75	12.658	1.288E+01	3.76	19	2	2.09	7
???	817.81	1168.30	1.9550	1.990E+00	13.48	10	1	2.70	8
???	834.25	1191.78	6.2100	6.323E+00	5.00	8	1	2.31	9
AG110M	884.10	1263.00	.96000	9.770E-01	36.80	12	2	1.50	10
AG110M	936.80	1338.28	1.1800	1.201E+00	14.93	7	1	2.46	11
CS134	1037.92	1482.75	1.1200	1.140E+00	16.75	8	1	2.45	12
???	1047.55	1496.51	1.1500	1.170E+00	14.31	8	1	2.34	13
CS134	1167.28	1667.54	2.0890	2.127E+00	11.13	17	2	2.59	14
???	1172.64	1675.20	1.3284	1.352E+00	14.04	17	2	2.07	15
???	1331.68	1902.40	1.0400	1.058E+00	13.31	9	1	2.44	16
CS134	1364.50	1949.29	3.1200	3.176E+00	6.02	11	1	2.64	17
AG110M	1383.38	1976.26	.55000	5.600E-01	20.43	15	4	1.38	18

4 - 7 - 1977 1307.01

HRB-12; EMPTY SLEEVE; POS.= ROD# 13, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	474.82	678.32	2.3975	2.426E+00	28.48	9	1	3.38	1
CS134	562.67	803.82	11.381	1.152E+01	5.92	18	2	2.01	2
CS134	568.71	812.44	18.968	1.919E+01	4.80	18	2	1.86	3
CS134	604.10	863.01	114.44	1.158E+02	1.12	12	1	1.95	4
AG110M	657.36	939.08	2.3584	2.387E+00	12.25	14	2	1.99	5
CS137	661.01	944.29	39.791	4.027E+01	2.11	14	2	2.02	6
CS134	795.25	1136.07	78.794	7.975E+01	1.27	19	2	2.09	7
CS134	801.42	1144.88	8.4000	8.502E+00	1.62	19	2	1.80	8
???	817.89	1168.41	1.0400	1.052E+00	17.09	7	1	2.50	9
???	834.29	1191.84	6.2850	6.301E+00	4.94	9	1	2.14	10
AG110M	883.80	1262.58	1.6600	1.680E+00	17.86	15	2	1.83	11

1/0

CS134	1037.97	1482.82	1.0225	1.034E+00	14.24	9	1	2.42	12
???	1074.62	1535.17	.21250	2.150E-01	37.48	5	1	1.10	13
???	1119.70	1599.57	.45500	4.605E-01	26.62	6	1	1.48	14
CS134	1167.14	1667.34	1.4695	1.437E+00	11.35	16	3	2.00	15
???	1172.48	1674.98	1.2104	1.225E+00	12.66	16	3	1.92	16
???	1332.03	1902.86	1.2200	1.234E+00	11.76	12	2	2.29	17
CS134	1364.43	1949.16	2.3550	2.383E+00	6.85	18	3	1.72	18

4 - 7 -1977 1318.42
HRB-12; EMPTY SLEEVE; POS.= ROD# 14, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CE144	132.72	189.60	2.7325	2.776E+00	24.27	5	1	1.84	1
CS134	474.59	677.99	1.5650	1.590E+00	37.26	6	1	1.26	2
CS134	562.65	803.79	15.695	1.594E+01	5.63	22	2	1.85	3
CS134	568.72	812.46	25.350	2.575E+01	4.79	22	2	1.99	4
CS134	604.10	863.00	158.08	1.606E+02	0.93	11	1	1.97	5
CS137	660.89	944.13	62.995	6.400E+01	1.68	15	2	1.83	6
NB95	765.11	1093.02	3.7700	3.830E+00	9.46	8	1	2.31	7
AG110M									
CS134	795.24	1136.06	111.37	1.131E+02	1.07	20	2	2.00	8
CS134	801.32	1144.75	11.202	1.138E+01	3.93	20	2	2.08	9
???	834.28	1191.83	6.3100	6.411E+00	5.05	10	1	2.11	10
AG110M	884.25	1263.21	1.0700	1.087E+00	16.84	6	1	2.42	11
???	888.96	1269.94	.63500	6.451E-01	22.50	5	1	1.06	12
CS134	1038.15	1483.08	1.0900	1.107E+00	14.93	8	1	1.84	13
???	1047.43	1496.33	.61500	6.248E-01	22.13	6	1	1.49	14
CS134	1167.37	1667.66	1.6600	1.686E+00	11.68	8	1	2.06	15
???	1172.60	1675.15	1.1550	1.173E+00	14.46	7	1	1.94	16
???	1235.03	1764.33	.22750	2.311E-01	26.67	5	1	1.25	17
???	1331.88	1902.69	1.1300	1.148E+00	11.23	8	1	2.22	18
CS134	1364.40	1949.14	2.7250	2.768E+00	6.70	10	1	2.27	19

4 - 7 - 1977 1314.04
HRB-12 EMPTY SLEEVE; POS. = ROD# 15, 1/8 IN. SLIT

[illegible]

ZR95	756.09	1080.12	14.495	1.478E+01	3.81	10	1	2.08	14
EUI54									
NB95	765.17	1093.09	40.880	4.168E+01	1.91	12	1	2.10	15
AG110M									
CS134	795.24	1136.06	120.00	1.223E+02	1.01	20	2	2.03	16
CS134	801.38	1144.83	11.781	1.201E+01	3.86	20	2	2.06	17
???	834.17	1191.67	1.3675	1.394E+00	16.00	7	1	1.91	18
AG110M	884.10	1263.00	1.9872	2.026E+00	13.86	15	2	2.05	19
???	888.65	1269.50	1.0652	1.086E+00	18.43	15	2	2.27	20
AG110M	936.80	1338.29	.99000	1.009E+00	20.48	8	1	2.58	21
CS134	1037.65	1482.36	.68000	6.933E-01	30.07	10	1	2.10	22
CS134	1167.42	1667.74	1.9578	1.996E+00	10.45	17	2	2.30	23
???	1172.95	1675.65	1.8971	1.934E+00	10.52	17	2	2.04	24
???	1331.87	1902.66	1.3100	1.335E+00	11.80	8	1	2.24	25
CS134	1364.48	1949.26	2.8100	2.865E+00	6.67	10	1	2.19	26
AG110M	1383.38	1976.26	.51000	5.200E-01	19.95	10	2	1.42	27

4 - 7 -1977 1317.32
HRB-12 EMPTY SLEEVE; POS.= ROD# 16, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	562.71	803.87	7.1550	7.220E+00	6.96	7	1	2.00	1
CS134	568.77	812.53	10.947	1.104E+01	5.86	9	1	1.87	2
CS134	604.10	863.01	78.110	7.882E+01	1.45	15	2	1.96	3
CS137	660.94	944.20	30.245	3.052E+01	2.53	15	2	1.66	4
CS134	795.28	1136.11	56.745	5.726E+01	1.50	23	2	2.03	5
CS134	801.44	1144.91	5.5343	5.585E+00	5.68	20	2	2.11	6
???	834.25	1191.79	1.4725	1.486E+00	13.64	9	1	2.09	7
AG110M	884.13	1263.04	.92002	9.284E-01	17.82	14	2	1.75	8
???	888.34	1269.06	.89998	9.082E-01	18.13	14	2	1.25	9
CS134	1037.93	1482.76	.43000	4.339E-01	29.69	8	1	2.89	10
???	1119.94	1599.91	.76000	7.669E-01	16.57	6	1	1.92	11
CS134	1167.29	1667.56	.85250	8.603E-01	16.82	7	1	2.10	12
???	1172.63	1675.19	1.2300	1.241E+00	12.36	8	1	2.42	13
???	1331.85	1902.65	1.2700	1.281E+00	9.68	8	1	2.48	14
CS134	1364.65	1949.50	1.1725	1.183E+00	10.06	9	1	2.04	15

4 - 7 -1977 1321.09
HRB-12 EMPTY SLEEVE; POS.= ROD# 17, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	562.65	803.78	15.151	1.540E+01	5.30	18	2	2.01	1
CS134	568.67	812.39	27.488	2.794E+01	4.17	18	2	2.00	2
CS134	604.10	863.00	74.44	1.773E+02	0.88	11	1	1.95	3
AG110M	657.32	939.03	4.4030	4.476E+00	8.45	17	2	2.34	4
CS137	661.01	944.30	67.199	6.832E+01	1.68	17	2	2.04	5
AG110M	706.18	1008.83	.61000	6.202E-01	37.86	5	1	0.95	6
CS134	795.25	1136.06	124.19	1.262E+02	1.00	19	2	2.10	7
CS134	801.35	1144.79	12.917	1.313E+01	3.73	19	2	1.97	8
???	834.27	1191.82	1.4550	1.479E+00	18.37	10	1	1.92	9
AG110M	883.91	1262.72	2.2100	2.247E+00	11.24	8	1	1.90	10

???	888.79	1269.70	.55250	5.617E-01	29.53	5	1	1.53	11
CS134	1038.05	1482.93	.98500	1.001E+00	17.03	7	1	1.75	12
???	1119.69	1599.56	.46000	4.677E-01	37.53	8	1	2.40	13
CS134	1167.30	1637.57	1.5904	1.617E+00	13.00	17	2	2.49	14
???	1172.34	1674.77	1.6620	1.689E+00	12.69	17	2	1.41	15
???	1331.73	1902.47	1.9700	2.002E+00	8.02	10	1	2.48	16
CS134	1364.35	1949.07	3.0500	3.101E+00	6.05	10	1	2.35	17
AG110M	1383.55	1976.50	.40500	4.117E-01	22.32	6	1	1.56	18

4 - 7 - 1977 1328.57
HRB-12 EMPTY SLEEVE; POS. = ROD# 18, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	65.90	94.15	1.3703	1.387E+00	40.39	5	1	0.98	1
CS134	474.92	678.46	1.8750	1.899E+00	31.24	7	1	1.67	2
CS134	562.60	823.72	10.560	1.069E+01	6.38	17	2	2.07	3
CS134	568.75	812.50	20.457	2.072E+01	4.80	17	2	1.89	4
CS134	604.10	863.00	129.58	1.312E+02	1.02	11	1	1.95	5
AG110M	657.22	930.89	3.5353	3.580E+00	9.68	16	2	2.01	6
CS137	661.00	944.28	46.194	4.679E+01	2.05	16	2	2.09	7
CS134	795.26	1136.08	92.056	9.324E+01	1.19	21	2	2.11	8
CS134	801.39	1144.85	9.0038	9.120E+00	4.54	21	2	2.09	9
???	817.93	1168.47	1.0425	1.055E+00	18.18	7	1	1.96	10
???	834.18	1191.60	1.4600	1.478E+00	13.30	7	1	1.78	11
AG110M	883.86	1262.66	1.7419	1.764E+00	13.41	13	2	1.73	12
???	888.51	1269.29	.82310	2.337E-01	16.82	13	2	1.31	13
AG110M	936.83	1338.33	.89000	9.014E-01	20.19	8	1	2.47	14
CS134	1037.90	1482.72	.71000	7.191E-01	20.65	8	1	2.21	15
???	1047.18	1495.96	.47000	4.720E-01	23.86	5	1	0.91	16
???	1119.97	1599.96	.68250	5.913E-01	21.12	7	1	1.98	17
CS134	1167.08	1667.25	1.5477	1.567E+00	12.11	15	2	2.15	18
???	1172.52	1675.03	1.1172	1.131E+00	14.50	15	2	2.40	19
???	1331.88	1902.69	1.1550	1.169E+00	10.93	9	1	2.09	20
CS134	1364.44	1949.21	2.1625	2.190E+00	6.96	11	1	2.02	21
AG110M	1383.37	1976.25	.54000	5.469E-01	17.47	10	2	1.44	22

4 - 7 - 1977 1332.25
HRB-12 EMPTY SLEEVE; POS. = ROD# 19, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	474.41	677.72	2.1750	2.175E+00	21.61	7	1	2.14	1
CS134	562.68	803.82	7.8775	7.951E+00	7.65	9	1	1.79	2
CS134	568.73	812.47	14.137	1.426E+01	4.68	9	1	2.03	3
CS134	604.13	863.05	88.030	8.885E+01	1.27	12	1	1.93	4
AG110M	657.30	939.00	2.7244	2.749E+00	10.44	15	2	2.28	5
CS137	661.06	944.37	29.653	2.993E+01	2.52	15	2	2.02	6
CS134	795.25	1136.08	61.377	6.195E+01	1.46	20	2	2.09	7
CS134	801.38	1144.82	6.8125	6.876E+00	5.14	20	2	1.80	8
AG110M	884.11	1263.01	1.6118	1.626E+00	13.42	14	2	2.04	9

???	888.80	1269.72	.85319	8.611E-01	18.47	14	2	2.39	10
CS134	1037.98	1482.83	.64750	6.535E-01	24.30	9	1	2.83	11
???	1047.51	1496.45	.71000	7.166E-01	23.86	12	2	2.66	12
???	1120.15	1600.21	.72000	7.267E-01	15.96	6	1	1.40	13
CS134	1167.23	1667.47	1.1390	1.149E+00	15.12	16	2	1.84	14
???	1172.53	1675.04	1.3209	1.333E+00	13.76	16	2	2.67	15
???	1332.07	1902.95	1.3950	1.408E+00	10.16	10	1	2.19	16
CS134	1364.41	1949.16	1.3750	1.387E+00	9.79	9	1	2.79	17
AG110M	1383.87	1976.96	.43500	4.390E-01	18.41	11	3	1.30	18

4 - 7 -1977 1336.13

HRB-12 EMPTY SLEEVE; POS.= ROD# 20, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
EUI55	58.83	84.05	1.2425	1.249E+00	32.03	5	1	0.92	1
CS134	562.55	803.64	4.1425	4.165E+00	8.85	7	1	1.82	2
CS134	568.85	812.65	6.9100	6.947E+00	7.38	10	1	2.00	3
CS134	604.15	863.07	42.195	4.242E+01	1.79	11	1	1.89	4
AG110M	657.32	939.03	1.5400	1.548E+00	13.31	14	2	2.68	5
CS137	661.12	944.45	13.860	1.393E+01	3.64	14	2	1.92	6
CS134	795.27	1136.10	28.480	2.863E+01	2.08	11	1	1.95	7
CS134	801.28	1144.69	2.4600	2.473E+00	8.62	8	1	1.80	8
AG110M	884.10	1263.00	.85750	8.621E-01	19.28	7	1	1.99	9
???	888.63	1269.47	.60500	6.083E-01	20.65	7	1	1.62	10
CS134	1038.24	1483.20	.43250	4.348E-01	25.71	9	2	1.35	11
???	1172.54	1675.05	.96000	9.652E-01	16.34	8	1	2.44	12
???	1331.41	1902.01	.58871	5.919E-01	14.01	9	2	2.20	13
???	1332.09	1903.84	.76379	7.679E-01	12.24	9	2	1.35	14
CS134	1364.65	1949.50	.82000	8.244E-01	11.44	8	1	2.57	15

4 - 7 -1977 1339.53

HRB-12 EMPTY SLEEVE; POS.= ROD# 21, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	562.67	803.81	2.7100	2.723E+00	14.47	8	1	1.70	1
CS134	568.67	812.39	5.9200	5.949E+00	7.38	9	1	2.06	2
CS134	604.13	863.04	34.977	3.515E+01	2.04	11	1	1.99	3
AG110M	657.15	938.79	1.6665	1.674E+00	13.49	15	2	2.51	4
CS137	661.07	944.38	11.533	1.159E+01	4.33	15	2	2.12	5
CS134	795.27	1136.10	25.707	2.583E+01	2.30	20	2	2.10	6
CS134	801.49	1144.98	2.8922	2.906E+00	8.04	20	2	1.82	7
AG110M	884.12	1263.03	1.2164	1.222E+00	14.82	13	2	1.62	8
???	888.42	1269.17	.69857	7.020E-01	19.08	13	2	2.15	9
???	963.87	1376.95	.26000	2.612E-01	38.07	8	1	0.80	10
???	1120.08	1600.12	.71750	7.210E-01	18.00	9	2	3.38	11
???	1172.70	1675.29	.92250	9.270E-01	15.07	7	1	2.00	12
???	1332.09	1902.98	1.4700	1.477E+00	9.09	14	2	2.58	13
CS134	1364.50	1949.29	.67500	6.783E-01	12.94	10	1	2.71	14

4 - 7 -1977 1343.36
 HRB-12 EMPTY SLEEVE; POS.= ROD# 22, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	562.67	803.82	4.7375	4.767E+00	9.04	7	1	2.02	1
CS134	568.74	812.49	9.5075	9.568E+00	5.51	9	1	1.85	2
CS134	604.14	863.05	57.052	5.741E+01	1.55	11	1	1.97	3
AG110M	657.27	938.96	2.8455	2.863E+00	9.44	17	3	1.34	4
CS137	660.93	944.18	17.849	1.796E+01	3.48	17	3	1.66	5
CS134	795.27	1136.10	40.564	4.082E+01	1.76	19	2	1.93	6
CS134	801.40	1144.86	3.7358	3.759E+00	6.80	19	2	1.99	7
AG110M	936.89	1338.42	.69500	6.994E-01	23.18	9	1	1.22	8
CS134	1037.70	1482.43	.44000	4.428E-01	26.31	6	1	2.68	9
???	1119.68	1599.54	.45500	4.579E-01	23.75	6	1	1.64	10
???	1172.81	1675.44	1.0400	1.046E+00	13.80	8	1	2.54	11
???	1331.99	1902.84	1.2350	1.242E+00	9.72	11	1	2.03	12
CS134	1364.45	1949.21	.89000	8.956E-01	11.60	10	1	1.72	13
AG110M	1383.98	1977.12	.28500	2.868E-01	23.04	9	1	3.19	14

4 - 7 -1977 1347.23
 HRB-12 EMPTY SLEEVE; POS.= ROD# 23, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	474.70	678.14	.66750	6.710E-01	42.39	5	1	0.77	1
CS134	562.65	803.78	3.9900	4.011E+00	10.19	8	1	1.97	2
CS134	568.72	812.45	7.4950	7.535E+00	6.25	9	1	1.88	3
CS134	604.15	863.08	45.285	4.552E+01	1.70	10	1	1.92	4
CS137	660.92	944.18	15.450	1.553E+01	3.69	16	2	1.59	5
CS134	795.28	1136.11	32.612	3.278E+01	2.04	19	2	2.11	6
CS134	801.41	1144.87	3.0805	3.096E+00	7.96	19	2	2.12	7
???	818.07	1168.67	.27000	2.714E-01	42.55	6	1	1.48	8
???	1047.27	1496.10	.20000	2.010E-01	36.66	5	1	1.07	9
???	1120.15	1600.21	.58000	5.830E-01	19.20	8	1	2.71	10
???	1172.68	1675.26	.92250	9.274E-01	16.48	9	1	1.95	11
???	1332.02	1902.88	.97000	9.751E-01	10.76	12	1	2.31	12
CS134	1364.49	1949.27	.66000	6.635E-01	14.37	8	1	2.09	13

4 - 7 -1977 1351.14
 HRB-12 EMPTY SLEEVE; POS.= ROD# 24, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
CS134	568.79	812.56	3.3000	3.311E+00	9.48	8	1	1.99	1
CS134	604.16	863.08	18.050	1.811E+01	2.87	10	1	2.00	2
AG110M	657.10	938.71	1.4082	1.412E+00	13.48	14	2	1.65	3
CS137	661.17	944.53	6.6817	6.704E+00	5.50	14	2	2.03	4
CS134	795.27	1136.10	12.401	1.244E+01	3.39	17	2	2.13	5
CS134	801.22	1144.60	1.6632	1.668E+00	10.62	17	2	1.70	6
AG110M	936.64	1338.06	.31500	3.160E-01	33.33	6	1	1.50	7
???	1120.30	1600.43	.58000	5.819E-01	20.98	8	1	2.22	8
???	1172.86	1675.51	1.1825	1.186E+00	12.77	9	1	1.88	9
???	1332.01	1902.86	1.0550	1.058E+00	11.26	15	2	1.89	10
CS134	1363.89	1948.41	.28000	2.809E-01	24.55	7	1	1.94	11

4 - 7 -1977 1355.33
 HRB-12 EMPTY SLEEVE; POS.= ROD#25, 1/8 IN. SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BASE WIDTH	MU	FWHM (KEV)	PK #
???	65.26	93.23	.81750	8.193E-01	35.89	5	1	1.06	1
RU103	293.88	419.83	.52500	5.262E-01	37.89	5	1	0.79	2
CS134	604.13	863.04	5.1850	5.196E+00	5.73	9	1	1.72	3
AG110M	657.35	939.08	1.0489	1.051E+00	15.72	14	2	1.63	4
CS137	661.12	944.46	2.4160	2.421E+00	10.32	14	2	1.86	5
CS134	795.33	1136.19	3.8650	3.873E+00	6.05	9	1	1.86	6
CS134	800.93	1144.18	.26750	2.681E-01	34.63	5	1	1.22	7
???	888.40	1269.14	1.0200	1.022E+00	23.50	14	2	1.23	8
???	1119.98	1599.97	.48500	4.861E-01	22.19	7	1	2.07	9
???	1172.66	1675.23	1.3650	1.368E+00	10.30	10	1	2.28	10
???	1331.74	1902.48	1.3600	1.363E+00	9.12	8	1	2.40	11

Annex C4. Gamma Spectra Acquired from HRB-12 Fuel Rods

2 - 9 -1977 1550.34
HRB 12 ROD 1 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
TE125	111.02	156.45	7.9800	1.007E+01	39.21	5	1	1.25	1
PA233									
CE141	145.65	205.83	65.380	8.258E+01	7.79	8	1	2.21	2
???	271.49	385.27	23.860	3.013E+01	18.27	8	1	2.22	3
PA233	300.18	426.16	413.85	5.227E+02	1.58	11	1	2.09	4
PA233	311.99	443.01	2561.1	3.235E+03	0.42	26	2	2.08	5
???	320.24	454.77	1123.4	1.419E+03	0.61	26	2	2.12	6
???	328.84	467.02	52.295	6.605E+01	7.91	9	1	2.19	7
PA233	340.61	483.81	293.82	3.711E+02	1.78	11	1	2.10	8
???	364.60	518.01	43.840	5.537E+01	8.06	8	1	1.88	9
PA233	375.60	533.68	41.760	5.274E+01	8.43	8	1	2.09	10
PA233	398.50	566.33	85.580	1.080E+02	4.57	9	1	2.03	11
PA233	415.80	591.00	112.73	1.423E+02	4.92	14	2	2.09	12
???	487.07	692.59	101.44	1.281E+02	4.49	11	1	2.27	13
RU103	497.17	706.98	135.02	1.705E+02	3.19	10	1	2.23	14
???	537.32	764.21	48.975	6.186E+01	7.56	9	1	2.19	15
CS134	604.58	860.08	37.890	4.786E+01	9.48	10	1	2.40	16
CS137	661.49	941.18	16.975	2.144E+01	13.48	7	1	2.32	17
ZR95	724.22	1030.58	240.66	3.039E+02	1.76	13	1	2.37	18
EU154									
ZR95	756.78	1076.97	273.13	3.450E+02	1.37	25	2	2.26	19
EU154									
NB95	765.87	1089.93	653.82	8.258E+02	0.88	25	2	2.28	20
AG110M									
CS134	795.89	1132.70	20.060	2.533E+01	14.15	10	1	2.15	21
???	810.84	1154.01	45.443	5.740E+01	6.27	19	2	2.20	22
???	815.78	1161.06	43.761	5.527E+01	6.38	19	2	2.50	23
???	834.84	1188.21	65.570	8.295E+01	4.80	11	1	2.22	24
???	867.79	1235.15	8.6800	1.096E+01	23.72	7	1	2.16	25
???	925.35	1317.17	11.140	1.407E+01	18.62	7	1	2.18	26
???	1099.28	1564.94	109.56	1.383E+02	2.82	12	1	2.43	27
???	1173.30	1670.38	400.96	5.064E+02	0.95	13	1	2.57	28
???	1291.68	1838.99	73.380	9.268E+01	2.92	11	1	2.62	29
???	1332.60	1897.26	367.67	4.644E+02	0.95	14	1	2.59	30

2 - 9 -1977 1546.16
HRB 12 ROD 2 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
CE141	145.67	205.86	57.625	7.384E+01	10.00	9	1	2.02	1
???	271.66	385.51	9.4050	1.205E+01	33.10	5	1	1.41	2
PA233	300.14	426.11	450.72	5.775E+02	1.18	43	5	2.22	3
PA233	311.98	442.99	2614.4	3.350E+03	0.49	43	5	2.12	4
???	320.31	454.86	1265.0	1.621E+03	0.65	43	5	2.47	5
???	328.87	467.07	52.120	6.679E+01	8.90	10	1	2.01	6
PA233	340.57	483.75	292.43	3.747E+02	1.73	10	1	2.14	7
???	364.53	517.90	50.725	6.500E+01	7.83	9	1	2.22	8

PA233	375.65	533.76	43.105	5.523E+01	9.15	9	1	2.08	9
PA233	398.55	566.41	86.130	1.103E+02	5.05	10	1	2.26	10
PA233	415.78	590.96	112.42	1.440E+02	3.57	9	1	2.29	11
???	487.02	692.52	109.21	1.399E+02	3.95	10	1	2.34	12
RUI03	497.14	706.94	141.33	1.811E+02	3.12	10	1	2.19	13
RUI06	510.45	725.92	12.050	1.544E+01	22.87	6	1	2.17	14
???	537.31	764.20	46.080	5.905E+01	7.65	8	1	2.14	15
CS134	604.29	859.67	36.255	4.645E+01	9.46	9	1	2.62	16
ZR95	724.18	1030.52	248.86	3.189E+02	1.66	12	1	2.41	17
EUI54									
ZR95	756.77	1076.97	292.27	3.745E+02	1.85	17	2	2.37	18
EUI54									
NB95	765.84	1089.89	681.01	8.726E+02	0.83	15	1	2.31	19
AG110M									
CS134	795.74	1132.50	26.600	3.408E+01	9.21	8	1	2.42	20
???	810.87	1154.05	36.390	4.663E+01	6.83	16	2	2.71	21
???	815.77	1161.04	38.809	4.973E+01	6.69	16	2	1.96	22
???	834.77	1188.11	70.570	9.043E+01	4.72	11	1	2.18	23
???	867.81	1235.18	5.6800	7.278E+00	38.09	7	1	1.81	24
???	925.15	1316.88	10.735	1.375E+01	20.28	7	1	1.81	25
???	1099.27	1564.93	116.55	1.493E+02	2.63	11	1	2.38	26
???	1173.26	1670.33	435.78	5.584E+02	0.87	12	1	2.59	27
???	1291.62	1838.90	82.395	1.055E+02	2.82	11	1	2.56	28
???	1332.48	1897.09	406.83	5.213E+02	0.99	19	1	2.57	29

2 - 9 - 1977 1542.23

HRB 12 ROD 3 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
CE144	133.51	188.52	9.3900	1.209E+01	41.49	6	1	1.32	1
CE141	145.46	205.57	61.785	7.956E+01	9.39	9	1	1.71	2
???	271.61	385.44	22.690	2.922E+01	15.93	6	1	1.65	3
PA233	300.14	426.12	393.57	5.068E+02	1.71	11	1	2.10	4
PA233	311.96	442.96	2456.6	3.163E+03	0.43	26	2	2.12	5
???	320.20	454.70	1329.6	1.712E+03	0.56	26	2	2.13	6
???	328.86	467.05	48.325	6.223E+01	8.93	9	1	2.12	7
PA233	340.56	483.73	273.43	3.521E+02	2.34	14	1	2.13	8
???	364.53	517.91	43.135	5.554E+01	9.39	9	1	2.02	9
PA233	375.45	533.47	39.580	5.097E+01	9.25	8	1	1.93	10
PA233	398.45	566.27	89.115	1.147E+02	4.50	9	1	2.14	11
PA233	415.78	590.96	103.82	1.337E+02	4.90	12	1	2.15	12
???	487.00	692.49	110.18	1.418E+02	4.22	11	1	2.15	13
RUI03	497.10	706.88	138.42	1.782E+02	3.42	11	1	2.22	14
???	537.26	764.13	42.240	5.439E+01	8.37	8	1	2.06	15
CS134	604.28	859.64	45.100	5.808E+01	8.32	10	1	2.72	16
CS137	661.72	941.51	15.385	1.981E+01	15.59	7	1	2.06	17
ZR95	724.16	1030.50	230.74	2.971E+02	1.82	12	1	2.47	18
EUI54									
ZR95	756.76	1076.94	276.98	3.566E+02	1.48	11	1	2.33	19
EUI54									
NB95	765.83	1089.87	636.88	8.201E+02	0.87	14	1	2.36	20
AG110M									
CS134	796.00	1132.87	28.405	3.658E+01	8.10	7	1	2.20	21
???	810.85	1154.02	41.128	5.296E+01	6.44	16	2	2.56	22
???	815.88	1161.19	38.311	4.933E+01	6.78	16	2	2.90	23
???	834.79	1188.14	79.210	1.020E+02	3.97	10	1	2.35	24
???	868.01	1235.48	7.0100	9.027E+00	31.59	7	1	2.20	25

???	925.17	1316.91	6.9200	8.911E+00	36.18	8	1	1.14	26
???	1099.27	1564.93	131.19	1.689E+02	2.46	11	1	2.46	27
???	1173.27	1570.34	474.52	6.110E+02	0.93	16	1	2.57	28
???	1291.50	1838.74	94.355	1.215E+02	2.48	11	1	2.64	29
???	1332.46	1897.07	429.13	5.526E+02	0.88	14	1	2.62	30

2 - 9 -1977 1538.23

HRB 12 ROD 4 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
CE141	145.56	205.71	51.225	6.632E+01	9.37	7	1	1.99	1
PA233	300.11	426.07	370.06	4.791E+02	1.93	12	1	2.14	2
PA233	311.94	442.94	2335.3	3.023E+03	0.44	26	2	2.14	3
???	320.19	454.69	1458.1	1.888E+03	0.54	26	2	2.17	4
???	328.89	467.09	42.490	5.501E+01	11.11	10	1	2.03	5
PA233	340.58	483.76	270.28	3.499E+02	2.11	12	1	2.16	6
???	364.50	517.86	44.875	5.810E+01	9.03	9	1	2.05	7
PA233	375.38	533.37	35.860	4.643E+01	10.33	8	1	2.26	8
PA233	398.41	566.21	78.280	1.013E+02	5.18	9	1	2.13	9
PA233	415.76	590.94	95.220	1.232E+02	4.61	10	1	2.16	10
???	487.06	692.57	97.770	1.265E+02	4.49	10	1	2.18	11
RUI03	497.09	706.88	135.39	1.753E+02	3.27	10	1	2.21	12
???	537.26	764.13	43.520	5.635E+01	10.45	11	1	2.30	13
CS134	604.55	860.03	43.605	5.646E+01	8.04	9	1	2.31	14
CS137	661.70	941.48	14.860	1.924E+01	14.68	6	1	2.08	15
ZR95	724.17	1030.50	225.98	2.926E+02	1.87	12	1	2.41	16
EUI54									
ZR95	756.74	1076.92	265.64	3.439E+02	1.56	11	1	2.30	17
EUI54									
NB95	765.83	1089.87	616.01	7.976E+02	0.90	14	1	2.36	18
AG110M									
CS134	795.94	1132.78	28.205	3.652E+01	10.08	9	1	2.31	19
???	810.80	1153.95	37.888	4.905E+01	7.13	16	2	2.41	20
???	815.81	1161.09	34.311	4.442E+01	7.67	16	2	2.40	21
???	834.75	1188.08	78.820	1.320E+02	3.85	9	1	2.48	22
???	1099.28	1564.95	145.01	1.877E+02	2.30	11	1	2.48	23
???	1173.25	1670.32	497.49	6.441E+02	0.88	14	1	2.59	24
???	1291.53	1838.77	108.26	1.401E+02	2.44	13	1	2.68	25
???	1332.45	1897.05	468.16	6.061E+02	0.85	15	1	2.46	26

2 - 9 -1977 1534.32

HRB 12 ROD 5 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
CE141	145.35	205.41	58.460	7.707E+01	9.40	8	1	2.16	1
PA233	300.10	426.06	365.87	4.823E+02	1.89	11	1	2.17	2
PA233	311.91	442.89	2312.9	3.049E+03	0.45	26	2	2.16	3
???	320.07	454.53	1511.4	1.992E+03	0.55	26	2	2.20	4
???	328.62	466.72	36.820	4.854E+01	15.73	12	1	1.68	5
PA233	340.54	483.71	262.77	3.464E+02	2.12	11	1	2.25	6
???	364.44	517.78	47.115	6.211E+01	8.95	9	1	2.08	7
PA233	375.70	533.83	41.910	5.525E+01	10.90	10	2	2.84	8
PA233	398.34	566.11	81.960	1.080E+02	5.58	10	1	2.28	9
PA233	415.77	590.96	104.10	1.372E+02	4.38	10	1	2.19	10

???	438.55	623.43	7.3558	9.697E+00	33.17	5	1	1.38	11
???	486.97	692.45	102.56	1.352E+02	4.48	10	1	2.26	12
RU103	497.18	706.88	132.91	1.752E+02	3.47	10	1	2.28	13
RU106	510.68	726.24	28.800	3.797E+01	17.37	12	2	1.45	14
???	537.23	764.89	47.888	6.196E+01	7.77	8	1	2.49	15
CS134	664.23	859.58	58.260	6.626E+01	10.45	14	2	2.81	16
ZR95	724.14	1039.46	232.36	3.863E+02	1.98	12	1	2.47	17
EUI54									
ZR95	756.71	1076.87	258.76	3.411E+02	1.75	12	1	2.38	18
EUI54									
NB95	765.88	1089.83	643.96	8.498E+02	0.85	13	1	2.39	19
AG110M									
CS134	795.58	1132.15	29.545	3.895E+01	13.63	13	2	2.81	20
???	810.79	1153.93	32.913	4.339E+01	8.28	16	2	2.13	21
???	815.75	1161.01	37.187	4.902E+01	7.79	16	2	2.35	22
???	834.72	1188.04	82.770	1.091E+02	4.03	10	1	2.44	23
???	867.93	1235.36	14.840	1.956E+01	17.61	8	1	2.71	24
???	1099.14	1564.75	163.34	2.153E+02	2.21	12	1	2.54	25
???	1173.23	1670.28	525.25	6.925E+02	0.85	14	1	2.58	26
???	1187.77	1698.99	3.1700	4.179E+00	38.42	5	1	0.63	27
???	1271.36	1810.05	2.8400	3.744E+00	41.81	6	1	1.22	28
???	1291.58	1838.74	108.81	1.434E+02	2.34	11	1	2.67	29
???	1332.44	1897.04	485.94	6.406E+02	0.84	15	1	2.63	30

2 - 9 - 1977 1530.41

HRB 12 ROD 6 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	MU	FWHM (KEV)	PK #
CE141	145.53	205.66	68.260	9.114E+01	9.87	10	1	2.09	1
PA233	300.06	425.99	387.84	5.178E+02	1.92	12	1	2.10	2
PA233	311.88	442.85	2419.5	3.230E+03	0.44	26	2	2.19	3
???	320.05	454.50	1618.9	2.161E+03	0.53	26	2	2.25	4
???	328.80	466.97	38.675	5.164E+01	12.15	9	1	1.86	5
PA233	340.41	483.52	276.01	3.685E+02	2.06	11	1	2.22	6
???	364.31	517.59	45.890	6.127E+01	10.26	10	1	2.39	7
PA233	375.27	533.22	34.270	4.576E+01	12.53	9	1	2.11	8
PA233	398.38	566.16	89.180	1.190E+02	6.83	14	2	2.27	9
PA233	415.74	590.91	103.51	1.382E+02	4.15	9	1	2.26	10
???	486.95	692.42	104.22	1.391E+02	4.43	10	1	2.43	11
RU103	497.04	706.79	147.55	1.970E+02	3.40	11	1	2.37	12
???	537.25	764.11	41.210	5.502E+01	9.95	9	1	2.28	13
CS134	604.13	859.43	38.865	5.189E+01	11.15	11	1	2.55	14
ZR95	723.90	1030.12	234.68	3.133E+02	2.92	21	3	2.14	15
EUI54									
ZR95	756.68	1076.84	266.60	3.559E+02	1.74	12	1	2.32	16
EUI54									
NB95	765.68	1089.66	638.24	8.522E+02	0.93	15	1	2.47	17
AG110M									
CS134	795.65	1132.36	28.800	2.670E+01	15.21	9	1	2.70	18
???	810.69	1153.80	31.741	4.238E+01	8.40	15	2	2.41	19
???	815.62	1160.83	33.848	4.519E+01	8.18	15	2	2.16	20
???	834.76	1188.09	89.790	1.198E+02	3.88	10	1	2.44	21
???	867.15	1234.25	6.1350	8.192E+00	30.84	5	1	1.22	22
???	1099.10	1564.69	175.88	2.348E+02	2.15	12	1	2.60	23
???	1173.11	1670.11	552.98	7.384E+02	0.83	14	1	2.56	24
???	1291.47	1838.69	121.74	1.625E+02	2.26	12	1	2.61	25
???	1332.42	1897.01	513.92	6.862E+02	0.86	17	1	2.61	26

2 - 9 - 1977 1526.51
HRB 12 ROD 7 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	MU	FWHM (KEV)	PK #
PA233	98.61	138.76	18.868	1.478E+01	36.86	6	1	1.37	1
CE141	145.26	285.28	55.695	7.543E+01	11.35	9	1	2.08	2
???	271.58	385.28	14.878	2.813E+01	26.44	6	1	2.06	3
PA233	388.84	425.97	385.81	5.225E+02	1.85	11	1	2.17	4
PA233	311.86	442.82	2481.3	3.252E+03	8.45	26	2	2.21	5
???	328.82	454.45	1789.8	2.315E+03	8.52	26	2	2.38	6
???	328.68	466.68	36.598	4.955E+01	14.27	18	1	1.95	7
PA233	348.39	483.58	265.12	3.598E+02	2.85	18	1	2.21	8
???	364.25	517.58	41.495	5.628E+01	18.77	9	1	1.95	9
PA233	375.24	533.17	36.365	4.925E+01	12.85	9	1	2.15	10
PA233	398.35	566.12	81.818	1.897E+02	5.44	9	1	2.14	11
PA233	415.67	598.81	183.55	1.482E+02	4.25	9	1	2.34	12
???	423.78	602.37	6.8358	9.257E+00	38.11	5	1	1.36	13
???	486.88	692.28	182.45	1.481E+02	4.58	18	1	2.44	14
RU183	497.84	786.88	145.88	1.964E+02	3.38	18	1	2.34	15
RU186	511.49	727.48	9.7888	1.324E+01	34.73	7	1	2.64	16
???	537.16	763.98	43.748	5.924E+01	9.68	9	1	2.21	17
CS134	684.21	859.55	52.888	7.162E+01	7.17	9	1	2.76	18
CS137	661.21	948.78	14.835	2.889E+01	18.18	7	1	2.12	19
ZR95	724.49	1838.39	247.26	3.348E+02	1.87	12	1	2.46	20
EU154									
ZR95	756.56	1876.67	268.18	3.522E+02	1.96	13	1	2.42	21
EU154									
NB95	765.65	1889.62	675.68	9.151E+02	4.87	14	1	2.48	22
AG110M									
CS134	795.62	1132.32	38.328	5.198E+01	18.28	12	1	2.72	23
???	818.82	1153.99	28.687	3.874E+01	9.65	15	2	2.28	24
???	815.66	1168.88	31.162	4.228E+01	9.33	15	2	2.38	25
???	834.67	1187.97	89.885	1.285E+02	4.34	11	1	2.47	26
???	924.92	1316.55	5.8558	7.929E+00	33.27	5	1	1.51	27
???	1099.18	1564.68	189.14	2.561E+02	2.87	12	1	2.57	28
???	1173.88	1678.87	576.81	7.881E+02	8.83	14	1	2.57	29
???	1291.44	1838.64	132.98	1.795E+02	2.52	15	1	2.67	30
???	1332.41	1897.88	535.86	7.246E+02	8.92	28	2	2.74	31

2 - 9 - 1977 1522.56
HRB 12 ROD 8 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	MU	FWHM (KEV)	PK #
???	57.77	88.53	8.3888	1.129E+01	48.27	5	1	1.48	1
CE141	145.28	285.28	68.225	9.282E+01	18.77	11	2	1.63	2
PA233	388.82	425.94	398.94	5.427E+02	1.91	12	1	2.22	3
PA233	311.85	442.88	2444.9	3.326E+03	8.46	28	2	2.24	4
???	319.99	454.41	1888.6	2.449E+03	8.52	28	2	2.31	5
???	328.73	466.87	48.895	6.652E+01	9.72	9	1	2.82	6
PA233	348.37	483.46	288.49	3.816E+02	2.88	11	1	2.24	7
???	364.38	517.68	46.785	6.365E+01	9.48	9	1	2.81	8
PA233	375.19	533.11	41.755	5.688E+01	8.61	7	1	1.92	9
PA233	398.37	566.15	78.388	1.866E+02	5.67	9	1	2.36	10

PA233	415.72	598.89	185.45	1.434E+02	4.52	18	1	2.29	11
???	486.81	692.22	118.48	1.582E+02	4.38	18	1	2.23	12
RUI83	496.93	786.64	159.92	2.175E+02	3.22	21	1	2.48	13
???	537.89	763.88	46.768	5.361E+01	8.25	8	1	2.33	14
CS134	684.15	859.46	40.188	6.691E+01	8.49	18	1	3.88	15
CS137	661.58	941.32	18.848	1.365E+01	21.15	5	1	1.51	16
ZR95	724.88	1838.37	257.96	3.589E+02	1.79	12	1	2.55	17
EUI54									
ZR95	756.57	1876.67	285.58	3.884E+02	1.57	28	2	2.51	18
EUI54									
NB95	765.64	1889.68	673.83	9.156E+02	1.85	28	2	2.44	19
AG110M									
CS134	795.88	1132.57	26.988	3.659E+01	18.78	8	1	2.58	20
???	818.58	1153.65	35.569	4.839E+01	8.48	17	2	2.78	21
???	815.75	1161.81	42.775	5.819E+01	7.62	17	2	2.51	22
???	834.69	1188.88	92.988	1.263E+02	3.94	18	1	2.52	23
???	867.12	1234.28	6.5888	8.843E+00	35.58	6	1	1.53	24
???	1899.87	1564.64	286.45	2.888E+02	2.88	13	1	2.65	25
???	1173.87	1678.86	618.17	8.381E+02	8.82	15	1	2.61	26
???	1291.43	1838.64	142.88	1.942E+02	2.18	13	1	2.77	27
???	1332.39	1896.97	561.15	7.634E+02	8.84	17	1	2.67	28

2 - 9 - 1977 1518.14
NRB 12 ROD 9 18 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	HU	FWHM (KEV)	PK #
CE141	145.52	285.65	61.838	8.338E+01	18.48	9	1	2.88	1
PA233	388.82	425.94	482.58	5.495E+02	1.88	12	1	2.19	2
PA233	311.84	442.79	2436.7	3.326E+03	8.49	34	3	2.28	3
???	328.88	454.42	1947.4	2.658E+03	8.53	34	3	2.31	4
PA233	348.36	483.45	286.84	3.915E+02	2.15	12	1	2.31	5
???	364.32	517.61	53.288	7.273E+01	8.38	9	1	2.58	6
PA233	375.19	533.18	36.595	4.995E+01	11.97	9	1	2.31	7
PA233	398.38	566.85	93.388	1.273E+02	5.93	12	1	2.27	8
PA233	415.65	598.78	98.198	1.348E+02	4.88	18	1	2.22	9
???	486.88	692.28	186.88	1.459E+02	4.88	11	1	2.22	10
RUI83	497.82	786.77	151.38	2.865E+02	3.19	18	1	2.38	11
???	537.11	763.91	58.485	6.891E+01	8.27	9	1	2.37	12
CS134	684.88	859.25	46.835	6.284E+01	8.38	9	1	3.48	13
CS137	668.38	939.68	5.7388	7.821E+00	37.24	5	1	1.44	14
ZR95	724.87	1838.37	245.56	3.352E+02	1.91	12	1	2.52	15
EUI54									
ZR95	756.56	1876.67	276.48	3.774E+02	1.66	29	2	2.46	16
EUI54									
NB95	765.63	1889.59	648.20	8.739E+02	1.14	29	2	2.48	17
AG110M									
CS134	795.91	1132.73	25.998	3.547E+01	12.49	9	1	2.51	18
???	818.76	1153.98	35.228	4.887E+01	8.35	16	2	2.46	19
???	815.68	1168.91	45.159	6.164E+01	7.18	16	2	2.54	20
???	834.66	1187.95	89.588	1.282E+02	4.28	18	1	2.35	21
???	925.89	1316.79	6.9288	9.446E+00	42.77	8	1	3.18	22
???	1899.88	1564.66	221.16	3.818E+02	1.96	13	1	2.67	23
???	1173.87	1678.86	637.24	8.698E+02	8.78	14	1	2.64	24
???	1291.46	1838.68	158.82	2.858E+02	2.82	12	1	2.58	25
???	1332.48	1896.98	587.37	8.818E+02	8.78	15	1	2.67	26

2 - 9 -1977 1514.09
HRB 12 ROD 10 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
PA233	98.54	138.66	12.385	1.711E+01	28.21	5	1	1.49	1
CE141	145.26	285.28	73.200	1.011E+02	8.00	8	1	2.27	2
PA233	299.99	425.98	434.86	6.009E+02	1.78	12	1	2.28	3
PA233	311.82	442.76	2622.7	3.624E+03	0.45	34	3	2.28	4
???	319.87	454.24	1938.8	2.679E+03	0.50	34	3	2.28	5
???	328.67	466.78	56.223	7.769E+01	6.10	34	3	1.89	6
PA233	348.35	483.43	297.44	4.110E+02	2.14	12	1	2.37	7
???	364.29	517.56	49.025	6.775E+01	9.28	9	1	2.48	8
PA233	375.21	533.14	46.880	6.368E+01	8.81	8	1	2.40	9
PA233	398.32	566.88	84.060	1.161E+02	5.86	10	1	2.09	10
PA233	415.66	590.79	112.84	1.559E+02	4.02	9	1	2.31	11
???	486.88	692.20	122.81	1.697E+02	3.65	9	1	2.42	12
RU103	496.86	706.54	160.28	2.215E+02	3.08	10	1	2.54	13
???	537.20	764.84	43.695	6.038E+01	9.94	9	1	2.48	14
CS134	604.44	859.88	35.280	4.875E+01	10.24	8	1	2.30	15
CS137	661.37	941.81	21.460	2.965E+01	13.02	7	1	1.74	16
ZR95	723.91	1030.14	255.64	3.532E+02	2.09	14	1	2.49	17
EUI54									
ZR95	756.53	1076.61	292.08	4.036E+02	1.57	27	2	2.43	18
EUI54									
NB95	765.61	1089.56	689.50	9.528E+02	1.03	27	2	2.54	19
AG110M									
CS134	795.60	1132.30	24.595	3.398E+01	11.03	7	1	2.00	20
???	810.88	1154.06	34.180	4.723E+01	8.92	17	2	2.56	21
???	815.71	1160.94	45.359	6.268E+01	7.59	17	2	2.06	22
???	834.70	1188.01	95.070	1.313E+02	3.96	10	1	2.52	23
???	925.01	1316.69	12.490	1.726E+01	18.79	6	1	1.78	24
???	1099.07	1564.64	221.55	3.061E+02	2.01	13	1	2.70	25
???	1173.05	1670.03	639.41	8.836E+02	0.81	15	1	2.67	26
???	1291.41	1838.60	152.23	2.103E+02	2.14	13	1	2.78	27
???	1332.26	1896.78	586.78	8.109E+02	0.84	17	1	2.76	28

2 - 9 -1/77 1510.15
HRB 12 ROD 11 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
CE141	145.26	285.28	77.735	1.078E+02	8.29	9	1	2.12	1
???	192.16	272.15	13.200	1.831E+01	31.40	6	1	1.87	2
PA233	299.98	425.89	424.52	5.890E+02	1.72	11	1	2.26	3
PA233	311.82	442.76	2621.1	3.637E+03	0.46	36	3	2.30	4
???	319.86	454.22	1951.2	2.721E+03	0.52	36	3	2.29	5
???	328.68	466.80	60.057	8.333E+01	5.76	36	3	1.92	6
PA233	348.23	483.26	305.00	4.232E+02	2.11	12	1	2.32	7
???	364.40	517.72	45.805	6.368E+01	9.98	9	1	2.06	8
PA233	375.18	533.09	38.300	5.318E+01	11.80	9	1	2.14	9
PA233	398.30	566.05	84.090	1.172E+02	5.87	10	1	2.26	10
PA233	415.66	590.79	103.73	1.439E+02	4.78	10	1	2.29	11
???	432.68	615.05	6.4950	9.012E+00	41.25	5	1	0.84	12

???	486.79	692.18	124.87	1.732E+02	3.91	18	1	2.28	13
RU103	496.87	786.56	166.18	2.385E+02	3.43	12	1	2.42	14
???	537.18	763.98	55.768	7.737E+01	7.85	8	1	2.48	15
CS134	684.87	859.35	53.988	7.498E+01	8.82	18	1	3.42	16
ZR95	724.85	1838.33	266.97	3.784E+02	2.82	14	1	2.51	17
EUI54									
ZR95	756.52	1876.68	295.89	4.894E+02	1.55	26	2	2.53	18
EUI54									
NB95	765.68	1889.54	698.83	9.585E+02	1.82	26	2	2.55	19
AG110M									
CS134	795.54	1132.21	26.668	3.699E+01	11.45	8	1	2.59	20
???	818.67	1153.77	31.661	4.393E+01	9.15	15	2	2.34	21
???	815.67	1168.89	36.783	5.183E+01	8.49	15	2	2.54	22
???	834.64	1187.92	98.158	1.361E+02	4.17	11	1	2.48	23
???	867.87	1235.28	9.7658	1.354E+01	27.57	7	1	1.87	24
???	1899.85	1564.62	238.32	3.195E+02	2.82	14	1	2.65	25
???	1173.85	1673.82	637.35	8.843E+02	8.82	15	1	2.78	26
???	1291.41	1838.68	159.57	2.214E+02	2.87	13	1	2.84	27
???	1332.27	1896.79	597.83	8.284E+02	8.83	17	1	2.75	28

2 - 9 - 1977 1586.28

HRB 12 ROD 12 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	HU	FWHM (KEV)	PK #
PA233	98.18	138.83	9.8258	1.237E+01	38.84	5	1	8.97	1
CE141	145.21	285.21	78.988	1.883E+02	7.27	8	1	2.15	2
???	271.52	385.31	13.885	1.783E+01	26.88	5	1	1.37	3
PA233	299.98	425.89	483.88	5.528E+02	1.89	12	1	2.28	4
PA233	311.83	442.77	2428.9	3.331E+03	8.51	36	3	2.29	5
???	319.89	454.27	2837.8	2.794E+03	8.54	36	3	2.38	6
PA233	348.5	483.43	278.78	3.713E+02	2.31	12	1	2.48	7
???	364.46	517.84	46.888	6.328E+01	18.56	18	1	2.81	8
PA233	375.22	533.14	34.328	4.711E+01	12.85	9	1	2.18	9
PA233	398.38	566.16	74.775	1.825E+02	5.95	9	1	2.42	10
PA233	415.57	598.67	95.558	1.318E+02	4.67	9	1	2.52	11
???	486.83	622.24	182.88	1.418E+02	5.87	11	1	2.38	12
RU103	497.88	786.74	145.45	1.995E+02	3.37	18	1	2.24	13
???	537.26	764.12	49.285	6.768E+01	8.56	9	1	2.18	14
CS134	684.13	859.44	49.855	6.838E+01	9.88	11	1	3.29	15
ZR95	724.86	1838.35	238.31	3.268E+02	2.12	13	1	2.58	16
EUI54									
ZR95	756.56	1876.66	269.52	3.696E+02	1.94	13	1	2.47	17
EUI54									
NB95	765.62	1889.57	661.61	9.874E+02	8.96	15	1	2.55	18
AG110M									
CS134	795.54	1132.21	23.228	3.184E+01	12.83	8	1	2.42	19
???	818.67	1153.77	29.157	3.999E+01	18.25	17	2	2.86	20
???	815.63	1168.84	42.537	5.834E+01	8.18	17	2	2.64	21
???	834.78	1188.81	95.825	1.314E+02	4.83	13	1	2.54	22
???	1899.88	1564.66	233.32	3.288E+02	1.83	12	1	2.63	23
???	1173.87	1673.83	652.38	8.948E+02	8.88	18	1	2.64	24
???	1291.43	1838.64	168.85	2.195E+02	2.83	13	1	2.71	25
???	1332.27	1896.88	599.31	8.228E+02	8.84	18	1	2.74	26

2 - 9 - 1977 1502.49
NRB 12 ROD 13 10 NIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	MU	FWHM (KEV)	PK #
CE141	145.27	285.29	67.368	9.129E+01	8.48	8	1	2.15	1
???	192.87	272.82	14.665	1.987E+01	23.89	5	1	1.87	2
???	271.46	385.22	15.878	2.842E+01	25.68	6	1	2.41	3
PA233	388.81	425.93	353.68	4.792E+02	1.98	11	1	2.17	4
PA233	311.85	442.88	2285.5	2.989E+03	8.49	35	3	2.25	5
???	328.88	454.43	2817.8	2.734E+03	8.58	35	3	2.32	6
???	328.78	466.83	49.389	6.693E+01	6.58	35	3	2.21	7
PA233	348.36	483.45	258.23	3.391E+02	2.29	11	1	2.24	8
???	364.46	517.88	46.988	6.367E+01	18.11	18	1	2.17	9
PA233	375.24	533.17	31.248	4.233E+01	11.35	7	1	2.33	10
PA233	398.29	566.83	69.468	9.413E+01	6.26	9	1	2.81	11
PA233	415.64	598.77	87.898	1.191E+02	5.36	18	1	2.39	12
???	486.93	692.39	92.588	1.254E+02	5.84	18	1	2.35	13
RUI83	496.98	786.59	141.88	1.912E+02	3.68	11	1	2.44	14
???	537.17	764.88	44.448	6.822E+01	18.18	18	1	1.97	15
CS134	684.87	859.35	48.168	6.526E+01	8.58	18	1	3.61	16
CS137	668.89	948.32	9.4258	1.277E+01	22.58	5	1	1.37	17
ZR95	724.87	1838.36	222.28	3.812E+02	2.28	13	1	2.46	18
EUI54									
ZR95	756.56	1876.66	251.88	3.413E+02	1.92	12	1	2.45	19
EUI54									
NB95	765.64	1889.68	594.31	8.854E+02	8.96	13	1	2.54	20
AG188									
CS134	795.97	1132.82	26.448	3.583E+01	11.16	8	1	2.38	21
???	818.87	1154.86	26.783	3.629E+01	18.81	16	2	2.88	22
???	815.78	1168.94	33.636	4.558E+01	9.48	16	2	2.84	23
???	834.78	1188.81	96.865	1.312E+02	4.13	11	1	2.32	24
???	1899.89	1564.68	247.46	3.353E+02	1.87	14	1	2.64	25
???	1173.89	1678.88	661.88	8.958E+02	8.76	14	1	2.58	26
???	1291.45	1838.67	159.78	2.165E+02	1.92	12	1	2.64	27
???	1332.41	1897.88	689.88	8.264E+02	8.79	17	1	2.66	28

2 - 9 - 1977 1459.13
NRB 12 ROD 14 10 NIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	MU	FWHM (KEV)	PK #
CE141	145.31	285.35	69.878	9.464E+01	18.53	11	2	2.41	1
???	271.38	385.88	21.115	2.868E+01	28.54	7	1	2.26	2
PA233	388.81	425.92	367.22	4.974E+02	2.81	12	1	2.22	3
PA233	311.84	442.79	2216.3	3.882E+03	8.53	36	3	2.28	4
???	328.81	454.43	2838.2	2.768E+03	8.54	36	3	2.32	5
PA233	348.38	483.47	245.98	3.331E+02	2.47	12	1	2.31	6
???	364.46	517.81	43.448	5.884E+01	8.27	7	1	2.81	7
PA233	375.28	533.23	37.235	5.843E+01	11.55	9	1	2.14	8
PA233	398.36	566.14	69.838	9.458E+01	6.79	18	1	2.23	9

PA233	415.65	598.78	27.598	1.199E+02	5.31	18	1	2.28	18
???	486.82	692.23	188.45	1.261E+02	4.27	9	1	2.39	11
RU183	496.92	786.62	137.18	1.858E+02	3.46	18	1	2.48	12
???	537.22	764.87	58.868	7.864E+01	18.28	14	2	2.46	13
CS134	684.20	859.54	38.928	5.271E+01	18.79	18	1	2.93	14
ZR95	724.86	1838.35	218.38	2.956E+02	2.11	12	1	2.56	15
EU154									
ZR95	756.67	1876.82	247.18	3.348E+02	1.95	12	1	2.41	16
EU154									
NB95	765.63	1889.59	685.59	8.282E+02	8.93	13	1	2.47	17
AG118M									
CS134	795.88	1132.69	26.598	3.681E+01	12.14	9	1	2.58	18
???	818.59	1153.66	29.111	3.943E+01	9.78	15	2	1.77	19
???	815.55	1168.73	29.863	4.845E+01	9.72	15	2	2.46	20
???	834.72	1188.84	99.168	1.343E+02	4.34	12	1	2.41	21
???	1899.89	1564.67	233.58	3.162E+02	1.89	13	1	2.64	22
???	1173.89	1678.88	654.16	8.868E+02	8.79	15	1	2.62	23
???	1291.45	1838.67	164.38	2.225E+02	2.14	15	1	2.73	24
???	1332.41	1896.99	686.98	8.228E+02	8.76	15	1	2.66	25

2 - 9 - 1977 1455.46

HRB 12 ROD 15 18 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	HU	FVHM (KEV)	PK
CE141	145.26	285.29	52.868	7.881E+01	18.45	8	1	2.13	1
???	271.52	385.31	11.388	1.513E+01	42.17	8	1	1.72	2
PA233	388.83	425.96	358.11	4.698E+02	3.53	23	3	2.38	3
PA2	311.83	442.77	1981.8	2.654E+03	8.55	34	3	2.29	4
???	328.84	45.48	2846.6	2.741E+03	8.53	34	3	2.32	5
PA233	348.34	483.43	233.56	3.128E+02	2.53	12	1	2.45	6
???	364.18	517.48	38.288	5.128E+01	18.11	8	1	2.41	7
PA233	375.19	533.18	33.138	4.438E+01	18.48	7	1	2.21	8
PA233	398.34	566.18	63.345	8.485E+01	6.78	9	1	2.44	9
PA233	415.74	598.91	73.525	9.849E+01	5.76	9	1	2.26	10
???	486.88	692.28	99.128	1.327E+02	4.94	11	1	2.28	11
RU183	497.81	786.76	122.93	1.646E+02	3.74	18	1	2.28	12
???	537.14	763.96	39.455	5.285E+01	8.41	7	1	2.81	13
CS134	684.18	859.48	35.788	4.793E+01	11.32	18	1	2.83	14
ZR95	724.85	1838.33	198.82	2.663E+02	2.13	11	1	2.47	15
EU154									
ZR95	756.55	1876.65	221.68	2.968E+02	2.89	12	1	2.46	16
EU154									
NB95	765.62	1889.58	537.11	7.195E+02	1.12	15	1	2.57	17
AG118M									
???	818.84	1154.81	23.928	3.285E+01	11.87	14	2	2.63	18
???	815.49	1168.64	25.291	3.388E+01	18.98	14	2	2.19	19
???	834.73	1188.85	98.888	1.216E+02	4.41	11	1	2.47	20
???	1899.12	1564.73	238.31	3.192E+02	1.85	13	1	2.62	21
???	1173.87	1678.85	662.55	8.875E+02	8.84	18	2	2.45	22
???	1291.48	1838.78	162.12	2.171E+02	2.8	14	1	2.73	23
???	1332.43	1897.83	617.64	8.274E+02	8.77	17	1	2.71	24
???	1437.59	2846.77	1.7688	2.357E+08	38.65	5	1	8.68	25

2 - 9 - 1977 1452.89
NRB 12 ROD 16 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	HU	FWHM (KEV)	PK #
PA233	94.18	132.44	8.8688	1.189E+01	42.71	5	1	1.33	1
CE141	145.28	285.28	88.395	1.186E+02	7.96	9	1	2.17	2
???	271.22	384.87	23.128	3.182E+01	17.88	6	1	2.18	3
PA233	299.99	425.89	431.21	5.935E+02	2.88	14	1	2.27	4
PA233	311.82	442.76	2598.4	3.565E+03	8.47	36	3	2.38	5
???	319.87	454.24	1934.3	2.662E+03	8.52	36	3	2.26	6
???	328.78	466.83	57.613	7.938E+01	5.91	36	3	2.18	7
PA233	348.37	483.46	292.26	4.823E+02	2.83	11	1	2.35	8
???	364.12	517.32	43.248	5.952E+01	11.38	18	1	2.19	9
PA233	375.19	533.18	38.688	5.324E+01	14.54	12	2	1.66	10
PA233	398.32	566.88	88.875	1.113E+02	5.61	9	1	2.17	11
PA233	415.54	598.63	113.48	1.562E+02	4.94	12	1	2.43	12
???	486.81	692.21	188.34	1.491E+02	4.58	18	1	2.31	13
RU183	496.98	786.68	158.27	2.178E+02	3.89	18	1	2.36	14
???	537.16	763.98	49.238	6.776E+01	9.58	18	1	2.48	15
CS134	684.14	859.44	43.278	5.956E+01	9.86	18	1	3.29	16
ZR95	723.96	1838.28	244.24	3.362E+02	1.96	12	1	2.48	17
EUI54									
ZR95	756.54	1876.64	291.78	4.816E+02	1.58	23	2	2.51	18
EUI54									
NB95	765.62	1889.57	693.27	9.543E+02	1.84	28	2	2.55	19
AG118M									
CS134	795.56	1132.23	31.788	4.374E+01	9.48	8	1	2.22	20
???	818.75	1153.88	35.876	4.938E+01	8.58	17	2	2.33	21
???	815.56	1168.74	47.843	6.586E+01	7.12	17	2	2.74	22
???	834.66	1187.95	89.855	1.236E+02	3.85	9	1	2.54	23
???	924.86	1316.47	18.885	1.388E+01	28.58	5	1	1.65	24
???	1899.86	1564.64	218.38	3.885E+02	2.14	14	1	2.56	25
???	1173.86	1678.84	626.25	8.628E+02	8.82	15	1	2.59	26
???	1291.42	1838.62	148.68	2.846E+02	2.11	12	1	2.74	27
???	1332.27	1896.79	597.58	8.226E+02	8.83	18	1	2.71	28

2 - 9 - 1977 1438.84
NRB 12 ROD 17 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	HU	FWHM (KEV)	PK #
CE141	145.28	285.19	78.648	9.744E+01	8.27	8	1	2.13	1
PA233	299.99	425.98	452.14	6.237E+02	1.71	12	1	2.25	2
PA233	311.81	442.75	2671.3	3.684E+03	8.45	35	3	2.31	3
???	319.87	454.23	1883.1	2.597E+03	8.52	35	3	2.29	4
???	328.76	466.91	56.785	7.822E+01	6.84	35	3	1.93	5
PA233	348.33	483.41	316.54	4.366E+02	2.88	12	1	2.31	6
???	364.15	517.36	53.888	7.597E+01	7.48	8	1	2.24	7
PA233	375.22	533.14	48.968	5.658E+01	12.82	18	1	2.42	8
PA233	398.38	566.85	92.468	1.275E+02	6.97	14	2	2.81	9
PA233	415.68	598.82	188.52	1.496E+02	4.55	18	1	2.38	10
???	486.92	692.37	128.87	1.777E+02	3.77	18	1	2.58	11

RU103	496.88	786.56	168.37	2.322E+02	3.15	11	1	2.39	12
???	536.97	763.71	51.426	7.093E+01	9.18	10	1	2.54	13
CS134	684.48	859.94	37.545	5.179E+01	8.77	7	1	2.13	14
CS137	661.53	941.24	11.818	1.629E+01	20.99	6	1	1.68	15
ZR95	723.94	1030.18	252.67	3.485E+02	1.88	11	1	2.38	16
EUI54									
ZR95	756.51	1076.59	301.09	4.153E+02	1.53	27	2	2.52	17
EUI54									
NB95	765.59	1089.54	703.14	9.699E+02	1.01	27	2	2.51	18
AG110M									
CS134	795.62	1132.32	30.660	4.229E+01	9.73	8	1	2.70	19
???	810.79	1153.94	29.089	4.012E+01	11.32	19	3	2.79	20
???	815.71	1160.95	36.330	5.011E+01	10.18	19	3	2.89	21
???	834.69	1188.88	94.900	1.309E+02	5.06	14	2	3.48	22
???	1099.04	1564.60	212.18	2.926E+02	2.27	15	1	2.66	23
???	1173.04	1670.02	610.99	8.420E+02	0.84	15	1	2.62	24
???	1291.41	1838.61	148.27	2.045E+02	2.19	13	1	2.75	25
???	1332.25	1896.77	575.36	7.936E+02	0.83	17	1	2.70	26

2 - 9 -1977 1426.21

NRB 12 ROD 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	NU	FWHM (KEV)	PK #
CE141	145.27	205.30	64.090	8.748E+01	8.14	7	1	2.00	1
???	271.59	385.40	20.370	2.780E+01	19.27	6	1	1.75	2
PA233	300.02	425.94	436.30	5.956E+02	1.76	12	1	2.16	3
PA233	311.83	442.78	2646.4	3.612E+03	0.45	35	3	2.23	4
???	319.89	454.27	1833.9	2.503E+03	0.52	35	3	2.29	5
???	328.74	466.88	62.767	8.507E+01	5.33	35	3	2.30	6
PA233	340.25	483.30	293.64	4.008E+02	2.13	12	1	2.20	7
???	364.38	517.70	51.760	7.005E+01	7.01	8	1	2.24	8
PA233	375.37	533.35	46.680	6.371E+01	9.36	7	1	2.33	9
PA233	398.72	566.08	89.985	1.228E+02	5.79	11	1	2.25	10
PA233	415.67	590.81	106.89	1.459E+02	4.54	10	1	2.43	11
???	406.03	692.24	114.56	1.563E+02	4.52	11	1	2.28	12
RU103	496.89	786.58	148.80	2.031E+02	3.51	11	1	2.28	13
???	537.14	763.95	55.840	7.622E+01	6.85	8	1	2.34	14
CS134	684.18	859.51	41.750	5.398E+01	10.13	10	1	2.97	15
CS137	661.16	940.72	10.880	1.485E+01	22.36	6	1	1.67	16
ZR95	723.92	1030.15	252.06	3.440E+02	1.86	12	1	2.47	17
EUI54									
ZR95	756.53	1076.62	288.16	3.933E+02	1.70	12	1	2.46	18
EUI54									
NB95	765.63	1089.59	686.72	9.373E+02	0.85	13	1	2.48	19
AG110M									
CS134	795.69	1132.43	25.100	3.426E+01	11.67	8	1	1.94	20
???	810.77	1153.92	29.328	4.003E+01	9.85	17	2	2.19	21
???	815.60	1160.79	43.276	5.907E+01	7.93	17	2	2.83	22
???	834.67	1187.96	91.370	1.247E+02	4.01	10	1	2.28	23
???	924.10	1315.39	5.8750	8.019E+00	34.22	5	1	1.28	24
???	1099.25	1564.90	219.86	2.578E+02	2.33	16	2	3.02	25
???	1173.05	1670.02	599.41	8.182E+02	0.84	15	1	2.60	26
???	1291.41	1838.61	144.29	1.969E+02	2.14	13	1	2.78	27
???	1332.38	1896.96	552.77	7.545E+02	0.87	10	1	2.63	28

2 - 9 - 1977 1422.32
NRB 12 ROD 19 18 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	HU	FWHM (KEV)	PK #
CE141	145.18	285.17	77.325	1.846E+02	8.18	9	1	2.27	1
???	192.11	272.88	28.198	2.733E+01	19.91	6	1	2.38	2
???	271.88	385.82	21.968	2.972E+01	19.82	7	1	2.21	3
PA233	388.83	425.95	444.24	6.814E+02	1.71	12	1	2.17	4
PA233	311.85	442.81	2678.9	3.626E+03	8.41	26	2	2.22	5
???	328.88	454.42	1741.6	2.357E+03	8.58	26	2	2.28	6
???	328.69	466.81	48.128	6.514E+01	9.82	8	1	2.85	7
PA233	348.37	483.46	381.44	4.888E+02	2.86	12	1	2.27	8
???	364.37	517.65	45.288	6.119E+01	8.93	8	1	2.28	9
PA233	375.27	533.22	42.868	5.694E+01	9.43	8	1	2.32	10
PA233	398.36	566.14	91.638	1.248E+02	5.28	18	1	2.37	11
PA233	415.78	598.86	187.65	1.457E+02	4.43	18	1	2.89	12
???	486.83	692.25	118.74	1.687E+02	4.26	11	1	2.32	13
RU183	497.83	786.79	157.63	2.133E+02	3.73	13	1	2.35	14
???	537.19	764.83	51.148	6.923E+01	8.94	18	1	2.27	15
CS134	684.83	859.29	47.238	6.393E+01	8.74	18	1	3.29	16
CS137	668.86	948.29	18.158	1.374E+01	28.71	5	1	1.28	17
ZR95	724.88	1838.37	259.11	3.587E+02	1.88	13	1	2.44	18
EUI54									
ZR95	756.55	1876.66	295.54	4.888E+02	1.64	12	1	2.48	19
EUI54									
NB95	765.64	1889.68	682.86	9.233E+02	8.92	15	1	2.48	20
AG118H									
CS134	795.57	1132.26	17.958	2.438E+01	13.85	6	1	1.93	21
???	818.75	1153.88	32.858	4.338E+01	8.15	14	2	2.33	22
???	815.49	1168.64	39.519	5.358E+01	7.16	14	2	2.57	23
???	834.71	1188.82	81.875	1.897E+02	4.13	9	1	2.38	24
???	868.84	1235.51	18.148	1.372E+01	21.93	6	1	2.87	25
???	1099.87	1564.65	198.31	2.576E+02	2.31	14	1	2.56	26
???	1173.86	1678.84	566.66	7.671E+02	8.84	14	1	2.62	27
???	1291.64	1838.93	138.94	1.772E+02	2.66	16	2	3.86	28
???	1332.48	1896.98	533.27	7.219E+02	8.98	19	1	2.66	29

2 - 9 - 1977 1419.21
NRB 12 ROD 20 18 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GAMMA/SEC	ERR (%)	BV	HU	FWHM (KEV)	PK #
PA233	98.53	138.64	16.820	2.274E+01	23.58	6	1	1.76	1
CE141	145.36	285.42	75.580	1.828E+02	7.63	8	1	2.15	2
???	271.48	335.25	23.688	3.282E+01	28.58	8	1	2.41	3
PA233	388.82	425.94	458.78	6.282E+02	1.57	11	1	2.16	4
PA233	311.85	442.81	2825.2	3.828E+03	8.45	36	3	2.23	5
???	319.91	454.29	1646.2	2.226E+03	8.55	36	3	2.27	6
???	328.77	466.93	59.981	8.899E+01	5.49	36	3	2.22	7
PA233	348.37	483.47	332.18	4.498E+02	1.87	12	1	2.33	8
???	364.47	517.83	57.848	7.713E+01	9.86	11	1	2.83	9
PA233	375.25	533.18	58.765	6.864E+01	8.51	9	1	2.21	10
PA233	398.33	566.18	91.988	1.243E+02	4.83	9	1	2.35	11
PA233	415.68	598.82	114.94	1.554E+02	4.18	18	1	2.16	12
???	486.88	692.28	125.89	1.691E+02	4.88	11	1	2.27	13

RU103	497.11	736.99	158.76	2.146E+02	3.72	13	2	2.72	14
RU106	511.19	726.96	17.769	2.401E+01	16.88	6	1	2.45	15
???	537.24	764.19	49.729	6.723E+01	7.73	8	1	1.84	16
CS134	694.53	860.59	38.363	5.187E+01	9.07	8	1	2.18	17
RU133	610.56	868.74	5.3850	7.281E+00	42.73	5	1	1.19	18
???	630.70	897.33	7.9452	1.674E+01	27.53	5	1	1.23	19
CS137	561.47	941.15	17.483	2.363E+01	17.29	8	1	2.80	20
ZR95	724.38	1032.37	259.83	3.513E+02	1.77	12	1	2.50	21
ZU154									
ZR95	756.55	1076.65	393.83	4.067E+02	1.60	12	1	2.45	22
EU154									
NB95	765.64	1389.62	713.79	9.552E+02	0.87	15	1	2.44	23
AG110M									
CS134	795.64	1132.36	27.123	3.657E+01	10.51	8	1	2.65	24
???	810.84	1154.02	33.879	4.581E+01	7.74	15	2	2.54	25
???	815.74	1161.33	46.605	6.572E+01	6.14	15	2	2.21	26
???	834.69	1188.02	77.703	1.052E+02	4.53	10	1	2.33	27
???	1099.05	1564.61	177.46	2.394E+02	2.84	11	1	2.63	28
???	1173.07	1673.05	555.15	7.506E+02	0.87	15	1	2.59	29
???	1291.42	1838.62	119.52	1.616E+02	2.47	13	1	2.73	30
???	1332.27	1896.79	535.01	6.842E+02	0.84	15	1	2.71	31

2 - 9 - 1977 1415.57

HRB 12 ROD 21 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHIL	CPS	GAMMA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
CE141	145.51	205.64	73.220	9.693E+01	7.61	8	1	2.05	1
???	192.00	271.92	11.110	1.470E+01	35.17	6	1	1.69	2
???	271.61	385.44	29.380	2.657E+01	23.55	8	1	2.31	3
PA233	300.06	425.00	423.91	5.573E+02	1.65	11	1	2.15	4
PA233	311.89	442.86	2587.3	3.424E+03	2.45	34	3	2.16	5
???	320.04	454.49	1574.0	2.303E+03	0.55	34	3	2.24	6
???	328.60	466.97	53.913	7.135E+01	5.81	34	3	1.84	7
PA233	340.41	483.52	334.36	4.328E+02	1.73	10	1	2.16	8
???	364.49	517.86	53.030	7.010E+01	7.03	9	1	2.32	9
PA233	375.35	533.34	34.720	4.595E+01	13.09	10	1	2.37	10
PA233	398.39	565.10	66.322	1.142E+02	5.32	10	1	2.26	11
PA233	415.73	590.90	112.99	1.495E+02	4.04	10	1	2.12	12
???	426.88	692.32	138.53	1.436E+02	4.21	10	1	2.24	13
RU103	497.36	736.82	147.79	1.956E+02	3.34	11	1	2.32	14
???	537.28	764.16	53.170	6.639E+01	7.91	9	1	2.23	15
CS134	604.25	859.61	47.555	6.293E+01	8.95	11	1	2.88	16
CS137	661.85	941.59	19.395	2.527E+01	16.16	9	1	2.24	17
ZR95	724.13	1032.41	241.26	3.193E+02	1.83	12	1	2.31	18
EU154									
ZR95	756.58	1076.83	277.73	3.675E+02	1.49	26	2	2.39	19
EU154									
NB95	765.77	1089.79	643.22	8.579E+02	0.99	26	2	2.34	20
AG110M									
CS134	795.60	1132.41	33.782	4.473E+01	8.04	8	1	2.70	21
???	815.61	1161.10	34.020	4.630E+01	8.28	8	1	2.14	22
???	834.73	1188.13	76.345	1.010E+02	4.09	9	1	2.41	23
???	924.66	1315.18	12.513	1.390E+01	20.31	6	1	1.51	24
???	1099.11	1564.71	171.13	2.264E+02	2.15	12	1	2.60	25
???	1173.39	1673.08	533.83	7.065E+02	2.85	14	1	2.58	26
???	1291.46	1838.63	116.52	1.542E+02	2.44	13	1	2.62	27
???	1332.41	1896.99	492.23	6.514E+02	0.85	15	1	2.67	28

2 - 9 - 1977 1412.56
H73 12 ROD 22 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	CALHA/SEC	ERR (%)	SV	MU	FWHM (KEV)	PK #
CE141	145.59	285.76	71.922	9.356E+31	9.73	11	2	2.68	1
???	271.21	384.87	23.023	2.682E+31	23.39	8	1	2.46	2
PA233	300.05	426.02	391.87	5.393E+32	2.36	14	2	2.12	3
PA233	311.91	442.89	2379.9	3.096E+33	3.43	26	2	2.16	4
???	320.17	454.67	1544.4	2.839E+33	2.53	26	2	2.19	5
???	328.85	467.04	45.320	5.854E+31	6.81	8	1	1.99	6
PA233	343.53	483.69	262.59	3.416E+32	1.94	18	1	2.13	7
???	364.46	517.81	44.310	5.725E+31	9.35	9	1	2.16	8
PA233	375.38	533.38	44.320	5.724E+31	9.14	9	1	2.34	9
PA233	398.44	566.25	75.160	9.778E+31	5.95	15	1	2.37	10
PA233	415.73	590.89	96.410	1.254E+32	4.96	11	1	2.06	11
???	466.95	692.42	97.320	1.262E+32	4.52	12	1	2.28	12
RUI03	497.11	736.39	136.31	1.773E+32	3.26	10	1	2.24	13
???	537.14	763.96	37.960	4.938E+31	9.35	8	1	2.05	14
CS134	604.30	859.68	45.940	5.976E+31	8.27	10	1	2.37	15
ZR95	724.11	1030.43	224.26	2.917E+32	1.88	12	1	2.45	16
EUI54									
ZR95	756.73	1076.90	255.44	3.323E+32	1.73	12	1	2.33	17
EUI54									
NB95	765.79	1039.32	514.21	7.991E+32	3.37	13	1	2.38	18
AG113M									
CS134	795.82	1132.61	24.135	3.139E+31	9.96	7	1	1.37	19
???	813.83	1153.99	37.411	4.867E+31	7.74	13	2	2.26	20
???	815.74	1160.99	39.218	5.102E+31	7.57	13	2	2.52	21
???	834.72	1183.33	75.355	9.833E+31	4.23	9	1	2.42	22
???	1299.26	1564.91	168.26	2.198E+32	2.32	14	1	2.39	23
???	1173.12	1573.12	514.27	6.688E+32	3.33	15	1	2.51	24
???	1291.63	1538.62	111.73	1.453E+32	2.12	11	1	2.55	25
???	1332.44	1597.34	472.32	6.151E+32	3.55	15	1	2.31	26

2 - 9 - 1977 1436.59
H72 12 ROD 23 10 MIL SLIT 1/4 IN. CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	CALHA/SEC	ERR (%)	SV	MU	FWHM (KEV)	PK #
CE141	145.43	285.53	63.575	3.243E+31	9.36	9	1	2.20	1
???	191.53	271.26	7.7450	1.334E+31	42.63	5	1	3.97	2
???	271.58	385.39	15.490	2.009E+31	35.27	13	1	2.69	3
PA233	300.09	426.03	402.30	5.219E+32	1.68	11	1	2.09	4
PA233	311.93	442.91	2440.0	3.155E+33	3.44	27	2	2.12	5
???	320.18	454.68	1463.7	1.899E+33	2.54	27	2	2.15	6
???	328.84	467.03	33.930	4.422E+31	14.15	10	1	2.12	7
PA233	340.55	483.72	277.84	3.604E+32	2.32	14	1	2.20	8
???	364.51	517.88	53.280	6.912E+31	7.60	9	1	2.32	9
PA233	375.33	533.31	39.840	5.169E+31	9.15	8	1	2.53	10
PA233	398.44	566.25	82.340	1.264E+32	5.30	11	1	2.21	11
PA233	415.73	593.89	132.36	1.320E+32	4.32	9	1	2.17	12
???	436.96	692.43	105.01	1.362E+32	4.47	11	1	2.35	13
RUI03	497.05	736.82	135.95	1.763E+32	3.26	10	1	2.18	14
RUI06	511.18	726.95	19.740	2.561E+31	19.15	9	1	3.38	15

???	537.13	763.95	33.143	4.940E+31	11.34	10	1	1.93	16
CS134	634.24	359.59	44.533	5.736E+31	7.79	9	1	2.85	17
ZR95	724.12	1335.41	225.33	2.923E+32	1.77	11	1	2.36	18
EU154									
ZR95	755.72	1376.93	249.57	3.233E+32	1.37	13	1	2.39	19
EU154									
NB95	765.83	1369.84	533.79	3.233E+32	3.32	13	1	2.36	20
AG113M									
CS134	795.75	1132.51	29.415	3.313E+31	9.53	9	1	2.59	21
???	813.83	1153.95	34.799	4.515E+31	7.19	15	2	2.52	22
???	815.57	1153.95	37.589	4.875E+31	5.99	15	2	2.47	23
???	834.73	1138.85	63.593	6.899E+31	4.37	9	1	2.31	24
???	925.45	1317.31	8.4352	1.133E+31	22.58	5	1	1.33	25
???	1099.25	1564.91	146.46	1.933E+32	2.36	12	1	2.56	26
???	1173.24	1673.29	497.36	6.449E+32	3.39	15	1	2.55	27
???	1291.49	1838.71	133.74	1.337E+32	2.53	12	1	2.76	28
???	1332.44	1897.33	152.65	5.273E+32	2.37	15	1	2.57	29

2 - 2 - 1977

1424.32

HRB 12 ROD 24 16 MIL SLIT 1/4 IN CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GALMA/SEC	ERR (%)	SW	NU	FWHM (KEV)	PK #
PA233	95.20	133.18	13.353	1.695E+21	28.74	6	1	1.47	1
CE141	145.45	235.55	45.945	5.969E+31	12.97	9	1	1.91	2
PA233	330.10	426.36	431.42	5.635E+32	1.56	11	1	2.13	3
PA233	311.93	442.91	2629.7	3.416E+33	3.41	25	2	2.12	4
???	320.16	454.66	1351.9	1.769E+33	3.55	25	2	2.17	5
???	328.54	467.33	51.563	6.698E+31	7.74	5	1	2.23	6
PA 33	340.54	433.71	299.74	3.894E+32	1.93	12	1	2.18	7
???	364.47	517.83	47.632	6.184E+31	7.89	3	1	2.29	8
PA233	375.33	533.32	49.433	6.418E+31	7.41	3	1	2.13	9
PA233	398.41	566.23	93.863	1.284E+32	4.46	13	1	2.22	10
PA233	415.75	592.92	113.84	1.434E+32	4.34	11	1	2.10	11
???	487.00	692.49	112.83	1.465E+32	4.19	24	3	2.36	12
RU103	497.15	706.95	146.30	1.896E+32	3.76	24	3	2.35	13
???	537.25	764.11	45.275	5.882E+31	8.71	9	1	2.24	14
CS134	604.44	859.37	47.993	6.235E+31	7.93	12	1	2.36	15
CS137	661.57	941.29	17.283	2.245E+31	17.36	9	1	2.31	16
CE144	696.18	990.62	8.1823	1.262E+31	31.78	8	1	1.82	17
ZR95	724.12	1030.44	247.02	3.209E+32	1.71	12	1	2.37	18
EU154									
ZR95	756.77	1075.96	336.28	3.979E+32	1.72	16	2	2.48	19
EU154									
NB95	765.83	1089.83	691.26	6.981E+32	3.73	13	1	2.35	20
AG113M									
CS134	795.56	1132.23	34.352	4.423E+31	8.26	9	1	2.39	21
???	813.82	1153.98	42.493	5.469E+31	6.96	23	3	2.59	22
???	815.71	1162.95	50.966	6.621E+31	6.30	20	3	2.61	23
???	834.73	1188.12	73.773	9.584E+31	4.28	12	1	2.23	24
???	867.33	1234.52	6.7323	3.333E+31	43.79	9	1	1.94	25
???	925.28	1317.37	11.383	1.439E+31	18.02	6	1	2.23	26
???	1099.25	1564.91	141.34	1.836E+32	2.26	11	1	2.49	27
???	1173.27	1673.35	459.93	6.125E+32	1.23	19	2	2.37	28
???	1291.49	1838.72	33.933	1.155E+32	2.69	11	1	2.65	29
???	1332.43	1897.03	427.11	5.549E+32	3.98	18	1	2.61	30

2 - 9 - 1977 1400.45
HRB 12 ROD 25 10 MIL SLIT 1/4 IN CU

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GALIA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
CE141	145.42	205.52	67.250	8.526E+31	8.43	9	1	2.36	1
???	271.63	385.47	14.923	1.891E+31	23.46	6	1	1.59	2
PA233	300.13	426.39	380.52	4.824E+02	1.71	11	1	2.18	3
PA233	311.94	442.93	2352.9	2.983E+03	2.43	25	2	2.09	4
???	320.22	454.73	1349.8	1.711E+03	2.55	25	2	2.13	5
???	328.75	466.90	41.025	5.201E+31	12.17	9	1	2.13	6
PA233	340.56	483.73	271.47	3.442E+32	2.26	14	2	2.16	7
???	364.50	517.87	39.665	5.329E+31	2.10	7	1	1.84	3
PA233	375.32	533.28	36.620	4.640E+31	10.51	9	1	2.22	9
PA233	398.42	566.21	77.415	9.815E+01	5.07	9	1	2.04	10
PA233	415.76	590.93	95.287	1.228E+32	4.78	11	1	2.01	11
???	487.01	692.51	103.67	1.276E+02	4.15	10	1	2.34	12
RUI33	497.09	706.87	132.14	1.675E+02	3.67	12	1	2.13	13
???	537.39	764.32	41.755	5.294E+31	10.44	11	1	2.26	14
CS134	604.61	860.11	38.080	4.828E+01	8.25	8	1	2.21	15
CS137	661.51	941.21	15.563	1.972E+31	16.61	8	1	2.41	16
ZR95	724.19	1030.54	223.22	2.827E+02	1.81	12	1	2.32	17
EU154									
ZR95	756.75	1076.93	245.12	3.127E+32	1.71	12	1	2.32	18
EU154									
NB95	765.82	1089.36	525.69	7.679E+32	2.34	13	1	2.32	19
AG113M									
CS134	795.79	1132.56	26.975	3.423E+31	9.96	9	1	2.66	20
???	810.84	1154.31	36.511	4.642E+31	7.63	19	2	2.21	21
???	815.77	1161.24	37.598	4.767E+31	7.56	19	2	2.48	22
???	834.30	1180.16	60.483	7.668E+31	5.34	10	1	2.33	23
???	1099.26	1564.93	134.73	1.727E+02	2.29	11	1	2.49	24
???	1173.23	1673.36	456.31	5.781E+02	0.89	14	1	2.53	25
???	1291.65	1838.95	89.570	1.135E+02	2.50	11	1	2.45	26
???	1332.47	1897.08	420.84	5.335E+02	2.87	14	1	2.59	27

2 - 9 - 1977 1330.24
HRB-12 ROD # 25 10 MIL SLIT

F.P.	ENERGY (KEV)	PEAK CHNL	CPS	GALIA/SEC	ERR (%)	BW	MU	FWHM (KEV)	PK #
???	89.71	125.26	126.22	1.809E+02	4.42	43	6	2.63	1
PA233	93.88	132.02	437.41	6.272E+02	1.97	43	6	3.12	2
PA233	98.10	135.03	535.33	7.672E+02	1.32	43	6	2.31	3
EU155	105.03	147.92	106.56	1.527E+02	5.22	43	6	3.39	4
PA233									
TE125	110.70	156.33	92.325	1.319E+02	6.29	43	6	3.34	5
PA233									
CE144	133.23	188.12	35.850	5.140E+01	15.58	7	1	2.26	6
CE141	145.12	205.09	249.20	3.573E+02	3.51	11	1	2.34	7
???	271.30	385.00	23.635	3.389E+01	19.82	7	1	2.19	8
PA233	299.90	425.76	616.92	3.346E+02	1.36	12	1	2.30	9
PA233	311.62	442.48	3728.3	5.317E+03	2.40	38	3	2.38	10
???	319.77	454.09	1686.5	2.418E+03	2.56	38	3	2.27	11
???	328.44	466.46	62.079	8.901E+01	5.84	38	3	2.53	12

PA233	348.14	453.14	421.52	6.844E+02	1.64	12	1	2.35	13
???	364.97	517.25	65.568	9.428E+01	7.39	9	1	2.26	14
PA233	375.13	533.82	59.338	8.507E+01	2.15	9	1	2.38	15
PA233	398.18	565.88	118.75	1.732E+02	4.47	18	1	2.37	16
PA233	415.42	598.46	147.34	2.112E+02	3.58	10	1	2.35	17
???	486.69	692.84	145.81	2.079E+02	3.75	11	1	2.24	18
RU103	496.63	756.21	184.38	2.642E+02	2.99	11	1	2.32	19
???	536.93	763.65	56.718	8.131E+01	8.63	13	1	2.59	20
CS134	584.17	859.49	45.095	6.466E+01	8.96	9	1	2.38	21
ZR95	723.88	1029.97	383.99	4.515E+02	1.74	14	1	2.42	22
EUI54									
ZR95	756.35	1076.36	323.18	4.634E+02	1.53	12	1	2.51	23
EUI54									
NB95	765.44	1089.32	772.83	1.108E+03	2.81	14	1	2.52	24
AG110M									
CS134	795.35	1131.93	29.268	4.195E+01	9.98	3	1	2.59	25
???	810.45	1153.46	48.826	5.854E+01	7.13	16	2	2.38	26
???	815.39	1163.58	54.894	7.756E+01	5.87	16	2	2.56	27
???	834.54	1187.78	66.950	9.630E+01	5.31	13	1	2.28	28
???	867.38	1234.57	6.8833	9.753E+00	41.63	8	1	2.73	29
???	1093.85	1564.34	129.33	1.861E+02	3.31	15	1	2.76	30
???	1172.74	1669.58	445.92	6.394E+02	1.31	14	1	2.71	31
???	1291.15	1833.24	52.957	1.139E+02	3.16	11	1	2.67	32
???	1332.32	1896.44	415.39	5.965E+02	1.88	15	1	2.86	33

Note: this page of data was acquired first for this Annex. The count rate was considered to be too high, and a 6.3-mm-thick copper plate was placed in front of the collimator to attenuate the gamma radiation. Then the spectrum for rod 25 was acquired again. The spectra for all other rods were acquired with the copper plate in place.